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ABSTRACT—We examined the sustainability of the livestock grazing industry in the Great Plains of North America relative to ecological processes, economic viability, and social acceptance. We conclude from the review that livestock grazing is an appropriate use of Great Plains grasslands and, when properly managed, ecologically sustainable. However, we also present evidence that the Great Plains grazing industry is not always economically sustainable or socially acceptable. We attribute this anomaly in large part to the consuming public's general lack of understanding and appreciation for the ecological linkages between current livestock grazing tactics and the evolutionary history of the Great Plains. A contributing factor to this problem is the scientific community's interjection of personal biases and value systems when interpreting ecological response patterns to varying forms of land use. We present evidence in support of this hypothesis by comparing statements and supporting literature citations from three recently published literature reviews addressing the ecological impacts of livestock grazing on North American rangelands.

KEY WORDS: ecological sustainability, economic viability, grazing, social acceptance

Introduction

In this paper, we comment on some scientific and social aspects of livestock grazing as a sustainable use of the grasslands of the Great Plains, specifically as it relates to ecological processes, economic viability, and social acceptance. We address these three components because they are the defining components of sustainability as it relates to land use (i.e., agriculture). For example, the Food and Agricultural Organization (1991) defines sustainable agriculture as "the management and conservation of the resource base and the orientation of technological and institutional changes in such a manner as to insure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable." This definition follows closely the definition of others (Keeney 1989; Brklacich et al. 1991; Hansen 1996; Hamilton 1998), including the legal definition as incorporated into the 1990 Farm Bill (US Public Law 101-624). It also reflects the essence of Aldo Leopold's writings of 60 years ago (Leopold 1938) when he suggested that the challenge to humans is "to live on a piece of land without spoiling it."

Ecological Sustainability

The preponderance of scientific evidence suggests livestock grazing can be an ecologically sustainable use of Great Plains' grasslands (Lauenroth et al. 1994). Although some argue rather vehemently about the ecological sustainability of livestock grazing on western US rangelands (Fleischner 1994; Noss 1994; Donahue 1999), they consistently exclude the Great Plains as a region of major concern. This is because Great Plains grasslands co-evolved with large ungulates, such as bison, elk, deer, and antelope, as well as with smaller herbivores such as prairie dogs (Stebbins 1981; Axelrod 1985). Granted, current livestock management strategies do not precisely mimic the historical landscape-use patterns of the estimated 30-60 million bison (Shaw 1995) and 5 billion prairie dogs (Costello 1970) that inhabited the Great Plains during the 1800s (Roe 1970). But the impacts are certainly more closely aligned with historical impacts than are other current-day land uses (e.g., farming, highways, developing suburbia, etc.) because large ungulates, regardless of species, affect ecological systems

via four fundamental processes: (1) defoliation, (2) trampling and treading, (3) deposition of feces and urine, and (4) atmospheric gas exchanges.

Response of individual plants to defoliation varies depending upon a wide array of biotic factors (e.g., plant morphological and physiological traits, phenological growth stage, etc.) and abiotic factors (e.g., availability of water and nutrients, temperature, etc.). Regardless of the modifying effects of these factors, repeated intensive defoliations generally reduce plant growth and productivity, whereas light to moderate levels only marginally suppress growth and occasionally enhance growth (Briske and Richards 1994). As such, selective defoliation processes alter competitive relationships that often cause shifts in plant species composition toward less productive and less desirable mixes (Dyksterhuis 1949; Ellison 1960; Friedel 1991; Pieper 1994). However, the rate and magnitude of the shift vary depending upon several macro-environmental factors, of which climate and evolutionary history are paramount (Milchunas et al. 1988; Milchunas and Lauenroth 1993). For example, changes in semi-arid regions with a long history of grazing (e.g., Great Plains shortgrass steppe) are generally rather slow and of limited magnitude, whereas those in subhumid regions with a long grazing history are generally relatively fast and more dramatic (e.g., Great Plains mixed-grass prairie).

Trampling and treading of vegetation and soil surfaces generally increases surface-water runoff and sediment production (Blackburn 1984) as a result of decreasing vegetation cover and increasing soil bulk densities. The consequential effects are a decline in soil organic matter content, aggregate stability, and water infiltration rate (Thurow 1991).

Defecation and urination on soil surfaces and *in situ* vegetation alter nutrient cycles over both time and space (Pieper 1977; Floate 1981) through the direct addition of nutrients (Woodmansee 1978; Heady and Childs 1994) and through the change in postdeposition soil biotic and vegetation growth patterns (Schimel et al. 1986; Detling 1988; Jaramillo and Detling 1992a, 1992b).

And finally, scientists' growing awareness of the potpourri of abiotic and biotic factors affecting the gaseous composition of Earth's atmosphere has resulted in their growing interest in the regulatory role that animals, particularly ruminants, might play. The potential impacts are substantial, considering that domestic livestock may contribute up to 15% of the world's methane (CH_4) output (Crutzen et al. 1986). But the significance of this contribution is difficult to assess without an estimate of the historical contribution of ruminants to methane production.

In summary, the scientific literature abundantly documents the cumulative effects of grazing on ecological processes. Specifically, these studies show that (1) grazing alters both the structure and function of ecological systems (Sims and Singh 1978a, 1978b, 1978c), including rates of energy flow and nutrient cycling (Briske and Heitschmidt 1991); (2) defoliation intensity has greater impact than trampling and treading (Curll and Wilkins 1983); and (3) moderate intensities of grazing are often ecologically sustainable in regions with long evolutionary grazing histories (Milchunas et al. 1988; Milchunas and Lauenroth 1993), such as the grasslands of the Great Plains of North America (Lauenroth et al. 1994).

Economic Sustainability and Social Acceptance

The probability that the Great Plains grazing industry would be economically viable and socially acceptable seems high because ecological sustainability should be a precursor to long-term economic sustainability and social acceptance. However, there is evidence suggesting this may not be the case for Great Plains agriculture. For example, data from the Census of Agriculture (USDA 1997) show that (1) 265 counties in the six states making up the central and northern Great Plains lost population between 1990 and 1997 (estimated total = 110,600); (2) every county of the top 50 US counties losing population between 1990 and 1997 were located in the Great Plains; (3) the number of full-time Great Plains agricultural producers decreased 20% between 1987 and 1997; and (4) those working off-farm for 200 or more days per year increased 20%. These trends indicate that a growing proportion of Great Plains ranching and farming operations may no longer be economically sustainable, at least not without outside sources of income. Although off-farm income relative to farm and ranch size is unknown, we know the number of large operations (i.e., >1000 acres) has remained nearly constant, whereas both the number and size of smaller operations has decreased (USDA 1997). One plausible explanation for this trend is that mid-sized operations (i.e., 200-1000 acres) are being sold to larger operations because they are not economically viable as a sole source of income, yet they are too large to manage if the owner has a full-time, off-farm job. This is in contrast to the small operations (i.e., <200 acres) that are owned and managed by individuals with off-farm income. Regardless of the precise causal factors, the ongoing trend is toward greater numbers of operations being managed for lifestyle rather than profit, thereby further challenging the sustainability of Great Plains agriculture at the household level.

These losses in economic viability may also be linked to an ongoing change in public attitude away from the view that the principal value of natural resources is to their role in providing commodities for consumption (Wagner 1994). This shift in public attitude is linked to a shift in values, or beliefs, of which economics is a measure (Robbins 1932; Samuelson et al. 1964). We buy and sell goods and services based upon what we believe they are worth. A simple illustration of the relationship between beliefs and economic prices is the selling prices of the two steers that won the local county fair in 1965 and 1998, respectively. If both steers were sold in 1965, the "short and stout" 1965 model would sell for considerably more than the "long and tall" 1998 model. However, if both steers were sold in 1998, the opposite would be true. We changed our minds between 1965 and 1998 about what we preferred, and this in turn changed the price we were willing to pay for the two steers. What caused us to change our minds? What new information did we assimilate between 1965 and 1998 that changed our belief as to the value of the two steers? And of equal importance, was the information accurate and who decided that it was accurate?

This example of the relationship between beliefs and economics provides a basis for an intuitive hypothesis that the continuing loss of small farms and ranches throughout the Great Plains reflects a change in society's beliefs. Granted, these changes may be unintended, but just the same they impact the social structure of Great Plains agriculture. If society believed it important for Great Plains agriculture to continue to function as previously, then economic incentives would be created to do so. So, the questions must be asked again: what has caused us to change our minds, what new information have we assimilated that changed our beliefs, and was the information accurate?

Although there are many sources of information, science and thus scientists traditionally are considered a reliable and trusted source of clear, accurate, and unbiased information. But in reality, information provided by the scientific community is like information from many other sources: it is often unclear, ambiguous, and fraught with biased interpretations. Consider, for example, the contrasting conclusions drawn by Fleischner (1994), Laycock (1994), and Pieper (1994) following their reviews of the western North American ungulate grazing literature. Fleischner (1994) wrote:

> By virtually any measure, livestock grazing has serious ecological costs in western North America. Grazing has reduced the density and biomass of many plant and animal species, reduced biodiversity,

> aided the spread of exotic species, interrupted ecological succession, impeded the cycling of the most important limiting nutrient (nitrogen), changed habitat structure, disturbed community organization, and has been the most severe impact on one of the biologically richest habitats in the region. While undoubtedly there are exceptions to this theme of destruction, clearly much of the ecological integrity of a variety of North American habitats is at risk from this land management practice.

In contrast, Laycock (1994) said:

> The current call for removal of livestock grazing from public lands apparently is based on the assumption that this would result in rapid increases in both range condition and species diversity. The review of the literature indicate that: a) many vegetation types on public land are in a stable state condition and would change little, if at all, if livestock were removed; b) very heavy grazing on small areas can decrease biodiversity in that limited area but moderate grazing often is beneficial to diversity; and c) grazing by herbivores increases patchiness of vegetation which should increase diversity of both plants and animals on a landscape level.

And, finally, Pieper (1994) wrote:

> With the present state of knowledge, there appears to be no justification for destructive grazing on any rangeland today. On the other hand, removing all livestock grazing would not return rangelands to pristine conditions. In many cases, the changes would be subtle, and in the long run might even be negative in terms of biodiversity and other desirable characteristics.

How does one explain such different conclusions, based on a review of what must be considered similar literature? The first conclusion is that a similar subject matter does not necessarily imply reviewers will review the same literature. For example, when we examined the literature cited in the bibliographies of these papers, we found a total of 534 different articles were reviewed by the three authors (Fig. 1). However, of that total, only six articles (Clements 1916; Sampson 1919; Mack and Thompson 1982; Westoby et al. 1989; Friedel 1991; Laycock 1991) were included in all three reviews. Moreover, the overlap of articles reviewed by any two of the three

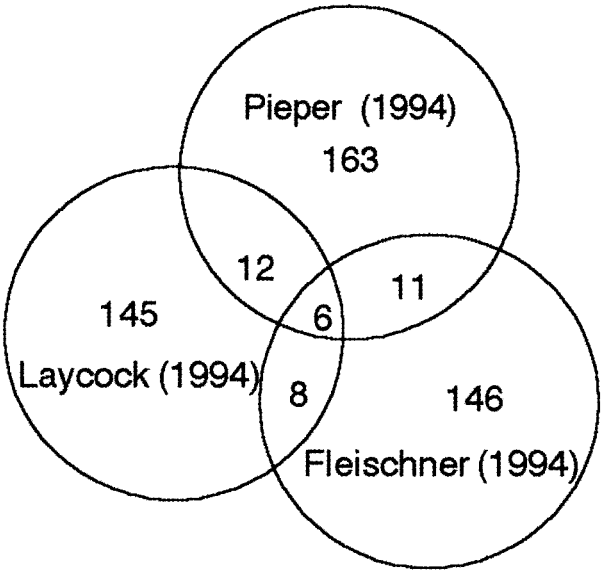

Figure 1. Venn diagram depicting the number of independently and mutually reviewed articles by Pieper (1994), Fleischner (1994), and Laycock (1994).

authors was never greater than 16% of the total articles reviewed. This demonstrates that each author's background, professional experiences, and perhaps personal values influenced the information they considered important in their review.

We also compared the manner in which the information from mutually reviewed articles was used in each article. The summaries and conclusions drawn from the six articles reviewed by all three authors were similar. Likewise, so were the summaries and conclusion for 10 of the 12 additional articles reviewed by both Laycock (1994) and Pieper (1994). The information presented from the two remaining articles (Paulson and Ares 1962; Hart and Norton 1988) was dissimilar in the two reviews but not conflicting. The same was true for two (Thomas et al. 1979; Kauffman et al. 1982) of the eight articles reviewed by both Laycock (1994) and Fleischner (1994) and for three (York and Dick Peddie 1969; Owen and Weigert 1979; Holechek et al. 1989) of the 11 articles reviewed by both Fleischner (1994) and Pieper (1994). In fact, we found only one instance (Orodho et al. 1990) out of the 37 articles reviewed by at least two of the authors wherein interpretations appeared to conflict. Close examination of the paper (Orodho et al. 1990)

revealed that neither author's statement about the findings in the paper was inaccurate nor inappropriate. Rather, the conclusive statements only served to emphasize that authors selectively use information from within a given source in support of their alternative interpretations.

We also examined literature citations relative to information source to determine if reviewers tended to favor or avoid using specific kinds or types of information. We found only small variation among the three reviews, with a majority of the articles cited being refereed journal articles and books, transactions, and technical reports (Table 1). We also found little difference between types of refereed journal articles utilized, although Fleischner (1994) used fewer dissertations, abstracts, and semitechnical and popular articles than did either Pieper (1994) or Laycock (1994).

We also examined literature citations relative to biogeographical area of study (i.e., Great Plains vs. Intermountain West) with the purpose of quantifying each reviewer's use of "the most appropriate" literature. In so doing, some differences were noted. For example, citations of studies conducted in the Southwest Desert and Intermountain West regions ranged from 38% of all citations in Fleishner's (1994) review to 15% and 18% of Laycock's (1994) and Pieper's (1994) citations, respectively. However, variation among reviews in Great Plains citations was small, ranging from 19% for Laycock (1994) to 15% and 16%, respectively, for Pieper (1994) and Fleishner (1994). We made no attempt to interpret the "appropriateness" of these citations. To do so would necessitate interjecting our own values into the review process, something we diligently tried to avoid in the process of comparing the three reviews.

Finally, it is interesting to note that others have concluded that neither Fleischner (1994), Laycock (1994), nor Pieper (1994) are unbiased scholarly work. For example, Donahue (1999) writes of Pieper's (1994) review that "The difficulty in interpreting range condition data of which Pieper warned can be attributed in part to casual interpretations by range professionals, including Pieper himself." More pointedly, Donahue (1999) concludes from a review of Laycock (1994) that "he implicitly discredits the antigrazing 'claim' by relegating it to the 'popular press,' while alluding to the 'evidence' from the 'range management literature' to support his own assertion concerning the effects of 'heavy grazing.'" Likewise, Fleischner's (1994) review has been sharply criticized as exceedingly biased (Brussard et al. 1994; Brown and McDonald 1995; Curtin 1995), with Jones (2000) citing it as an example wherein "literature reviews can sometimes be a front for specific agendas."

TABLE 1

NUMBER AND PERCENTAGE OF CITATIONS CLASSIFIED ACCORDING TO TYPE AND SUBJECT MATTER

Citations	Author		
	Laycock	Pieper	Fleischner
Refereed Journal	83 (48.5%)	83 (43.2%)	79 (46.2%)
Management[a]	39 (22.8%)	31 (16.2%)	26 (15.2%)
Ecological[b]	15 (8.8%)	15 (7.8%)	13 (7.6%)
Naturalist[c]	5 (2.9%)	11 (5.7%)	10 (5.9%)
Others	24 (14.0%)	26 (13.5%)	30 (17.5%)
Books, etc.[d]	70 (40.9%)	95 (49.5%)	91 (53.2%)
Others[e]	18 (10.6%)	14 (7.3%)	1 (0.6%)
Total	171 (100.0%)	192 (100.0%)	171 (100.0%)

[a] Articles from *Journal of Range Management, Rangeland Journal,* and *Australian Journal of Agriculture Research.*

[b] Articles from *Ecology, Ecological Monographs, Journal of Ecology, Journal of Applied Ecology, Ecological Applications,* and *Oecologia.*

[c] Articles from *American Naturalist, American Midland Naturalist, Great Basin Naturalist,* and *Southwestern Naturalist.*

[d] Includes books, book chapters, proceedings, transactions, and technical reports and bulletins.

[e] Includes dissertations, abstracts, and semitechnical and popular articles.

Conclusions

We conclude from our review that (1) livestock grazing is an appropriate use of Great Plains lands and when properly managed, it is ecologically sustainable; (2) livestock grazing in the Great Plains may not always be economically sustainable and socially acceptable; and (3) creditable scientific support can be generated for a wide array of land uses, including conflicting uses, because author interpretations (including ours) of similar scientific information can vary depending upon personal experiences and values. This, in turn, means society's information base may be filled with conflicting information that makes good land management decisions more difficult.

Fleischner (1994) posed the question, "Is there an ecologically sustainable future for livestock grazing in western North America?" His answer was, "This ultimately is a question of human values, not of science." We

agree with Fleischner, thus we strongly urge Great Plains rangeland agriculturalists to focus their attention on telling their story in a positive, proactive manner. It is important to producers that the public understand and appreciate the differences between grazed Great Plains and grazed Southwest Desert and Intermountain ecological systems. As in many natural resource issues, policy is less the product of rational economics or scientific understanding than it is a political battle over social values. While resolution of these issues may well evolve in the marketplace, there have been few instances when market dynamics effectively influence policy. Rather, policymaking is, as historian Patricia Limerick (1995) describes, a boxing match where contestants hope for a knockout but usually merely bludgeon each other until they reach a wobbly standoff.

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