Recovery of Cryptogamic Soil Crusts from Grazing on Utah Winter Ranges

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Abstract

Range exclosures located throughout Utah in cool desert shrub communities were analyzed to determine, (1) the response of cryptogamic crusts to grazing, (2) soil variables that influence the development of cryptogamic crusts and (3) the time needed for reestablishment of cryptogamic communities after disturbance. The amount of lichen, moss and algal cover was found to be considerably reduced by domestic grazing. Sites with moderate to high as opposed to light cryptogamic cover were characterized by significantly heavier textured soils and greater salinity. Cryptogamic cover increased from 4% to 15% during the first 14–18 years of exclusion from grazing, but increased only 1% during the next 20 years. Reestablishment of a cryptogamic crust occurs in at least 14–18 years and possibly sooner.

Until recently little attention has been given the soil stabilizing role of nonvascular plants (cryptogams). Studies in the semidesert regions of Utah in the past decade have made it increasingly clear that such plants (particularly lichens, mosses and algae) exert a significant impact on soil stability and rates of water infiltration (Anderson et al., 1982; Kleiner and Harper 1972; Kleiner and Harper 1977; Loope and Gifford 1972).

The control of wind erosion is of primary importance in the arid West. Many desert ranges are sparsely vegetated, resulting in large amounts of exposed soil surface. Brady (1974) suggested "the presence of a stable soil crust" or a "rough" soil surface decreased the severity of wind erosion. Cryptogamic soil crusts have such a double protective influence at the soil surface, since they "cement" soil fragments into cohesive units and produce roughened surfaces. Filamentous blue-green algae associated with soil crusts produce thick gelatinous sheaths (Durrell and Shields 1961) that render them more tolerant to the desiccating conditions of the desert (Fig. 1). These gelatinous sheaths coupled with the intertwinning growth habit of algal filaments effectively bind surface soil particles, forming a distinct felt-like surface or shallow subsurface meshwork on many desert soils.

Moss and lichen constituents of cryptogamic crusts are also important soil stabilizers. Thalli of these plants often cover much of the soil surface and small ventral rhizoids penetrate the surface in much the same way that algal filaments do. Lichens and mosses thus become anchored on the soil surface and shield the soil from erosive winds and the rain.

The irregular soil surface caused by algal growth and lichen and/or moss thalli (Fig. 2) breaks up the micro-patterns of wind flow, reduces windborne soil losses and traps drifting soil particles. The stabilizing effect of cryptogamic crusts as described here lacks quantitative analysis, thus our conclusions are based on personal experience and the observations of others (Anantani and Marathe 1974, Durrell and Shields 1961, Fletcher and Martin 1948, Kleiner and Harper 1972, Kleiner and Harper 1977, Singh 1950). However, there is little question that cryptogamic communities are of importance in stabilization of many arid regions of western North American.

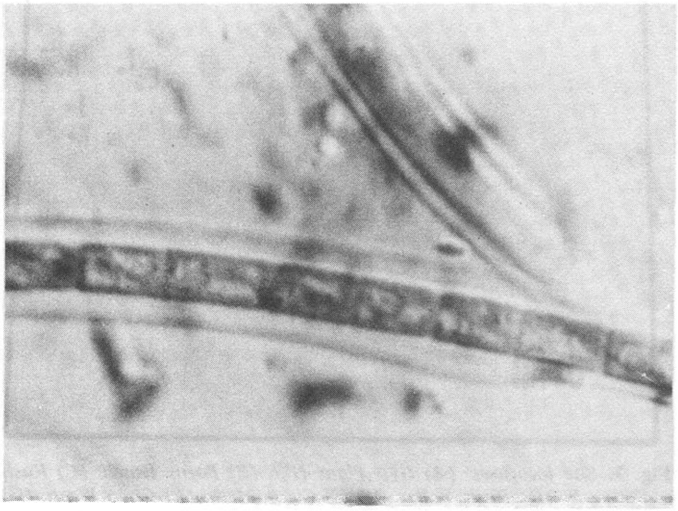

Fig. 1. *This filamentous blue-green alga is a common constituent of cryptogamic soil crusts. Note the unusually thick sheath.*

Wind erosion on arid ranges is probably intensified by grazing during dry periods. Although hooved grazing animals are destructive to highly developed cryptogamic soils crusts, it seems possible that grazing programs can be developed that minimize damage to

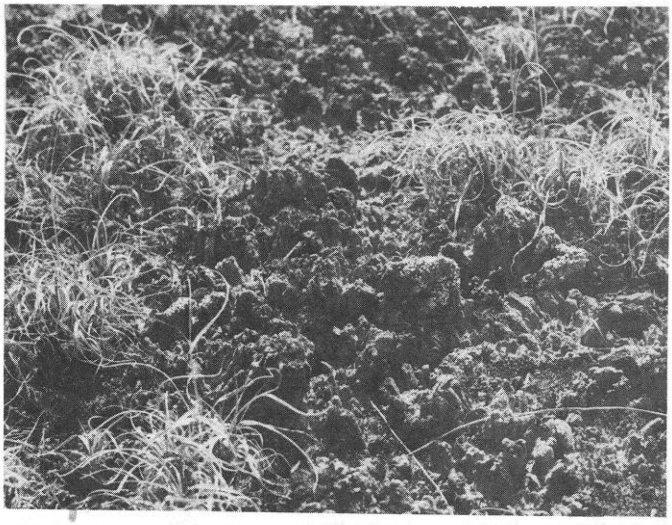

Fig. 2. *The pinnacling of the soil surface seen here is a common characteristic of the more highly developed cryptogamic soil crusts.*

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Manuscript received June 2, 1979.

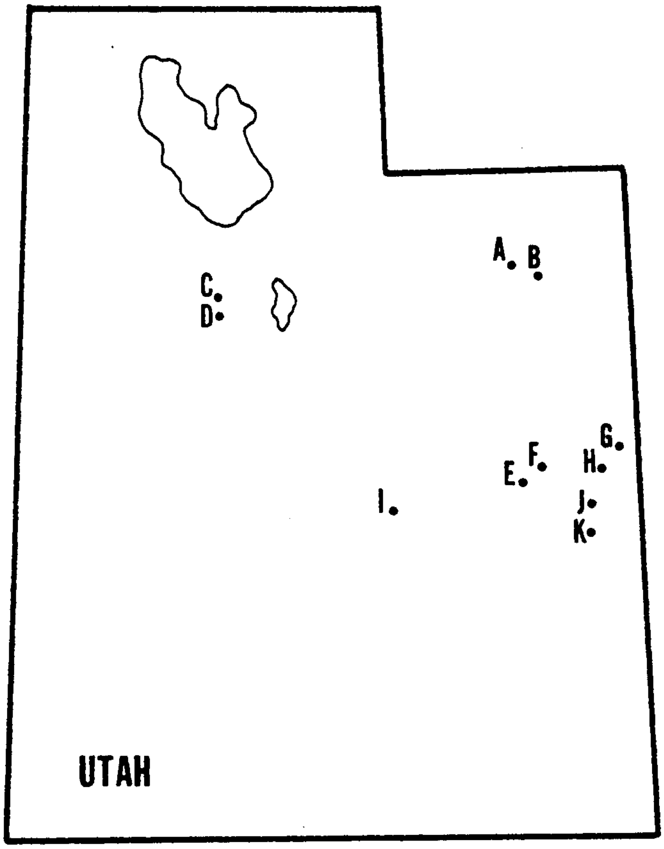

Fig. 3. *Site locations: (A) Gyp Plant Hill; (B) Burns Bench; (C) Rush Valley B; (D) Rush Valley A; (E) Cisco Mesa; (F) Cisco Wash; (G) Westwater; (H) Cottonwood; (I) Walker Flat; (J) Hotel Mesa; (K) Cowskin.*

the crusts and provide good protection against wind erosion (Anderson et al., 1982).

The primary purpose of this study is to determine the rate of cryptogamic crust reestablishment when domestic grazers are excluded. Such information combined with an understanding of the effects of grazing and soil chemistry on cryptogamic crust development should permit managers to develop management practices that utilize cryptogamic crusts to improve soil stability on many western ranges.

Materials and Methods

Eleven grazing exclosure located in the cold desert shrub zone of central and eastern Utah (Fig. 3 and Table 1) were selected to provide as broad a time range as possible for protection from domestic grazers. The exclosures are all dominated by *Atriplex* (saltbush) species. All study sites are characterized by high summer and low winter temperatures. Precipitation occurs mostly during winter months as snow or light rains. Summer precipitation is usually minimal and often comes in torrential downpours.

Table 1. Name, location, elevation, and years of protection for the 11 grazing exclosures utilized in this study. All exclosures are managed by the Bureau of Land Management. For Additional information concerning specific exclosures, see Laycock (1969).

	Location			
Exclosure	County	Physiographic providence	Elevation (m)	Years of protection
Rush Valley A	Tooele	Great Basin	1556	38
Rush Valley B	"	" "	"	38
Walker Flat	Sevier	Colorado Plateau	1891	37
Cisco Mesa	Grand	" "	1476	18
Cisco Wash	"	" "	1373	17
Hotel Mesa	"	" "	1342	17
Cowskin	"	" "	1537	17
Cottonwood	"	" "	1403	18
Westwater	"	" "	1464	17
Burns Bench	Uintah	Uintah Basin	1589	14
Gyp Plant Hill	"	" "	1629	14

At each site, two areas were subjectively selected along exclosure fences where topography, soil, and vegetative potential appeared uniform between exclosure and adjacent grazed area. One transect was placed inside the exclosure where grazing had been excluded for a known number of years. The other was located outside the exclosure fence in the grazed area. In both instances, the starting point and direction of the transect were randomly selected.

Fifteen quadrats, each .5m × .5m (0.25.^{2}) were distributed along each transect at 2-m intervals. Percent cover of vascular and nonvascular species (algae excluded) was estimated visually using six cover classes and a method similar to that proposed by Daubenmire (1959, p. 43). The amount of nonvascular cover was further divided into the amount contributed by soil lichens, rock lichens, and mosses. Algal cover was estimated visually and expressed as a percent of the total quadrat area. The algal cover estimates were somewhat subjective and dependent upon experienced observers, since algae are less obvious than lichens and mosses. For this reason, algal cover was estimated separately from that of lichens and mosses. Since all observers regularly conferred to standardize algal cover estimates, we consider the estimates to be reliable.

As a check on accuracy of algal cover estimates, we estimated cover in the field and then removed a block of the undisturbed surface soil to the laboratory where it was incubated under favorable conditions for algal growth for 3 days. At the conclusion of the incubation period when the algal growth was conspicuous, algal cover was again estimated, and recorded. Algal cover estimates in the laboratory indicate algal cover outside the exclosures was 53% of that inside the exclosure. Estimates made in the field show a similar 53%. Cover estimates in the lab were approximately 3 times that of estimates in the field, even further confirming that soil algae although inconspicuous are present in greater abundance than thought.

Table 2. Comparison of six independent variables between sites having different degrees of algal cover. Standard deviations are in parentheses.

Independent variable	Cryptogamic Cover		
	<10% cover	>10% cover	*T* value
No sites	5	6	
pH	7.92 (±.26)	8.05 (±.10)	1.0277[NS1]
EC (mmhos/cm)	.64 (± .12)	.69 (± .33)	.3450[NS]
P (ppm)	2.40 (± 1.52)	2.13 (± .93)	–.3468[NS]
% Sand	58.36 (± 10.85)	41.88 (± 16.73)	–1.9670[NS]
% Silt	25.46 (± 6.91)	41.83 (± 11.36)	2.9374*[2]
% Clay	16.18 (±6.87)	16.28 (±6.04)	.0254[NS]
Vas. plant cover	12.28 (± 6.13)	15.33 (±5.42)	.8657[NS]

[1NS] Difference not significant at the .05 level.

[2] Difference significant at the .05 level.

A subsample of the surface 2.5-cm of soil was taken at each 0.25-m quadrat and the 15 subsamples were pooled to provide a single soil sample for each transect. The soil was air dried in the laboratory and analyzed by the Agronomy Department of Brigham Young University.

Texture, pH, electrical conductivity (EC), and extractable phosphorus (P) were determined for each soil sample. The results of these analysis are used to test our initial assumption that the primary factor controlling differential cover of cryptogams inside and outside exclosures is grazing, not soil chemistry.

Electrical conductivity was determined using a 1:5 soil-to-water solution. Cation exchange capacity was determined by standard procedures (Chapman 1965). Soil phosphorus was extracted with a solution of 0.2 N acetic acid and analyzed using the method of

Table 3. Summary of vascular and non-vascular characteristics considered at each pair of transects.

	% Cover					No. spp./0.25m^2	
Site location	Vascular	Moss	Lichen	Algal (field)	Algal (lab)	Lichens	Mosses
Avg. outside exclosure	15.13	.61	3.18	8.49	24.50	.40	.72
Avg. inside exclosure	13.95	6.00	9.42	16.05	46.40	.88	1.53
T-value	.64^{NS1}	-3.40^{**3}	-2.50^{*2}	-2.27*	-2.90^{**3}	-4.33^{**3}	-3.91^{**3}

^{NS1}Difference not significant at .05 level.
^{2}*Difference significant at .05 level.
^{3}**Difference significant at .01 level.

Goldenberg and Fernandez (1966). Soil texture was determined by the hydrometer method (Day 1965).

Significance tests applied are based on paired *t*-test models described by Steel and Torrie (1960).

Results

Abiotic Factors

Previous studies indicate that soil texture and soil salinity are strongly correlated with cryptogamic crust development (Anderson et al., 1982; Kleiner and Harper 1972; Kleiner and Harper 1977). In this study, six soil characteristics (ph, P, EC, % sand, % silt, and % clay) were compared between ungrazed transects having less than 10% and over 10% cryptogamic cover (algae excluded in both cases). The analysis was restricted to within-exclosure transects, since grazing has been shown to have a negative influence on cryptogamic cover (Kleiner and Harper 1972). Our results coincide with those from other studies in that the finer textured soils (increased % silt) supported more cryptogamic cover than did coarse textured soils (Table 2).

When the six soil characteristics noted in the foregoing paragraph are regressed against cryptogamic cover using a stepwise multiple regression analysis, electrical conductivity, % silt and % clay account for almost 90% of the variation in cryptogamic cover on ungrazed transects. The regression equation $\hat{Y} = -2.9674 + 5.59 (EC) + .07 (\% \text{ silt}) - .11 (\% \text{ clay})$, showed that both EC and % silt are positively and % clay negatively correlated with cryptogamic cover. Electrical conductivity exerts the strongest influence, accounting for 65% of the variation. These results confirm previous attempts to identify those soil characteristics that are strongly correlated with the degree of cryptogamic crust development (Anderson et al., 1982; Kleiner and Harper 1972; Kleiner and Harper 1977).

We also conclude as did Kleiner and Harper (1972) that the development of cryptogamic crusts is not detrimental to vascular plant success. Table 2 illustrates that vascular plant cover does not decrease or increase as cryptogam cover increases.

Grazing

The exclosures we examined throughout Utah provided excellent fence line contrasts where the effects of grazing on cryptogamic cover could be evaluated. The kind of domestic grazer, whether sheep or cattle, differed among exclosures (Laycock 1969). The intensity and season of grazing in most cases is unknown, although it was obvious that most of the sites were grazed in the winter and grazing was intense at most sites. We made no attempt to quantify range conditions outside or within exclosures.

Cover characteristics of vascular and nonvascular communities for each grazed-ungrazed pair of transects are reported in Table 3. Our results demonstrate no significant difference in vascular cover attributable to grazing. In contrast, total cryptogamic cover (moss, lichen, and algal) differs strongly between transect pairs, as does the number of moss and lichen species per 0.25m^2. Grazed areas supported only one-tenth as much moss cover, one-third as much lichen cover and about one-half as much algal cover as did the areas within exclosures. The number of lichen and moss species per 0.25m^2 was reduced by about 50% on the grazed transects.

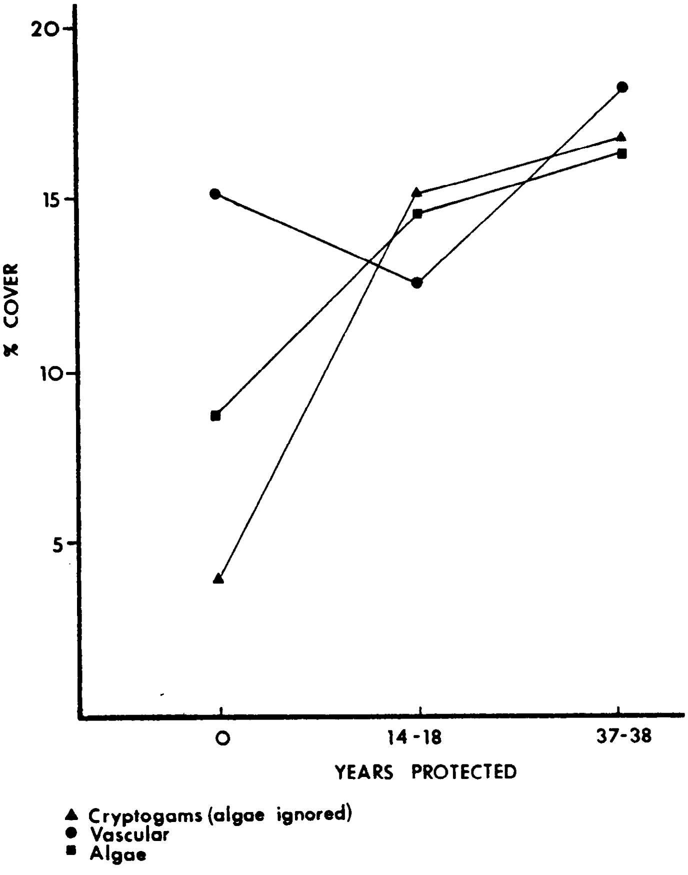

Fig. 4. *Cover variations of both cryptogamic and vascular cover over a period of 38 years. Eleven sites are pooled in the category of 0 years of protection, 8 sites are pooled in the 14-18 year category, and 3 sites are pooled in the 37-38 years protected category.*

Table 4. Summary of soil characteristics considered at each pair of transects.

				Soil texture		
Site location	pH	EC (mmhos/cm)	P (ppm)	% Sand	% Silt	% Clay
Avg. outside exclosure	8.0	.74	2.05	48.7	35.0	16.3
Avg. inside exclosure	8.0	.67	2.25	49.4	34.4	16.2
t-value	-.41^{NS}	.59^{NS}	-1.04^{NS1}	-.20^{NS1}	.24^{NS1}	.10^{NS1}

^{1NS}Difference not significant at .05 level.

A summary of the soil analysis is reported in Table 4. The results confirm that our selection of transect pairs avoided soil differences. None of the six variable considered differ significantly between transect pairs. Thus, observed differences in the cryptogamic communities seem attributable to grazing alone.

The reduction of cryptogamic cover by grazing observed in our results parallels the result of a previous study in the Great Basin Region of Utah (Anderson et al. 1982). We conclude that if a functional cryptogamic crust is to be maintained on our ranges, new grazing programs must be implemented.

Recovery Rates

We selected exclosures of known ages to evaluate the response of cryptogamic communities over time when domestic grazing pressure is removed. The change in vascular and cryptogamic plant cover over a 30-year period within the 11 exclosures is summarized in Figure 4. A sharp increase can be seen in cryptogamic and algal cover after a period of from 14 to 18 years of protection from grazing. The 20-year span following this initial period of recovery shows only a slight increase in cryptogamic and algal cover. Apparently, the crust is almost fully recovered from grazing in a period of less than 18 years. The vascular plant cover vacillates in the three temporal categories but no significantly positive or negative trends can be shown.

The contribution of different cryptogamic groups to the crusts in the three protection categories is shown in Figure 5. Of particular interest is the high relative importance of algal cover on the grazed sites (0 years protection). Obviously algae resist grazing disturbance better than either lichens or mosses. The relative contribution of algae to total cover decreases after 14–18 years of protection from domestic grazers, but the lichens and mosses still provide only 40% of the total cover. Nevertheless, the relative contribution of lichens and mosses after 14–18 years of protection is double their contribution in grazed communities. It appears that after the first 15–20 years, the cryptogamic community reaches an equilibrium, since the next 20-year period shows little change in percent composition. The number of soil lichen species encountered per transect increases over this period (Fig. 6), but the flora is merely enriched since the data show no significant increase in cover (Fig. 5). New lichen species still appear to be colonizing the exclosures almost 40 years of protection. The ratio of cryptogamic cover between grazed and ungrazed areas over time is shown in Figure 7. After 14–18 years the outside community shows only 16% as much cryptogamic cover as exists inside (algae excluded). After 38 years only 4% as much cryptogamic cover is noted. We should be cautious about the slow recovery rate of cryptogamic communities after the first 14–18 year period. Differences in the cryptogamic communities will be difficult to detect after 15 years of protection and we may not readily perceive a gradual increase or decrease in cryptogamic cover. Without relic areas such as range exclosures, we would not know the capacity of our ranges to support cryptogamic species.

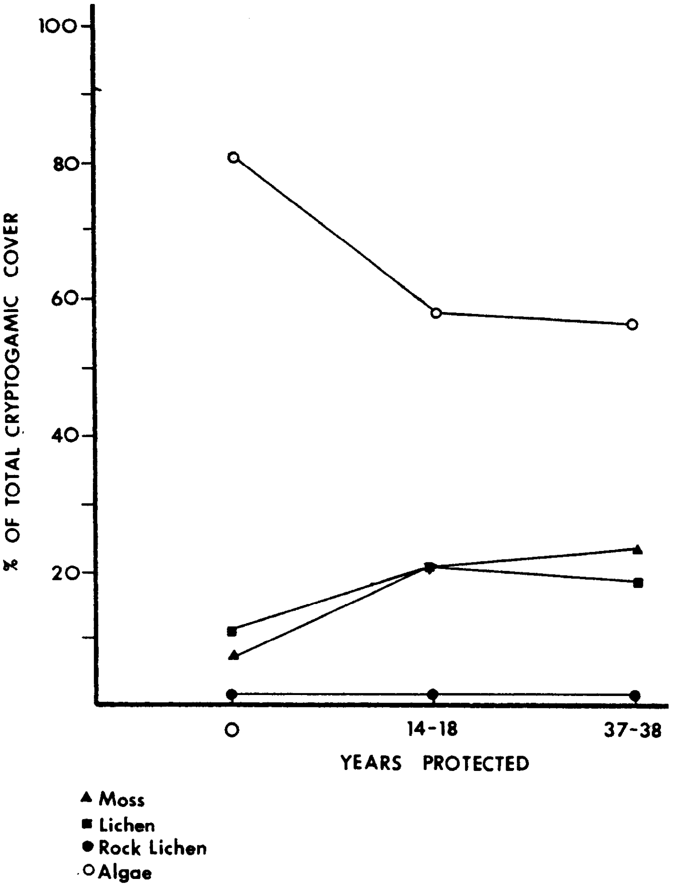

Fig. 5. *Percent of total cryptogamic cover contributed by each group of cryptogams in each protection category.*

Discussion

The soil stabilizing ability of cryptogams and their unique ability to check the erosive forces of wind and water have gained credibility in recent years. If range management schemes could be designed that would favor cryptogam species, without greatly reducing domestic animal carrying capacity, soil stability on western ranges would be enhanced at little cost to the grazing industry.

Our data demonstrated that cryptogamic cover is severely reduced by domestic grazers. Both the number of cryptogamic species and their contribution to the total cover suffer under the hooves of grazing animals. Management techniques favoring reestablishment of cryptogamic soil crusts will apparently not be detrimental to vascular plant success, since the two plant groups do not appear to be in competition (Table 2 and Fig. 4). Other studies (Anderson et al., 1982; Kleiner and Harper 1972) also show that an increase in cryptogamic cover is not associated with a decrease in vascular cover.

Cryptogamic soil crusts are prevalent throughout the arid and semiarid regions of the western North America. Although most are reduced by current management practices, cryptogams account for up to one-third of the total cover even under harsh grazing conditions (Anderson et al., in review; Table 3). The 15% moss and lichen cover (Table 3) observed on the exclosures of the winter ranges considered in this study is not abnormally high for desert soils even though the figure is considerably higher than the 4% cover of mosses and lichens on the grazing exclosures of the Desert

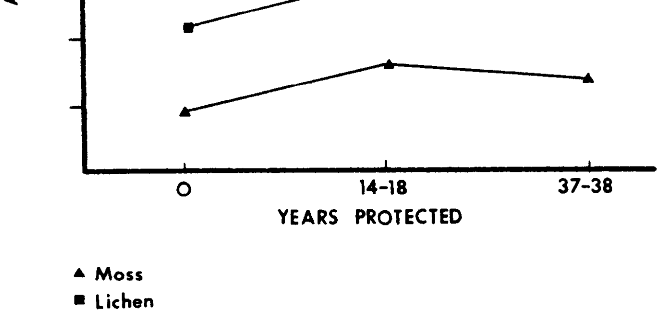

Fig. 6. *Average number of soil lichen and moss species encountered per transect at three periods of grazing protection.*

Experimental Range of the Intermountain Forest and Range Experiment Station in the Great Basin (Anderson et al., 1982).

As noted in Figure 5, algae make up 80% of the total cryptogamic cover on grazed sites. To the untrained eye, the algal crusts are not recognized as a biological phenomenon and usually go unnoticed. It is not difficult to see why cryptogamic crusts have been ignored and excluded from range management practices in the past.

Management practices favoring cryptogamic crust development seem possible, although much is yet to be learned. The present study suggests that crusts recover in a relatively short period of time under complete protection from grazing. We recognize that in some cases, the degree of cryptogamic crust development observed inside range exclosures may not be compatible with use of our range resources by domestic grazers. It is our opinion, however, that management practices can be implemented that will maintain crusts that are more capable of controlling erosion than can be maintained under current management practices. For example, prolonged grazing during seasons of low precipitation, high temperature and persistent wind is almost certain to destroy even well-developed cryptogamic crusts. During such seasons the cryptogam species are dormant and the crusts become fragile and susceptible to any mechanical disturbance. The hooves of grazing animals, whether domestic or wild, will crush the crusts. Nevertheless, year-round grazing is permitted on some semidesert ranges of the arid West.

Along the Colorado Plateau and in the Great Basin, the bulk of the precipitation occurs in the winter months as either snow or light rains. The summers are dry and hot. What precipitation does fall during the summer often comes as torrential rains. Adjusting the time of grazing to increase the likelihood that cryptogamic growth will be able to reestablish before the arrival of dry summer conditions should minimize soil erosion by both wind and water. The practice of summer grazing in such areas can only lead to a decline in the stabilizing effect of cryptogamic crusts.

Our data suggest that recovery of disturbed cryptogamic crust occurs in less than 15 years. Since we know of no exclosure in Utah semideserts that are younger than about 15 years, we have no way of knowing the shape of the recovery curve of cryptogamic crusts for the interval between 1 and 15 years. Future studies on recovery rates of cryptogamic crust communities would be greatly aided by establishment of new range exclosures and documentation of crust recovery on a year-by-year basis. Our incubation studies do demonstrate, however, that even the algal components which are more resistant to grazing than either mosses or lichens (Fig. 4) do not recover immediately.

Soils currently under grazing pressure generated only about 25% cover during incubation while adjacent ungrazed soil produced over 46% algal cover under comparable conditions (Table 3).

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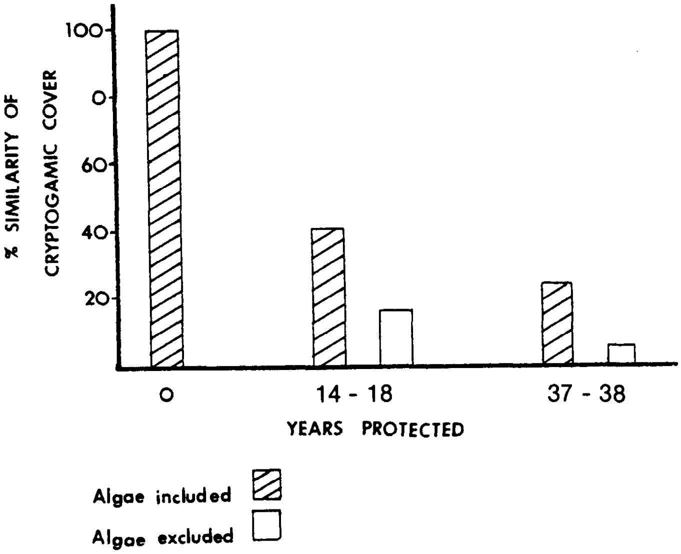

Fig. 7. *Similarity of outside cryptogamic cover expressed as % cryptogamic cover outside the exclosure divided by % cryptogamic cover inside. Cross-hatched includes algal cover. All other factors being equal, at 0 years of protection from grazing outside/inside cryptogamic cover would show 100% similarity.*

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