Effect of Range Condition on Plant Vigor, Production, and Nutritive Value of Forage

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The effect of condition or health of the range on forage production and nutritive value has been of interest for many years. Misuse of the range changes the species composition of the vegetation. These changes generally result in a decrease in production and density[1] of desirable forage species and an increase in production and density of undesirable species. The chemical content of the individual species may be changed by altering the physical structure of the plant.

Soil characteristics may also be modified by changes in range condition. Trampling and other disturbances modify the surface structure of the soil. Likewise, a change in species composition may affect soil structure by a change in the abundance and depth of roots.

From 1955 to 1957 a study was conducted on the deserts of southern Utah to determine the effects of range condition on vigor of plants, floristic composition, chemical content of the vegetation, total herbage production, and certain physical characteristics of the soil.

Review of Literature

Much has been written in the last two decades on range condition. Most of the literature has dealt with the vegetation and soil characteristics of ranges in different stages of deterioration.

The criteria most frequently used in describing condition of the range include floral composition, plant density, comparative vigor of forage species, total forage production, litter accumulation, and soil stability (Parker 1954).

Investigators have found that any disturbance that interferes with the growing conditions of the plant community results in changes in the vegetation composition (Klemmedson 1956, Short and Woolfolk 1956, Stewart *et al.* 1940). Other workers have reported decreases in total basal density of vegetation with increased grazing or decline in range condition (Klemmedson 1956, Reid and Pickford 1946). Still others have observed little change in density on deteriorating ranges (Arnold 1955, Costello and Turner 1941, Hanson 1951, Ingram 1931), and concluded that density as an index to range condition tells little because undesirable species often replace desirable species as rapidly as the latter die.

Range technicians do not agree on the usefulness of vigor as an indicator of grazing disturbances. Principal objections to the use of vigor are: (A) vigor may be modified by the effects of current weather, (B) a perennial on depleted ranges may exhibit more vigor after a short omission of grazing than the same species in climax, and (C) vigor is hard to measure or describe (Dyksterhuis 1949, Humphrey 1949, Parker 1954). Other investigators regard change of vigor as one of the important indicators of change in range condition since it is frequently the first response to a change in management (Johnson 1956, Pechanec 1945, Short and Woolfolk 1956, Weaver and Darland 1947).

Total herbage production is considered to be correlated with the condition of the range. Humphrey (1949) related range condition to present forage production in comparison to what the range is capable of producing. This method is referred to as the range-potential concept. Dyk-

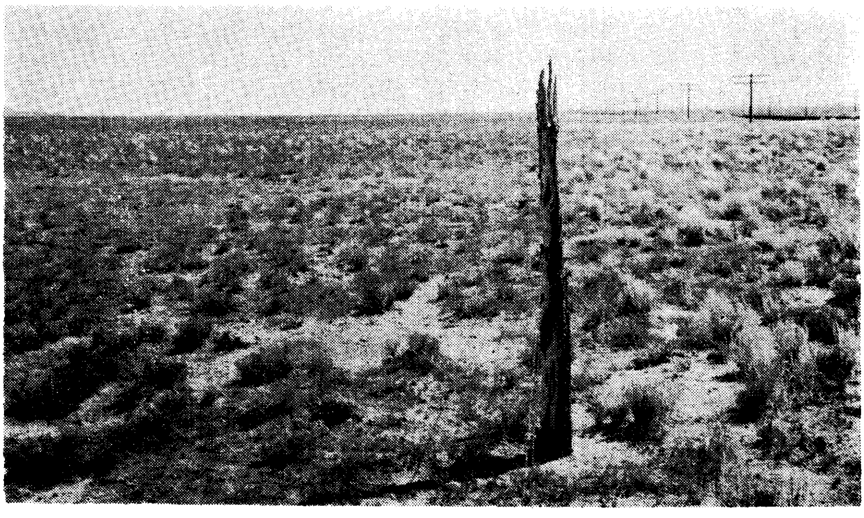

FIGURE 1. A fence-like contrast in a desert grass-shrub type. The range on the right was considered good range condition and that on the left, poor range condition.

[1] *Density in this paper is used as the percent of ground surface area covered with herbage.*

sterhuis (1949) found that only a general relation exists between forage production and range condition.

Although few studies have been made of the influence of range condition on the nutritive content of range vegetation, range managers often assume that a decline in range condition results in a decline in the nutritive value of the plants (Renner and Johnson 1942). Hutchings (1954) reported that undesirable species are low in forage quality on winter range, and desirable forage plants are highly nutritious. Esplin *et al.* (1937) reported that certain invading species were less nutritious, less palatable, and less dependable than climax forage plants.

Organic matter in the soil has long been recognized as an important factor in improving and maintaining soil structure (Kramer 1949). The amount of organic matter in soils varies, ranging from practically nothing in some dry, warm areas to 15 to 20 percent in humid, cold areas (Ellison 1954, Lyon *et al.* 1950). It is important in the aggregation of soil particles and as a direct source of energy for microorganisms. In addition, it increases the water holding capacity and the cation absorption capacity of a soil (Lyon *et al.* 1950). Thus, there is a complex relation between vegetation, soil characteristics, and condition of the range.

Description of the Area

Vegetation in the study areas was representative of extensive portions of the northern desert shrub region (Shantz and Piemeisel 1940). Shrubs included big sagebrush *(Artemisia tridentata* Nutt.), black sage *(Atemisia nova* A. Nels.) winterfat *(Eurotia lanata* (Pursh) Moq.), shadscale *(Atriplex confertifolia* (Torr. & Frem.) Wats.), fourwing saltbush *(Atriplex canescens* (Pursh) Nutt.), snakeweed *(Gutierrezia sarothrae* (Pursh) Britt and Rusby), small rabbitbrush *(Chrysothamnus viscidiflorous* (Hook) Nutt) subsp. *stenophyllus* (Gray) Hall), greasewood *(Sarcobatus vermiculatus* (Hook.) Torr.), and slenderbush eriogonum *(Eriogonum microthecum* Nutt.). Grasses included needle-and-thread grass *(Stipa comata* Trin. and Rupr.), squirreltail *(Sitanion hystrix* (Nutt.) J. G. Smith), galleta grass *(Hilaria jamesii* (Torr.) Benth.), sand dropseed *(Sporobolus cryptandrus* (Torr.) Gray), blue grama *(Bouteloua gracilis* (H.B.K.) Lag.), Indian ricegrass *(Oryzopsis hymenoides* (Room. & Schult.) Ricker), three-awn grass *(Aristida longiseta* (Steud.), and muttongrass *(Poa fendleriana* (Steud.) Vasey). Some annuals such as halogeton *(Halogeton glomeratus* (Biob.) May), Russian thistle *(Salsola kali* var. *tenuifolia* Tausch, and lambsquarters *(Chenopodium album* L.) were present. Globemallow *(Sphaeralcea grossulariaefolia* (Hook & Arn) Rydb.) was abundant in local areas.

The region has been used primarily as winter range for livestock; occasionally, portions have been grazed all year. Overgrazing has resulted in marked changes in the floristic cover compared to protected areas. The more palatable vegetation has largely been replaced by less palatable vegetation.

The average annual precipitation for the area is about 10.4 inches with maximum temperatures as high as 102°F during the summer and minimum temperatures as low as —26°F during the winter.

Methods and Procedures

Twenty-three fence-line contracts judged in good and poor range condition on opposite sides were studied (Figure 1). Classification of range condition was made according to the procedures outlined by the 2-phase method currently being used by the Bureau of Land Management (1957).

Density and production of vegetation were obtained with a 25 square-foot frame constructed of light steel tubing (Goebel *et al.* 1958). The current year's growth of each species on each side of the fence on each study area was harvested to determine production and for chemical analysis.

After plant growth reached its peak in the spring of 1957, vigor measurements were made on the dominant species at 8 study areas which showed particularly strong range condition contrasts. Measurements were taken on density, height of flowering stalks, number of flowering stalks per plant, leaf length, and length of vegetative stem growth.

To obtain leaf length on shrubs, 4 randomly located leaves from each plant were measured from petiole to tip. On grasses, the second leaf from the base of the plant was measured.

On 3 grass species, the filled caryopses per flowering stalk were counted. Seeds from Indian ricegrass and galleta grass were retained for germination studies. There were not enough sand dropseed plants for an adequate sample of seed. Seed germination trials were carried out using 14 samples of 200 seeds each. Seeds were soaked in 15 percent sulfuric acid for 60 min. before germination.

Soil determinations included infiltration rate, percent organic matter, and bulk-density. Infiltration studies were made by using steel cylinders 9.6 inches across and approximately 18 inches high. The cylinders were driven 4 inches into the ground by driving a hammer onto a 14 inch cover plate placed on the infiltrometer. Two gallons of water were added to each infiltrometer and the drop in water level was determined at 5-

Table 1. Average floral composition and chemical content of current growth of vegetation on 23 fence-line contrasts displaying poor and good range condition

Species and condition	Composition	Plant density	Production	Ether extract	Total protein	Ash	Lignin	Cellulose	Other carbohydrates	Calcium	Phosphorus	Gross energy
	(Percent)		(lbs/A)	— — —	— — —	— —	(Percent)	— —	— —	— —	— —	(Cal/lb)
POOR CONDITION												
Good forage species												
Globemallow	.19	.02	1.14	2.2	14.5	13.1	6.8	18.4	44.9	2.17	.23	1881
Indian ricegrass	3.28	.35	5.87	2.0	6.0	14.0	8.0	28.3	41.7	.81	.08	1843
Squirreltail	.28	.03	.78	4. 5	10.3	17.2	6.0	21.3	40.7	.80	.12	1868
Black sagebrush	5.25	.56	35.88	6.4	9.5	5.6	14.2	16.2	48.2	.70	.18	2274
Winterfat	3.84	.41	30.87	2.3	11.2	19.8	8.4	20.4	38.1	2.24	.13	1699
Muttongrass	.19	.02	.37	3.4	5.5	15.8	5.7	23.5	46.1	.53	.16	1950
Fourwing saltbush	2.06	.22	16.25	2.3	11.6	13.6	12.3	17.9	42.3	1.23	.11	2004
Needle-and-thread	.19	.02	.80	3.2	5.1	16.7	7.8	30.2	37.2	.73	.09	1849
Galleta	15.47	1.65	52.89	1.4	5.3	15.0	7.9	30.5	40.2	.62	.09	1753
Subtotals and averages	30.75	3.28	144.85	3.1	8.8	14.5	8.6	23.0	42.2	1.09	.13	1902
Fair forage species												
Slenderbush eriogonum	.09	.01	.31	1.8	7.4	9.1	21.4	22.2	38.1	1.16	.12	1914
Western wheatgrass	.09	.01	.20	3.0	4.0	20.3	5.4	26.7	40.6	.66	.09	1791
Lambsquarters	.19	.02	.56	2.0	10.8	19.0	8.7	15.7	42.1	2.01	.13	1722
Sand dropseed	1.12	.12	3.09	1.1	7.2	9.9	9.8	34.0	37.9	.46	1.2	1873
Shadscale	6.37	.68	56.03	2.4	12.6	20.2	15.4	17.6	32.4	1.90	.13	1860
Blue grama	4.31	.46	14.70	1.1	4.4	19.6	8.1	30.4	36.3	.47	.07	1654
Big sagebrush	10.97	1.17	82.40	6.0	12.2	6.0	11.8	16.5	47.5	.69	.22	2386
Subtotals and averages	23.14	2.47	157.29	2.5	8.4	1.49	11.5	23.3	39.3	1.05	.13	1886
Poor forage species												
Snakeweed	1.22	.13	12.52	8.7	10.9	9.2	11.8	13.9	43.1	.96	.18	2182
Small rabbitbrush	15.37	1.64	80.24	7.5	10.5	12.4	13.4	13.5	42.9	2.30	.15	2107
Russian thistle	24.18	2.58	139.73	2.6	7.9	18.0	8.5	22.2	39.2	2.90	.12	1576
Three-awn	.84	.09	5.29	1.1	4.9	16.6	8.9	30.1	38.4	.66	.06	1751
Miscellaneous species	4.50	.48	14.21	....	......	......	......	......	......	......	....	....
Subtotals and averages	46.11	4.92	251.99	5.0	8.6	14.1	10.6	19.9	40.9	1.70	.12	1904
Averages and totals	100.00	10.67	554.13	3.2	8.6	14.6	10.0	22.5	40.9	1.20	.13	1897
GOOD CONDITION												
Good forage species												
Globemallow	2.44	.30	1.34	2.2	13.2	12.0	7.2	20.2	45.2	2.15	.21	1886
Indian ricegrass	7.80	.96	37.40	1.8	5.5	13.0	8.6	29.4	41.7	.83	.06	1879
Squirreltail	1.06	.13	3.55	4.0	9.4	20.5	5.9	20.1	40.0	.82	.13	1797
Black sagebrush	5.20	.64	32.43	6.0	10.1	5.2	15.2	15.2	48.4	.69	.17	2331
Winterfat	15.11	1.86	121.26	2.6	10.8	14.5	11.2	21.2	39.1	2.14	.11	1843
Muttongrass	.73	.09	2.14	4.0	7.7	16.3	6.1	27.5	38.4	.54	.11	1927
Fourwing saltbush	3.41	.42	39.20	2.2	11.2	13.8	12.6	18.1	41.9	1.46	.11	2001
Needle-and-thread	3.01	.37	14.34	4.5	5.7	14.7	7.7	32.1	35.3	.74	.07	1885
Galleta	11.37	1.40	64.56	1.3	4.2	15.9	8.2	30.9	39.5	.67	.08	1746
Subtotals and averages	50.13	6.17	316.22	3.2	8.6	13.9	9.2	28.3	41.1	1.12	.12	1922
Fair forage species												
Slenderbush eriogonum	.07	.01	.46	1.6	6.6	8.0	22.0	21.8	40.0	1.12	. 10	1964
Western wheatgrass	.49	.06	1.96	3.0	4.0	20.3	5.4	26.7	40.6	.66	.09	1791
Lambsquarters	.07	.01	.50	2.3	11.2	20.9	7.8	14.4	43.5	1.60	.13	1693
Sand dropseed	1.62	.20	6.56	1.1	6.4	10.6	9.8	33.7	38.4	.46	.11	1847
Shadscale	4.63	.57	42.62	3.0	9.8	17.2	18.7	20.1	31.2	1.51	.11	1962
Blue grama	3.01	.37	11.31	1.1	4.0	21.9	7.9	26.1	39.0	.66	.08	1642
Big sagebrush	12.51	1.54	105.05	5.3	11.2	5.2	13.4	17.6	47.1	.74	.23	2462
Subtotals and averages	22.40	2.76	168.46	2.5	7.6	14.9	12.1	22.8	40.0	.96	.12	1909
Poor forage species												
Snakeweed	.25	.03	1.42	8.5	11.1	9.9	11.5	15.7	43.1	1.09	.23	2219

Small rabbitbrush	14.30	1.76	86.62	7.8	11.2	12.2	13.6	13.1	42.0	2.29	.16	2158
Russian thistle	11.30	1.39	56.36	2.1	8.3	17.2	9.4	24.2	38.9	2.87	.27	1716
Three-awn	.81	.10	4.36	1.2	4.9	15.5	8.6	30.0	39.8	.68	.08	1772
Miscellaneous species	.81	.10	3.79	....	......	......	......	......	......	......	....	....
Subtotals and averages	27.47	3.38	152.55	4.9	8.9	13.7	10.8	20.8	41.0	1.73	.18	1966
Averages and totals	100.00	12.31	637.23	3.3	8.3	14.2	10.5	22.9	40.6	1.19	.13	1926
Average difference in percent chemical content in current year's growth on poor and good ranges[1]				0.1	-.3	-.4	.5	.4	-.3	-.01	.00	

[1]Negative numbers indicate a higher amount or percentage on the poorer condition range.

minute intervals for the first 15 minutes, again after another 15-min. interval, and thereafter at 30-minute intervals until the water completely disappeared. When all of the water had entered the soil, a bisect was dug to expose the pattern of the wetted area below the infiltrometer. This was measured at its deepest and widest points.

To obtain bulk-density of the surface soils, a ¾ inch brass tube with a steel cutting edge was inserted vertically to a depth of 2½ inches in the soil. Twenty-four samples were randomly collected from each area, 12 from each side of the fence. Samples were taken in open area between plants.

Sixteen surface soil samples were collected from each study area to determine organic matter content. The method of sampling was the same as for bulk-density except that 8 samples were collected on each side of the fence. The Schollenberger (1945) rapid method of organic matter determination was used in the laboratory analysis.

Results and Discussion

Vegetation Studies

Floral Composition and Density

Knowledge of differences in palatability of various range species is useful in classifying them with respect to their desirability as forage. This permits the separation of species into good, fair, and poor forage. A difficulty in using this method is the variability in palatability of the same species in different plant associations. Under most conditions, however, it is possible to devise a relative preference list for species normally found on an area. Hutchings (1954) devised such a list for sheep on winter ranges of southwestern Utah.

Good forage species in the study areas included winterfat, fourwing saltbush, black sagebrush, needle-and-thread grass, galleta grass, mutton grass, squirreltail, and globemallow. Fair forage species most abundant in the areas studied were big sagebrush, shadscale, sand dropseed, and blue grama grass. Poor forage species included snakeweed, small rabbitbush, three-awn grass, and Russian thistle.

Study areas judged to be in good range condition had a higher percentage of highly palatable forage species than did poor-condition ranges.

The most productive species on the good-condition ranges was winterfat, accounting for about 19 percent of the total air-dry herbage (Table 1). In contrast, on the poor-condition ranges only about 6 percent of the herbage was produced by winterfat.

Good forage species accounted for 49.63 percent of the total herbage production on the good-condition ranges and only 26.14 percent on the poor-condition ranges (Table 1).

Poor forage species produced 23.94 percent of the total production of the good-condition ranges but produced 45.47 percent on poor ranges.

Shrubs on the good-condition ranges produced 429.06 pounds of herbage per acre while on the poor ranges they produced 314.50 pounds. On good ranges the grasses produced 146.18 pounds of herbage per acre while on the poor ranges they produced only 83.99 pounds. The remainder of the herbage production was made up predominately of annual forbs which accounted for 61.99 pounds per acre on the good ranges and 155.64 pounds on the poor.

Total density averaged 12.31 percent on good-condition range and 10.67 percent on adjacent poor ranges (Table 1). In several study areas, however, density was higher on the poor-condition ranges than on the good-condition ranges. This suggests that density is not always a good criterion of range condition, particularly when invading plants on poor ranges are annuals. These may exist in greater density on poor ranges than good forage species do on good ranges.

Herbage Production

Total herbage production on good-condition ranges was 83.10 pounds per acre higher than production on poor-condition ranges (Table 1). This difference was statistically significant at the 5 percent level of probability.

Nutritive Content of the Current Year's Growth

Results of this study indicate that improvement in range condition will not always result in higher nutrient content of the forage.

On poor ranges, good forage species were higher than poor forage species in percent total protein, ash, cellulose, other carbohydrates, and phosphorus but on good ranges, the good

Table 2. Average differences in measurements for vigor of plants found on good and poor ranges (figures represent measurements of poor ranges subtracted from good ranges)

Species	Herbage cover plant	Leaf length	Vegetative stem length	No. of seedstalks	Seedstalk lengths	Caryopses/ stalk
	(1/16 sq. ft.)	(mm.)	(mm.)		(mm.)	
Yellowbrush	- .49	- 1**	-11**	-14	- 2**	....
Winterfat	1.34**	2**	46**	15**	3	..
Fourwing saltbush	2.82**	- 5**	-39**	68**	- 6	....
Shadscale	.45	0	- 8	....	....	....
Snakeweed	-1.65	- 3	-10*	-29	- 5**	....
Indian ricegrass	2.27**	66**	....	16**	84**	16*
Needle-and-thread	1.18	54*	....	12	124*	9
Galleta grass	.31**	14**	....	2**	41**	1*
Sand dropseed	.05	19**	....	1	-19	....
Average	.70	16	- 5	9	28	9

* Significant at the .05 level
**Significant at the .01 level

forage species were higher only in percent ash and cellulose (Table 1). Differences in chemical composition between the same species on adjacent good and poor ranges probably resulted from a change in the character of growth of the plants. The overall average of good forage species was somewhat higher in cellulose and other carbohydrates but the poor forage species were higher in ether extract, total protein, calcium, and phosphorus.

Vigor

Measurements to determine differences in vigor of the same species on good and poor ranges are presented in Table 2. Generally, good forage species on good-condition ranges produced significantly more herbage cover per plant, more and taller flowering stalks, longer leaves and vegetative stem growth, and, in addition, grasses produced more filled caryopses per flowering stalk than the same species on poor ranges.

Poor forage species (snakeweed and small rabbitbrush) produced less herbage cover, fewer and shorter flowering stalks, shorter leaf lengths, and less vegetative stem growth on good ranges than on poor. These differences were statistically significant only for vegetative stem growth and length of flowering stalk.

Trials using 3,200 Indian ricegrass seeds and 2,200 galleta grass seeds showed no significant differences in germination of seeds from good and poor ranges. This agrees with the data of Cook *et at.* (1958) which showed plants in lowered vigor produced fewer caryopses per plant but viability of seeds was not affected.

Soil Analysis

Infiltration

Rates of infiltration were generally more rapid on good range than on poor range. Infiltration on good-condition ranges averaged 3 inches per hour for the first 2 hours and on poor-condition ranges averaged 2.4 inches per hour (Table 3). This difference was highly significant.

Coarse-textured soils had significantly higher rates of infiltration than fine-textured soils (Table 3). On fine-textured soils, differences of infiltration rates on good and poor ranges were large immediately following the application of water but on coarse-textured soils differences were relatively uniform between good and poor ranges.

The range condition and texture of soil had a significant effect on the total time for 2 gallons of water to enter the soil (Table 4). On good-condition ranges only 161 minutes were required for 2 gallons of water to enter the soil; whereas, poor-condition ranges required 227 minutes.

Table 3. Average infiltration rates for the first two hours following application of water on good and poor ranges for eight areas

Soil types	Range condition class	1	2	3	4	5	6	7	Average
		Infiltration rates by time periods[1] (inches/hr.)							
Sandy loam	Poor	6.3	3.6	2.9	2.9	2.5	2.0	1.7	3.1
	Good	7.5	4.0	3.7	3.3	2.9	2.4	1.8	3.6
	Average	6.9	3.8	3.3	3.1	2.7	2.2	1.8	3.3
Silty clay loam	Poor	2.3	1.9	1.3	1.1	0.9	0.7	0.6	1.3
	Good	4.2	2.8	1.9	1.5	1.2	1.0	0.7	1.9
	Average	3.2	2.4	1.6	1.3	1.0	0.8	0.6	1.6
Average	Poor	4.8	2.9	2.3	2.3	1.9	1.5	1.3	2.4
	Good	6.2	3.6	3.0	2.6	2.3	1.9	1.4	3.0

[1] Periods 1 to 3 were of 5-minute durations, period 4 of 15 minutes, and periods 5 to 7 of 30 minutes.

Table 4. Average infiltration time for two gallons of water, and width and depth of penetration on good and poor-condition range from eight areas

Soil type	Condition class	Infiltration time	Penetration Width	Depth
		(Min/2 gal.)	(Inches)	
Sandy loam	Poor	234	12.6	15.5
	Good	153	13.1	16.1
	Average	193	12.8	15.8
Silty clay loam	Poor	215	10.6	17.4
	Good	174	11.1	17.8
	Average	195	10.8	17.6
Average	Poor	227	11.9	16.2
	Good	161	12.4	16.7

Infiltration trials showed that water penetrated somewhat deeper and spread laterally a greater distance on good ranges than on poor ranges (Table 4). There were also differences between the width and depth of water penetration between the 2 types of soils. Coarse-textured soils displayed a significantly wider pattern of penetration than fine-textured soils. However, fine-textured soils exhibited a significantly greater depth of penetration than coarse-textured soils.

Organic Matter

The organic fraction of these desert soils is relatively small and varies only slightly between good and poor ranges (Table 5).

Bulk-density

Soils from poor ranges were significantly higher in bulk-density than those from good ranges (Table 5). However, on 3 of the 8 areas studied, bulk-density was slightly higher on the good ranges.

Average bulk-density measurements on coarse-textured soils were significantly higher than on fine-textured soils (Table 5). Bulk-densities on silty clay loams averaged 1.37 grams per cubic centimeter and ranged from 1.28 to 1.41. In comparison, soils of the sandy loam types averaged 1.57 and ranged from 1.42 to 2.23. This difference might be expected since particles of sandy soil generally lack structure (Lyon *et al.* 1950). The slightly lower organic matter content of the sandy loam sites may also have contributed to the higher bulk-density.

Condition Criteria

It appears from this study that many soil and vegetation criteria may be used to describe range condition. Total plant density is generally helpful in classifying range condition but is not dependable. Percent organic matter is not a reliable criterion unless a more detailed or delicate analytical procedure can be used to determine minute differences.

Floristic expression and relative vigor of the vegetation were rather consistent criteria of range conditions in this study.

Summary

Studies were conducted on desert ranges in southwestern Utah during 1955 and 1957 to determine effects of range condition on plant density, floristic composition, herbage production, vigor of plants, chemical content of vegetation, and certain physical characteristics of the soil.

Range condition had a pronounced effect on the expression of vegetation on the range. Good-condition ranges generally had a slightly higher density, a more desirable floral composition, and higher production than poor-condition ranges.

Good forage species on poor ranges were higher than poor forages in percent total protein, ash, cellulose, other carbohydrates, and phosphorus but good forage species on good ranges were higher than poor forage species only in percent ash and cellulose.

Generally, a decrease in range condition is accompanied by a decline in length of leaves and stems, and in number and length of flowering stalks on good forage species. In addition, grass species in good vigor produce more caryopses per flowering stalk than those in poor vigor. Viability of caryopses produced by plants in good and poor vigor showed no significant differences.

Rates of infiltration were faster and water penetration was wider and deeper in soils of good-condition ranges compared to poor-condition ranges. Bulk-density was significantly higher on poor-condition ranges. There were no significant differences in amount of organic matter between good and poor ranges.

Coarse-textured soils had significantly higher infiltration rates and bulk-density values than fine-textured soils.

Table 5. Average percent organic matter and bulk-density from soils of good and poor ranges for eight areas

Soil type	Condition class	Organic matter	Bulk-density
		(percent)	(gms./cc)
Sandy loam	Poor	0.83	1.64
	Good	0.89	1.50
	Average	0.86	1.57
Silty clay loam	Poor	0.84	1.39
	Good	0.91	1.35
	Average	0.88	1.37
Average	Poor	0.83	1.52
	Good	0.90	1.42

It was concluded that most of the criteria studied could be useful in classifying range condition. However, criteria such as total plant density and percent organic matter did not appear to be reliable indexes.

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