Biomass productivity and range condition on range sites in southern Arizona

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Abstract

Range condition is usually defined by similarity of current to climax or potential vegetation. It is often assumed that rangelands in low condition are biologically less productive than those in higher condition. The objective of this study was to determine if range condition (ecological status) is related to total productivity or to forage production for livestock. Adjacent areas along fencelines representing differences in range condition were sampled in 58 locations. These comparisons represented 31 different range sites across southern Arizona. Weight by species of above-ground peak standing crop current year's growth of vegetation was estimated using the dry-weight-rank/comparative yield methods. Range condition was rated with Soil Conservation Service range site descriptions. Species were classified as forage or non-forage to estimate forage available for cattle. In 75–85% of comparisons of good condition sites to fair condition, good to poor, and fair to poor, total current year's standing crop did not differ significantly. Where differences were significant, productivity was not consistently more on the high condition class. Forage production, however, was more from the stand in the higher condition class in about 2/3 of the comparisons. We concluded that in southern Arizona rangelands in higher condition (higher seral) classes usually produce more forage for cattle than lower condition classes on the same range site. Nevertheless, it is not usually true that total biomass productivity on low condition range is less than the same range site in higher condition.

Key Words: forage production, biomass production

Condition of rangeland is commonly defined in terms of the similarity of the present vegetation to the climax or potential vegetation of the range site (Smith 1979). This climax or "ecological" approach (Dyksterhuis 1949, 1952) is a measure of "ecological status" (RISC 1983) of the vegetation which, presumably, is independent of its value for a specific use. This approach has been the basis for most of the reporting of "range condition" on both public and private rangelands in the United States.

It seems logical that classification of range condition should reflect current productivity of rangeland in relation to its inherent potential as determined by climate, soil, and topographic position. Thus, both resource managers and laymen may implicitly assume that ranges in "poor" condition are biologically less productive than those in "good" condition. Reports on range condition have stated this assumption explicitly. For example, the Bureau of Land Management (1979) stated that 135 million out of 170 million acres of public domain were in "fair condition or worse" and concluded "there is no question that vegetation production is far below potential." These statements imply that ranges are less productive than they could be for all uses, not just livestock grazing. Such conclusions may be incorrect.

Change in the rating of range condition is based on increase in relative amount of some species and decrease in others. In the climax approach to condition assessment a change from "good" to "poor" condition means the species which increase are considered to be of lower successional status than those which decrease. If the species which increase are less palatable, less available, or less digestible for a specific herbivore than those which decrease, forage value of the vegetation may be diminished for that animal. In some cases forage production for livestock has been shown to be greater on good condition ranges than on poor condition ranges as rated by the climax approach (Goebel and Cook 1960, Cook et al. 1962, Christie and Hughes 1981, Powell et al. 1982 and others). In other cases, poor or fair condition rangeland may produce more forage for livestock than good condition range (e.g., Cook et al. 1965). There is no reason that we know of to suppose that similarity to "climax" should be correlated to forage production for any particular animal. Therefore, instances where such correlations do occur must be specific to certain vegetation types. Otherwise, these correlations may reflect a bias toward forage species for specific animals in describing the presumed climax vegetation.

Less information is available to indicate whether total site productivity is related to climax-based ratings of range condition. All the studies cited above reported only forage production, not total biomass production. Chew and Chew (1965) found that primary productivity in desert shrub communities in Arizona was similar regardless of major species or life form, and that it was similar to rates reported in the literature from widely separated areas with similar areas with similar precipitation. Evenari et al. (1975) and Fischer and Turner (1978) also concluded that precipitation, rather than vegetation composition, is the main determinant of biomass production in semiarid areas. Friedel (1981), working in a semiarid region of Australia, found no relationship between range condition assessed as similarity to climax and species diversity or total productivity. She also found there were no significant differences in total standing crop or percentage of green material present in different condition classes. This work was done in *Astrebla* grasslands, open woodlands, and *Acacia* shrublands.

Based on the evidence available, we hypothesized that productivity of rangeland vegetation in arid/semiarid areas is determined primarily by site characteristics (precipitation, soil, topography) which influence the main limiting factor, moisture. Therefore, species or life form composition have relatively little effect on total biomass production, except where extreme disturbance (e.g., around water holes) or areas of large, denuded patches of crusted or "scalded" soil prevent reasonable populations of plants. From this hypothesis, the objective of this study was to determine if range condition (ecological status) is related to total vegetation productivity or to forage production for livestock on a cross-section of range sites in southern Arizona.

Methods

Vegetation data were collected at 58 locations selected to represent a variety of range sites in several Major Land Resource and Sub-Resource Areas in southern Arizona (Table 1). All locations had a mixture of plant life forms and species. Each location was sampled on both sides of a fenceline which provided a comparison of 2 range condition classes on the same range site.

Actual productivity (plant biomass produced per year) of rangeland vegetation is difficult to measure because different species and

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Table 1. Range sites sampled within Major Land Resource Areas (MLRA) and Sub-Resource Areas (SRA) within Southern Arizona.

MLRA/SRA	Range sites sampled		Number of locations	Characteristic vegetation
D39 Arizona and New Mexico Mountains				
D39-4 AZ Interior	Deep Sandy Loam	16–20 p.z.	1	Shrub live oak *(Quercus turbinella)*
Chaparral-Grassland	Loamy Upland	12–16 p.z.	2	manzanita (*Arctostaphylos* spp.),
	Limy Upland	12–16 p.z.	1	grama grasses (*Bouteloua* spp.),
				squirrel tail *(Sitanion hystrix)*
D40 Central Arizona Basin and Range				
D40-2 Phoenix Desert	Limy Slopes	7–10 p.z.	2	Creosotebush *(Larrea tridentata),*
Shrub	Loamy Upland	7–10 p.z.	2	saguaro *(Carnegiea gigantea),*
	Sandy Loam Upland	7–10 p.z.	3	fluffgrass *(Erioneuron pulchellum)*
	Shallow Upland	7–10 p.z.	1	bush muhly *(Muhlenbergia porteri)*
D40-3 Central Arizona	Loamy Slopes	10–12 p.z.	1	Paloverde (*Cercidium* spp.),
Desert Grassland-Shrubs	Loamy Hills	10–12 p.z.	1	Joshua Tree *(Yucca brevifolia),*
	Sandy Loam Upland	10–12 p.z.	1	creosotebush, big galleta
				(Hilaria rigida), dropseeds
				(*Sporobolus* spp.)
D40-1 Upper Sonoran	Deep Sandy Loam	10–12 p.z.	1	Paloverde, saguaro, creosotebush,
Desert Shrub	Deep Sandy Loam	12–15 p.z.	1	mesquite *(Prosopis juliflora),*
	Limy Fan	10–12 p.z.	1	bursage (*Ambrosia* spp.),
	Limy Slopes	12–15 p.z.	1	tobosagrass *(Hilaria mutica),*
	Limy Upland	10–12 p.z.	2	Arizona cottontop *(Digitaria*
	Loamy Bottom	10–12 p.z.	1	*californica.*
	Loamy Hills	12–15 p.z.	3	
	Sandy Loam Upland	12–15 p.z.	3	
	Shallow Upland	10–12 p.z.	1	
D41 Southwestern Arizona Basin and Range Basin and Range				
D41-2 Chihuahuan	Limy Fan	7–10 p.z.	2	Creosotebush, mesquite,
Desert Shrub	Limy Upland	7–10 p.z.	2	tarbrush *(Flourensia cernua)*
	Loamy Upland	7–10 p.z.	4	black grama *(Bouteloua eriopoda)*
	Sandy Loam Upland	7–10 p.z.	4	*bush muhly, three awns*
				(*Aristida* spp.).
D41-3 Chihuahuan Semi-	Limy Upland	12–16 p.z.	1	Mesquite, whitethorn
desert Grassland	Limy Slopes	12–16 p.z.	2	*(Acacia constricta),* yucca
	Loamy Upland	12–16 p.z.	3	(*Yucca* spp.), grama grass
	Sandy Loam Upland	12–16 p.z.	3	(*Bouteloua* spp.), plains
				lovegrass *(Eragrostis intermedia)*
				plains bristlegrass *(Setaria*
				macrostachya), Arizona cottontop
D41-1 Mexican Oak-Pine Woodland and Oak Savanna				
	Deep Sandy Loam	16–20 p.z.	2	Liveoaks (*Quercus* spp.)
	Limy Upland	16–20 p.z.	2	grama grasses, cane bermudagrass
	Loamy Upland	16–20 p.z.	2	*(Bothriochloa barbinodis),*
	Sandy Loam Upland	16–20 p.z.	2	Texas bluestem *(Schizachyrium*
				cirratus).

life forms differ in phenology. Therefore, the standing crop of current year's growth was estimated at the approximate time of peak standing crop for all vegetation and considered an index to annual productivity. Data were collected from August through October, 1985. Rainfall data for representative locations (Table 2) indicate that 1984 was considerably wetter than average and 1985 slightly wetter than average, thus biomass production was probably above average at most or all locations.

Species composition by weight was estimated using the dry weight rank method (t'Mannetje and Haydock 1963). The comparative yield method (Haydock and Shaw 1975), a double sampling procedure, was used to estimate total annual standing crop (or current year's growth for woody species). Standing crop and species composition data were collected using 40 cm × 40 cm quadrats, with a minimum of 4 and a maximum of 10 transects of 25 quadrats each for each stand sampled. The dry weight rank and comparative yield methods have been extensively tested in these vegetation types and found to give estimates of species composition and standing crop which agree closely with those obtained by harvesting or weight estimate techniques (Smith and Despain, in press; Despain and Smith, in press). Forage production for cattle was calculated by multiplying percent composition of forage species by the total estimated standing crop. Forage was defined as "browse and herbage which is available and may provide food for grazing animals" (RISC 1983). Species known to be used by cattle were considered forage.

Estimates of botanical composition on a dry-weight basis were used to assign each sample area to a condition class according to Soil Conservation Service range site descriptions and procedures. A *t*-test was conducted to determine if the 2 range condition classes

Table 2. Precipitation in Tucson, Phoenix, and Safford, Arizona during 1984 and 1985.

	Tucson		Phoenix		Safford	
Month	1984	1985	1984	1985	1984	1985
			(mm)			
Jan.	13	32	9	24	31	19
Feb.	0	37	0	9	0	11
Mar.	0	5	0	0	0	19
Apr.	13	12	32	4	14	20
May	1	0	0	0	20	0
June	24	0	3	0	23	1
July	192	71	124	28	82	57
Aug.	68	21	21	4	80	17
Sep.	34	28	68	26	29	82
Oct.	28	35	6	10	11	52
Nov.	13	41	23	43	5	22
Dec.	80	8	82	28	59	0
Total	466	290	368	176	354	300
Long Term Average	288		168		218	

at each location had significantly different total annual standing crop of all vegetation and of forage species (Little and Hills 1978). The number of condition class comparisons were: 21 fair to good; 24 poor to fair; and 13 poor to good. Data from all locations within each precipitation zone were pooled and subjected to an analysis of variance to determine if significant differences ($p<=.05$) in mean total annual standing crop or forage production existed among classes.

Results

Paired comparisons of total annual standing crop revealed that, generally, there was no difference between different condition classes on the same range site (Table 3). Comparisons of fair to

Table 3. Total standing crop comparisons by range condition classes. Number of areas with significantly higher standing crop (p = .10).

Condition class comparison	Good	Fair	Poor	No difference
Fair to Good	3	2		16
Poor to Fair		4	2	18
Poor to Good	2		0	11

good condition classes showed that in 76% of the cases no significant differences ($p<=.10$) existed. In 14% of the comparisons the good condition class had larger standing crop, and in 10% the fair condition class had a larger standing crop. The same pattern occurred in the poor to fair condition class comparisons with no difference 75% of the time, fair condition having a larger standing crop 17% of the time, and poor condition having a larger standing crop 8% of the time. Even when poor condition was compared to good condition there was rarely a significant difference in standing crop. Only 15% of the comparisons showed a larger standing crop for good condition than for poor condition, while the other 85% were not significantly different (Table 3).

Amounts of forage for cattle were better related to condition class assessments than was the total annual standing crop (Table 4). Good condition class areas had significantly ($p<=.10$) more forage than the fair condition class areas 62% of the time, while fair condition stands had more forage than good in 14% of the comparisons, and there was no difference in the remaining 24% of the cases. Similarly, in 24 comparisons of fair to poor condition stands

Table 4. Forage production comparisons by range condition classes. Number of areas with significantly higher forage production (p = .10).

Condition class comparison	Good	Fair	Poor	No difference
Fair to Good	13	3	—	5
Poor to Fair	—	15	4	5
Poor to Good	9	—	3	1

the fair condition area had more forage in 63% of the cases, the poor condition area produced more forage in 17% of the comparisons, and there was no difference 20% of the time. When compared to poor condition stands, areas assessed in good condition had more forage in 69% of the locations, the poor condition stand produced more forage in 23% of the locations, and there was no difference in the remaining 8% of the comparisons (Table 4).

Analysis of variance of the data pooled for all range sites in each precipitation zone showed that there was no significant difference (p = .05) in total annual standing crop among the 3 condition classes in any of the 3 zones (Table 5). On the other hand, production of cattle forage was significantly greater for good condition

Table 5. Means of total annual standing crop and forage production grouped by range condition classes.

Condition class	Total annual standing crop	Forage production	Proportion of forage in standing crop
	(kg/ha)	(kg/ha)	(%)
	7″ - 10″ precipitation		
Good	649a	571a	88
Fair	678a	446b	66
Poor	638a	332c	52
	10″ - 16″ precipitation		
Good	960a	803a	84
Fair	991a	664b	67
Poor	927a	465c	50
	16″ - 20″ precipitation		
Good	1331a	1062a	80
Fair	1326a	898b	68
Poor	1241a	633c	51

(Means in columns within precipitation zone followed by the same letter are not significantly different (p = .05).

than for fair condition stands and also greater for fair condition stands when compared to poor condition stands in each of the precipitation zones (Table 5). Forage species averaged 34, 28, and 26% of the total species encountered in sampling the 7–10 inch, 10–16 inch and 16–20 inch precipitation zones, respectively.

Discussion

It was found that across a variety of range sites in Arizona range condition class was not related to total standing crop of annual biomass. These results support the hypothesis that differences in composition of the vegetation on a range site which result in different range condition classes using the climax approach do not usually indicate changes in overall productivity of the range ecosystem. These results agree with those of Chew and Chew (1965), Evenari et al. (1975), Fischer and Turner (1978), and Friedel (1981). For these semiarid/arid desert shrub and desert grassland rangelands, range condition ratings of "fair" or "poor" using the climax or potential vegetation as a standard should not imply that productivity of rangeland vegetation is "far below its potential" as some reports have stated. Such statements should be avoided by agencies reporting "ecological condition" of rangelands.

The amount of forage for cattle differed among range condition classes. Generally, good condition areas produced the most forage, followed by fair condition stands, with poor condition areas producing the least forage. These results are similar to those reported by Goebel and Cook (1960), Cook et al. (1962), Christie and Hughes (1981), and Powell et al. (1982). Nevertheless, this relationship was found in only 60% of the locations sampled. In 20% of the comparisons, the lower condition class had more forage than the higher class, and in the remaining 20% of the cases there was no difference. The general trend of increasing forage for cattle as range condition improves (vegetation becomes more similar to "climax") indicates that either climax vegetation is more productive of cattle forage than seral stages, or a bias toward cattle forage has been introduced into the range site descriptions. Since the relationship of forage production to range condition is not consistent, use of condition classes as indicators of carrying capacity of "initial stocking rate" for cattle should be applied with caution by range managers.

The results obtained were based on data collected in 1 growing season. This study encompassed a broad spectrum of range sites with annual precipitation ranging from about 170–500 mm (7–20 inches). The differences in species composition measured at each location were the result of several to many years of different land use. Although total production is known to fluctuate in relation to amount of yearly precipitation, species composition would not change drastically in 1 or 2 years because most of the important species are long-lived perennials. If weather were a significant factor determining the relationship of biomass or forage production to range condition classes, one might expect it to show greatest effects in wet years when different plant species or life forms could express their full potential for production. That few consistent differences were noted in a relatively wet year suggests that even fewer would be evident in drier years.

If range condition, or ecological status, assessed by similarity to climax vegetation is not reliably related to overall productivity of the range ecosystem and not consistently related to forage production for livestock either, then we must question whether such ratings provide any useful information at all to managers and policy makers. "Ecological status" seems to be a concept too complex to evaluate using one attribute (composition) on a simple linear scale (see Wilson and Tupper 1982). The approach now being developed by some agencies of rating condition in relation to a "desired plant community" which provides the best mix of resource values for specific management objectives, including the fundamental objective of soil conservation, appears to have promise for management and policy decisions for multiple use of rangelands.

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