Cover Requirements for the Protection of Range Site and Biota

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How much forage can be removed from ranges by grazing without reducing later yields? This is the crucial question of proper range use. Various standards have been devised, each based on some important consideration in range welfare or livestock management. Common criteria are the physiological responses of certain key plants, observed "improvement" of the range, or condition of the animals.

These guides have been useful in improving range management. But many ranges managed by them have continued to waste away, or have met disaster from drought. A reexamination of utilization standards seems in order.

This paper proposes to consider range utilization from the viewpoint of bioecology, and to examine available information on the requirements of site protection as an essential of safe range use.

The Range Biota

Leopold (1939) stated the biotic view of land and illustrated it with an adaptation of the Eltonian "pyramid of life." The application of these concepts to grassland ranges is illustrated in Figure 1.

A range with its population of livestock and wildlife constitutes a complex of biotic communities. The health of this biota depends upon the continued flow of energy and matter from the inorganic environment through the different levels of life and back to the beginning of the cycle. The magnitude of this flow depends upon the climatic and edaphic base of each ecological association, and generally varies from large to small as the climate changes from wet to dry and from warm to cold.

Forage production is one of the manifestations of this energy-matter cycle. Under undisturbed natural conditions, its volume is maintained at a sustained level, changing from year to year only as the weather varies within the climatic pattern.

In using the range, man has imposed a livestock population into the structure of the biota. To some extent domestic grazing animals have been substituted for wild ones, but to a varying degree they have been added to the original grazing animal population. The matter which goes into the building of livestock bodies, unlike that in native animals, does not return in its entirety to the earth from which it came, but part is drawn off for man's use in other regions.

The natural replenishment of the energy cycle is possible from only a few sources. The principal ones are: (1) the release of minerals in the local site by weathering of the parent rock and decay of plant and animal remains; (2) the interchange of gases and moisture in the atmosphere between different parts of the world and their incorporation into the local cycle; and (3) the intake of energy in the form of sunlight and the manufacture of new organic materials by photosynthesis. The supply of energy may be increased locally by the addition of artificial fertilizers to the soil or the importation of livestock feed produced elsewhere.

The continued full-scale functioning of the range biota, therefore, depends upon three corresponding fundamental requirements: (1) The *soil* must be kept intact from wastage by erosion or other impairment; (2) the continued intake and use of *water and gases* from the atmosphere must be assured; and (3) the volume of photosynthetic tissue in the vegetation must be maintained at a level to utilize the energy of the *sunlight.*

The mantle of vegetative cover on the land is the means of meeting all these requirements. This includes both the living plants of the season and the accumulation of dead plant parts on and in the soil.

Proper range use, then, is a question of how much of the current foliage production can be safely diverted to the use of livestock and ultimate withdrawal from the local energy cycle, and how much must be left to carry on growth processes and be allowed to follow its natural course through the bodies of native animals and back to the soil.

Effects of Foliage Removal

The first effect of grazing is upon the volume of living plant material on the land. This is important both to the individual plants and to the whole biotic community.

Early research on range utilization was aimed at determining the percentage of foliage that could be removed from the plant without endangering its survival or reducing forage yields. The first utilization standards were based upon this consideration. Removal of 75 to 90 percent of the herbage of palatable species was regarded as "proper" utilization (Sampson and Malmsten 1926).

Clipping studies of several grasses in the West (Aldous 1930, Canfield 1939, Weaver and Hougen 1939, Holscher 1945) showed that plants could not survive this treatment. Crider (1955) recently demonstrated with several species of grasses that removal of more than 50 percent of the top growth by clipping promptly stopped the growth of roots for several days. The tendency has been to recommend lighter use as more is learned of range responses. More recent standards for short-grass ranges, using stubble heights as guides to proper use, provide for removing 30 to 50 percent of the total herb-

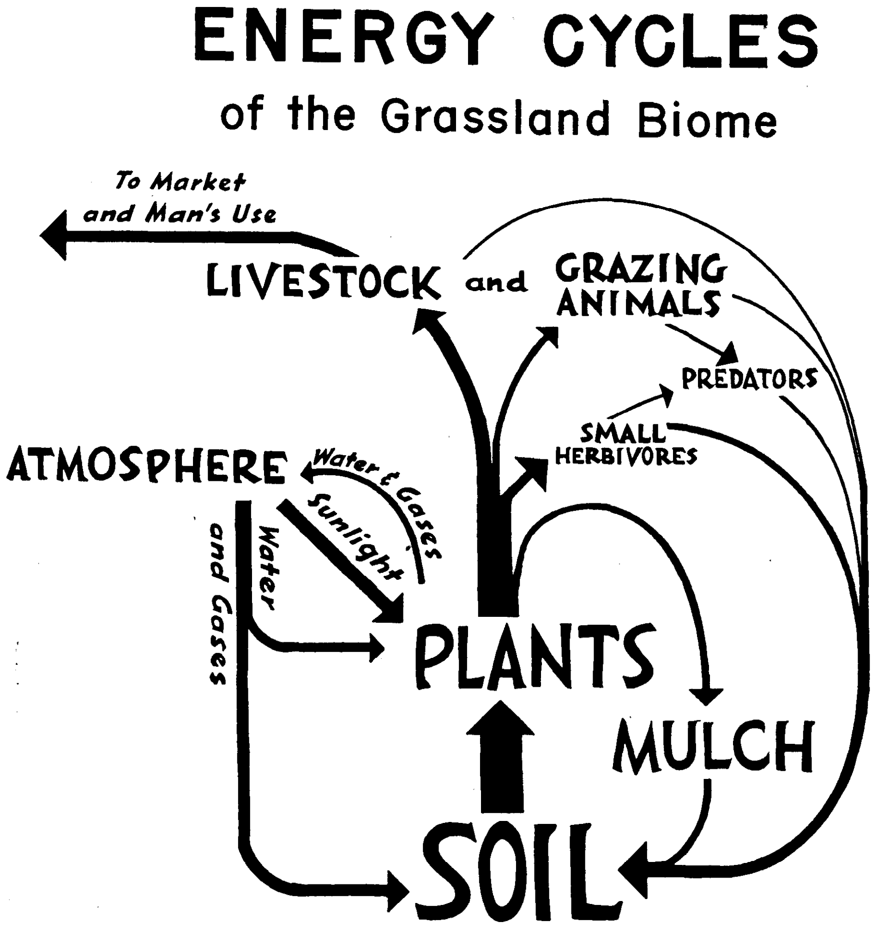

FIGURE 1. Energy cycles of the grassland biome.

age (Costello and Turner 1944). The familiar "take half and leave half" rule, which has been widely used in some areas, is an extension of this same idea.

Removal of living foliage affects not only the physiological welfare of the individual plant. It also limits the capacity of the biotic community to make use of the energy available to it from the sunlight.

Only through photosynthesis can plants combine the minerals from the soil and the gases and moisture from the air into new organic materials—new forage for livestock. Production is limited to whatever extent the density and volume of foliage is sufficient to intercept enough of the sunlight to make full use of the inorganic resources of the site. Adequate cover to make full use of sunlight is as essential to sustained production as conservation of soil and moisture.

Cover for Site Protection

Another vital effect of foliage removal is upon the supply of plant materials left to shelter the soil and maintain favorable site conditions.

Both the living plants and the dead stubble and litter are important in site protection. Amount, rather than the kind or growth form, is the important feature of cover in protecting the soil from splash erosion by raindrop impact (Osborn 1952).

Natural mulches, composed of the dead and decaying remains of plants, play a vital role in preventing erosion and reducing runoff (Beutner and Anderson 1943, Dyksterhuis and Schmutz 1947, Hedrick 1948). The maintenance of this mulch by annual additions of stems and leaves left after grazing is necessary to keep the energy cycles operating.

Prevention of Erosion

The first requirement of site protection is to keep the soil itself intact. Water and wind threaten exposed soil with different intensities in different climatic regions. Raindrops and runoff act differently to detach and transport soil, and wind is unlike either. Soils themselves vary in their susceptibilities to each of these erosion agents.

Various amounts of cover are therefore required to prevent erosion under these variable conditions.

Water Erosion

To prevent initiation of soil movement by raindrop impact requires 2,000 to 6,000 pounds of cover per acre, depending upon the growth form of the vegetation (Osborn 1954a). Essentially complete protection (i.e., 95 percent effective) is provided by 3,000 pounds per acre of range plants of mixed growth form such as normally occur in natural range types (Table 1). This includes both forage and litter, weighed air-dry after being shaken to remove dirt.

Similar protection is provided by any herbaceous cover such that the weight in pounds per acre multiplied by percent surface coverage gives an "effective-weight" index of 1,500 pounds per acre.

If the soil is not fully protected from the force of the rain, the amount of erosion is influenced by the varying susceptibility of the soil itself to detachment (Osborn 1954b). The amount of cover needed to limit soil movement within tolerable limits then varies with the erodibility of each site. Figure 2 indicates the erosion hazards of different soils in relation to weight of cover when subjected to rains equivalent to a hard thundershower of 2 inches in 20 minutes.

These curves show that to limit detachment to 1 ton per acre requires 5,000 pounds of cover per acre for a soil with a very high detachability index of 90 percent (as compared to a standard structureless sand as 100 percent). At the other extreme, a soil with a detachability index of 10 percent requires only 1,500 pounds of cover per acre for equal protection. This wide variation in erodibilities was found in range soils in Texas and Oklahoma. Detachability indexes in the 30 to 60 percent range were most common.

Similar determinations of the amount of cover necessary to prevent erosion by the exclusive action of surface flow have not been made. However, since most water erosion on the general land surface is the combined effect of rainfall and runoff, the foregoing amounts of cover should be adequate to prevent erosion by rainstorms. Lesser amounts would suffice in climatic regions subject to less violent storms.

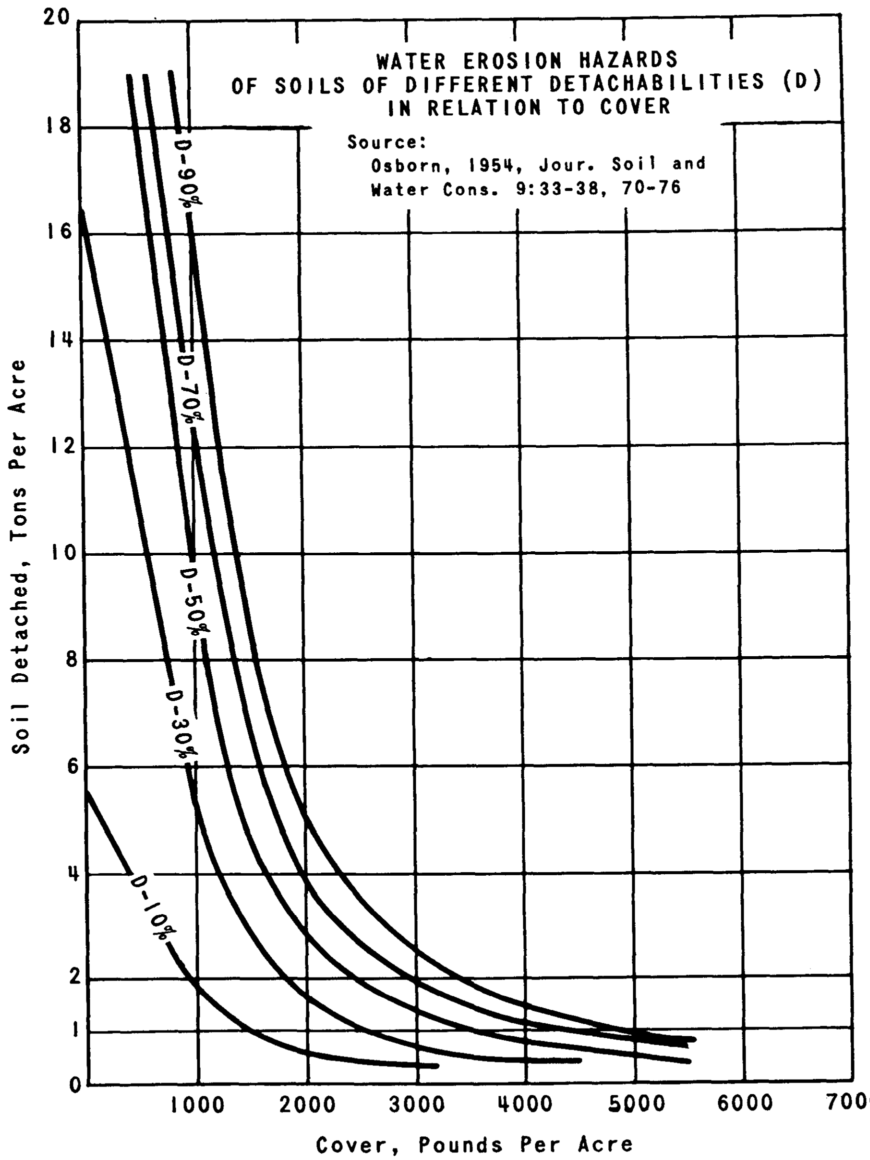

FIGURE 2. Water erosion hazards vary with soil detachability.

Wind Erosion

In more arid regions, wind is the principal agent of erosion. Here water erosion is confined largely to watercourses where runoff is concentrated, but wind erosion is a threat to the entire land surface. Proper range use must maintain adequate cover to protect the soil from this hazard.

Wind erosion investigations have dealt mainly with cultivated lands of the Great Plains. No direct determinations of the amount of cover required to protect rangelands from blowing are at hand. However, some indications may be obtained by examining the results of the cropland studies.

Measurements of soil removal under a wide variety of field conditions with a portable wind tunnel have revealed the principal factors influencing the erodibility of a land surface by wind. These are (1) the structure of the dry soil, (2) its surface roughness, and (3) crop residues or cover on the surface. Chepil and Woodruff (1954, with Zingg 1955) describe the measurement of these factors and present a formula expressing their average relationship. They also provide an alignment chart from which the wind erosion hazard for any combination of these factors can be read in tons per acre of soil removed by wind with a drag of 3,000 pounds per acre, as produced in the wind tunnel and continued until soil removal stops.

These studies do not completely separate the influence of cover from the other factors, but use it in a "residue-roughness" index obtained by multiplying the pounds per acre of residues by a "ridge-roughness equivalent" in inches. The ridge-roughness equivalent is measured directly with the wind tunnel, which reveals the effect of surface roughness on wind velocities at different heights. Cover, if present, contributes to the reductions in velocity and its effect is measured directly as a part of the ridge-roughness equivalent.

Zingg (1953) presented a curve showing the percentage of wind force taken by cover at 1 inch above ground level in relation to the residue-roughness index mentioned above. In a later publication, Chepil, Woodruff, and Zingg (1955) presented a line regression showing the average relationship of the residue-roughness index to pounds per acre of crop residues left standing without tillage after harvest. By substituting corresponding values from this chart for the residue-roughness variable of Zingg's curve, an approximate

Table 1. Amounts of cover required to prevent erosion by raindrop impact.

Effectiveness	Effective Weight of Cover[1]	Total Weight of Cover[2]: Short Sod Grasses	Mixed Range Grasses	Ordinary Crops and Grasses	Tall, Coarse Crops and Weeds
%	lb/ac	lb/ac	lb/ac	lb/ac	lb/ac
98	3,000	4,000	5,000	6,000	
97	2,500	3,000	3,750	5,000	
95	1,500[3]	2,000	3,000	3,500	6,000
90	1,000	1,500	2,000	2,500	4,000
85	750	1,200	1,600	2,000	3,000
80	600	1,000	1,400	1,750	2,250
75	500	850	1,200	1,500	1,800
70	400	700	1,100	1,300	1,500
60	300	500	900	1,000	1,100
50	200	400	750	800	900
35	100	250	500	600	600
25	80	175	400	400	400

[1]Total weight (lb/ac) x coverage (%).
[2]Weighed air-dry after shaking to remove dirt.
[3]2,000 lb/ac for tall, coarse crops and weeds; cover of this growth form ordinarily does not exceed 96% effectiveness, attained when effective weight is 3,000 lb/ac.

face, erodibility declines, and soil movement finally ceases.

By reference to Chepil and Woodruff's chart, the wind erosion hazards for soils of different erodibilities can be determined for different residue-roughness conditions. Again, by substituting average weights of standing cover for the corresponding residue-roughness values, erosion potentials can be related to amounts of cover, which should be roughly applicable to rangelands. Curves for soils of selected erodibility values are shown in Figure 4. These erodibility percentages are within the range of values found by Chepil (1953) in a large series of samples from cultivated lands of the High Plains.

indication of the effectiveness of cover alone in protecting the land from wind erosion is obtained (Figure 3). Approximately 2,000 pounds of residues per acre reduce wind force near ground level by 95 percent. In these studies the residues were washed and oven-dried before being weighed.

The cover evaluated in the wind erosion studies consisted of stubble and residues of sorghums, cotton and wheat. Such cover may differ somewhat in protective values from pure stands of range grasses, just as different plant forms provide different degrees of protection from raindrop impact (Table 1). However, many western ranges contain coarse weeds and half-shrubs which would be similar in effect to crop stubble.

Soil properties limit wind erosion even more than they do water erosion. For the wind intensities studied, virtually all particles or aggregates transported by wind are smaller than .84 mm in diameter (Chepil 1953). The amount of soil removed is limited by the percentage of this erodible fraction in the exposed surface. As erosion progresses, and the larger particles left behind accumulate on the sur-

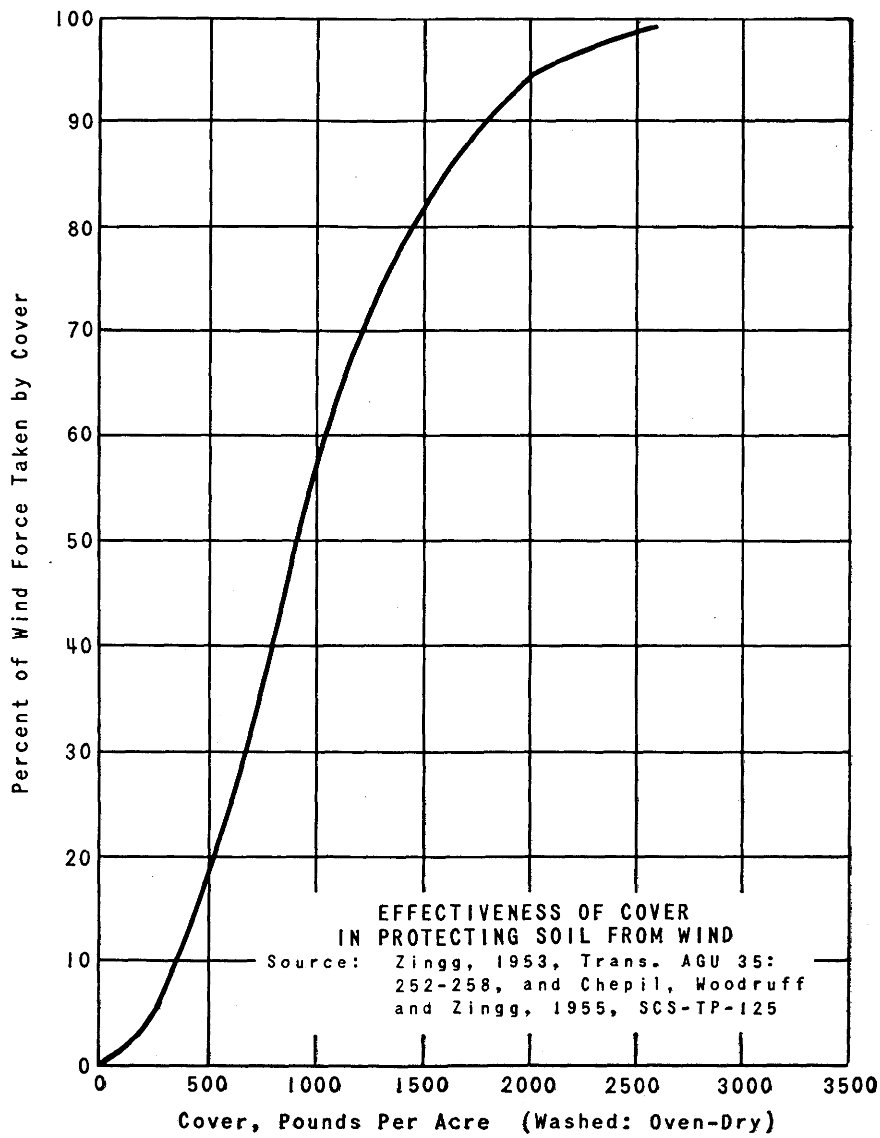

FIGURE 3. Standing cover absorbs the force of the wind.

Under the conditions of the wind-tunnel tests, erosion hazards of less than .25 ton per acre were considered insignificant, .25 to 5 tons as slight to moderate, and more than 5 tons high to very high. By these standards, approximately 2,500 pounds of cover per acre is required to control wind erosion on sands (90 percent erodible fraction), 1,500 pounds on clays (80 percent), and 500 pounds on sandy loams (60 percent) and silt loams and loams (50 percent).

These wide differences in the amounts of cover needed to give similar degrees of protection to cultivated soils suggest the need for considering variations in texture and structure of range soils in deciding the safe degree of utilization. Other properties of range soils, not usually associated with croplands, may further reduce the required amounts of cover for soil protection in the arid regions. These would include various types of crusting and the presence of gravel or rocks on the surface. Whatever these conditions are, they need to be evaluated for each range site. Then safe minimum quantity of protective cover for each might be determined.

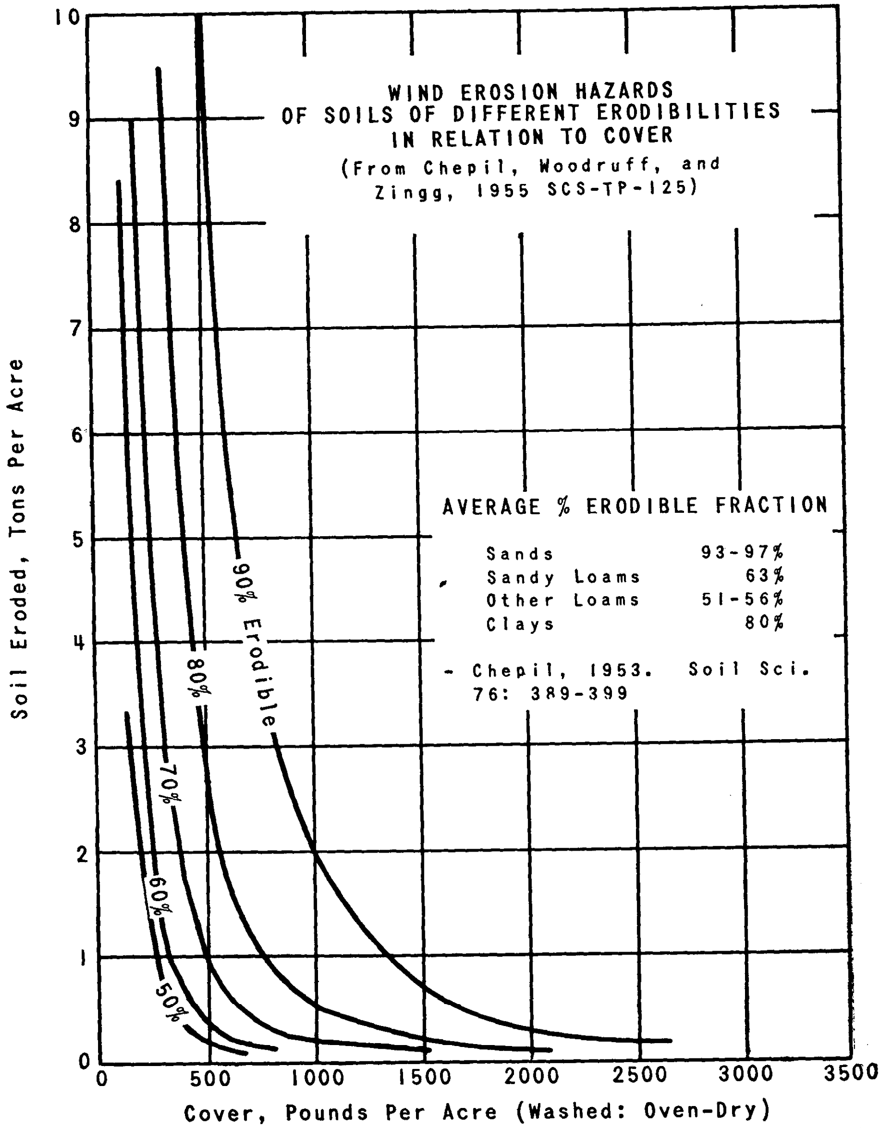

FIGURE 4. Erodibility of soil influences wind erosion hazards.

Moisture and Air in the Soil

The free entry of water and air from the atmosphere into the soil is essential to the normal functioning of the energy cycle of the biota previously described. Maintaining optimum conditions for the retention and use of rain where it falls, and good soil aeration, are another requirement of site protection.

Adequate cover on the ground contributes to ready intake of water. Two conditions are essential for maximum infiltration: (1) Adequate surface cover to cushion the impact of falling drops, and (2) favorable soil conditions at the surface and throughout the profile. These conditions are usually associated with a relatively advanced stage of ecological succession for the site, typical of one of the higher range condition classes.

Restriction of infiltration at the surface is largely the result of the puddling and sealing action of raindrops striking the soil. The amount of cover needed to insure maximum water intake for the current season, then, is the same as that required to prevent splash erosion, as already described. This may make it desirable to maintain larger amounts of protective cover on some of the more arid ranges than would be necessary for protection from wind erosion alone.

To provide for improvement or maintenance of permeability and storage capacity within the soil profile, the long-time processes of plant succession and site reaction involved in maintaining top range condition must be depended upon.

Cover evaluations in the Southwest (Osborn 1952) showed that water losses consistently increased, and water-holding capacities declined, with each lower range condition class on every site, except those of very shallow soil profiles. Measurable soil conditions, such as organic matter content and volume-weight, were progressively less favorable for good moisture relations and soil aeration as range condition declined.

It is essential from every angle, therefore, that range utilization be regulated to maintain, or restore if necessary, the highest range condition practicable.

Amount of Cover Needed

Information on the quantities of forage produced by ranges in different condition classes is seldom complete enough to make possible calculation of the proper harvest of forage, even if the amount of cover required for site protection is known. Separate measurements of forage, as distinguished from mulch or litter, are essential. Also needed is knowledge of the normal seasonal increment of new foliage and the rate of exhaustion of the protective mulch. If such information were available, it might be possible to set up a theoretical balance sheet of natural gains and losses in total cover, and the allowable consumption of forage to maintain the required cover balance on the land.

Proper range use cannot be reduced to mathematical guides with our present knowledge. We can, however, summarize present information on needed amounts of cover for site protection (Table 2). It should be remembered that these values are based on determinations from a few selected range sites in the Southwest and from cultivated soils in the Great Plains. They serve more to indicate the degree of variation to be expected in protective cover needs than to provide established standards in judging range utilization.

In any case, the goal is to turn to economic use whatever portion possible of the stream of energy of the biota without reducing its volume as expressed in forage produced from generation to generation. Constant watchfulness and care for the protection of the site and the welfare of the desired plant populations are the key to continued high forage production.

Table 2. Total cover needed for site protection

Erodibility of soil	From water erosion			From wind erosion		
	Detachability index	Usual textures	Cover needed	Erodible fraction	Usual textures	Cover needed
	%		lb/ac[1]	%		lb/ac[2]
High	65-100	Sands and sandy loams	4,000 to 5,000	75-90	Sands and clays	1,500 to 3,000
Moderate	35-65	Clays and clay loams	3,000 to 4,000	65-75	Sandy loams	1,000 to 1,500
Low	10-35	Silt loams	1,500 to 3,000	45-65	Silt loams and clay loams	500 to 1,000

[1]Shaken, air-dry.
[2]Washed, oven-dry.

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