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An ecological perspective of livestock grazing

Martin Vavra

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Author is superintendent/professor Eastern Oregon Agricultural Research Center, Oregon State University, HC 71 4.51 Hwy 205, Burns, 97720

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Abstract

Critics of livestock grazing have identified the environmental consequences of grazing. However, in many cases the degradation identified is the result of historic use or improper practices. Humans have always impacted their environment. Natural events, such as climate change and fire, greatly confound our ability to differentiate between natural disturbances and those caused by livestock grazing. Herbivory, both wild and domestic, are known to influence ecosystems. The evolutionary grazing history of an ecosystem, together with the climate regime, may provide valuable information in predicting the response of a particular ecosystem to grazing. Ungulates can influence the nitrogen cycle, primary production, and fire frequency. Ungulates are important agents of change, creating spatial heterogeneity, modulating successional processes, and controlling the switching between alternative states. Specific wildlife species react to these disturbances. As plant communities change in response to grazing or the lack thereof, wildlife species present can also be expected to change. The concept of incomplete habitats is important in understanding the effects of livestock grazing on wildlife species. In the development of livestock grazing systems compatible with wildlife, two main objectives can be considered. A change from continuous grazing to a system that employs rest or deferment usually will benefit wildlife. Four methods designed to manipulate plant communities for wildlife are altering the composition of the vegetation, increasing the productivity of selected species, increasing the nutritive quality of the forage, and altering the structure of the habitat. Riparian areas are especially problematic in development of appropriate grazing strategies. The development of new grazing systems that are

compatible with environmental considerations should also be designed to provide for more efficient livestock production.

Introduction

At the same time scientists worldwide are confronted with feeding the increasing human population there is equal concern over the effects of agriculture on the environment (Waggoner 1994). The questions of sustainability and the use of natural resources have become important issues of scientific discussion (Vavra 1996). Specific to this symposium, the effects of livestock production on the environment has also been scrutinized (Steinfeld et al. 1997). Unfortunately, most of the research and non-peer reviewed publications are produced by opponents of livestock grazing. Knopf (1996) stated that the scientific evidence about grazing effects has often been flawed by 1) poor design of studies, 2) abusively grazed sites carelessly construed to represent proper range management, and 3) investigator advocacy for a fisheries and wildlife resource. Equally unfortunate, is the fact that poor grazing practices are common enough so that critics are able to illustrate the detrimental effects of livestock grazing (Fleischner 1994). In his paper, Fleischner (1994) identified the cost of livestock grazing as the loss of biodiversity; lowering of population densities of a wide variety of taxa; disruption of ecosystem functions, including nutrient cycling and succession; changes in community organization; and change in the physical characteristics of both terrestrial and aquatic habitats. Livestock grazing was termed the most pervasive land use in western North America and the single most important factor limiting wildlife production. On a worldwide view, Durning and Brough (1991) stated that complex economic and social forces lead to mismanagement of herds, causing extensive and sometimes irreversible degradation of dry lands and destruction of forests. The authors went on to say that many of the world's rangelands bear the scars of improper livestock management: proliferating weeds, depleted soils, and eroded landscapes.

In spite of the criticisms, livestock grazing will continue on most lands, but it is still imperative that it be done in a sustainable manner. Brussard et al. (1994) criticized the attitude of Fleishner (1994) by stating that conservation biologists would be more effective by asking and answering the question: How can livestock grazing be managed to have the fewest impacts on biodiversity and ecosystem integrity? Gall and Stanton (1992) called for cooperation between agricultural and conservation biologists to ensure continued production of high quality food and fiber for all the earth's peoples, and to protect biological diversity.

In this paper I would like to discuss the effects of livestock grazing; review how livestock may influence ecosystems; interact with individual plant species, plant communities, and animal species; provide examples on how livestock may enhance wildlife habitat and biodiversity; and provide some suggestions for the future.

Considerations of the effects of livestock grazing

Historical perspectives

Humans have maintained domesticated ruminants for about 10,000 years. Excavations in Iraq indicate both sheep and goats were raised as domesticates as early as 8500 B. C., and cattle in Greece about 6500 B. C. (Fitzhugh et al. 1978). By 6500 B. C. domesticated ruminants reached southeastern Europe (Bokonyi 1983). In the New World the first domestication of camelids appears in the highlands of western South America about 4000 B. C. (Bokonyi 1983). From these early beginnings came the agents of rapid environmental change. Domesticated animals are self-replicators, which gives them both speed and efficiency in altering environments, even continental environments (Crosby 1986). In some cases livestock grazing has occurred for several millenia. These areas were impacted so long ago there is no record of the changes that occurred or the organisms that were lost. It is an interesting footnote that from southwestern Asia, the area of first ruminant domestication, come the most opportunistic weeds which have in turn followed the spread of domesticated animals around the globe (Crosby 1986).

True pastoralism that is nomadic in nature probably has had little effect on the environment. However, pastoralism that is practiced for commercial ends (maximizing off-take) and is somewhat sedentary in nature may cause progressive environmental deterioration (Darling 1956). Pastoralism in Mongolia flourished for millenia but became degrading to the environment only when the socialist political and economic system instituted changes (Sheehy, unpubl. manuscript). The application of modern range management practices that are tailored to specific ecosystems can in most cases, neutralize the environmental deterioration mentioned by Darling (1956).

The westward movement of livestock from the mainland of Africa and Europe first occurred in the Canary Islands about 2000 B. C. (Crosby 1986) as immigrants from the African mainland settled there and brought goats and probably sheep. Iceland was settled in 847 A. D. (Fridriksson 1986). Iceland's vegetation underwent drastic changes during the Little Ice Age from 1600 to 1900. Fridriksson (1986) estimates the interaction of climate shift to colder and the concomitant grazing by the introduced livestock interacted to reduce the vegetated area of Iceland by 50 percent during this period.

Columbus' voyage to the New World began the age of discovery and colonization of many parts of the world by Europeans and their livestock. By the end of the sixteenth century cattle and horses were numerous in many parts of the Americas and had become feral (Crosby 1986). Direct changes in plant species distribution and abundance, plant communities, soils (via erosion) and weed invasion occurred and resulted in drastically altered fish and wildlife habitat. Events similar to those of Iceland occurred in North America in the late 1800's during the period of livestock expansion throughout the American West. Based on tree-ring studies in the American West, the period from 1880 through 1905 was one of the driest periods in the past 1500 years (Box 1990). Some of the severe erosion that occurred might have occurred anyway, but was probably made worse by the overgrazing of livestock.

Generally, wherever Europeans colonized and brought livestock, the region was overgrazed and native plant communities often replaced by or at least invaded by European weeds. Wildlife species were affected by the loss or alteration of habitat, and in some cases by eradication due to perceived competition or for market value (hides, etc).

Reasons for the abusive land management practices were greed, ignorance, and the attitudes that New World resources were endless. Ignorance probably played a significant role since most Europeans were not familiar with growing limitations in most New World climates and the fact that European grazing lands had been altered thousands of years previously and no history of detrimental effects of livestock grazing was known. That point may not have mattered to colonies based on extraction and return of wealth to Europe. But colonies, established in the New World for reasons such as religious freedom or other "new beginnings", probably would have done better had they known. Worldwide, grazing managers are now faced with managing remnants of ecosystems that have been impacted by varying periods of exploitive use; millenia in the Old World and 500 years in the New World.

I do not mean to leave the impression that prior to European settlement many ecosystems could be considered pristine. Indigenous peoples were active landscape managers prior to invasion by Europeans. In the United States, indigenous peoples burned the forests of the eastern part of the country and the mountains of the West, controlled shrubs and trees in the Great Basin, and burned much of the swampland of the Southeast (Pyne 1982). Australia had been settled for 50,000 years before Europeans settled there. The indigenous people used frequent, patchy, often cool fires to maintain disclimax vegetation communities (Duncan and Jarman 1993). However, in most cases, Europeans had greater capabilities for environmental change. Humans, wherever they occur, have always influenced their environment for food, building materials, warfare and intertribal intimidation (Pyne 1982).

As grazing managers develop systems to better manage livestock the first priority has been to create a balance between productivity of the rangeland and animal offtake. Historically, this has been termed a sustainable system; the grazing of livestock at some level of production (kg of meat and/or fiber) does not decay the ability of the land base to continue producing forage for future offtake. However, in recent years this definition has been changed with worldwide concerns for environmental integrity (Vavra 1996). Now, insuring the protection of the land base to produce commodities is not enough. Protection of ecosystem integrity (the interaction of native plants and animals with their environment) has to be considered in the development of grazing systems (Vavra 1996). Sustainability now may be defined as the degree of overlap between what people collectively want, reflecting social values and economic concerns, and what is ecologically possible in the long term (Borman et al. 1994). Livestock producers, scientists, and economists must now work together to understand ecosystem functions and plan grazing management systems to be compatible with the environment while maintaining economic viability of the livestock enterprise.

Livestock impacts on ecosystems

Fleischner (1994) does an excellent job of describing all the possible detrimental effects of livestock grazing. However, what he really has done is describe the effects of improper grazing. With that important point in mind, much can be learned from his review of other work, keeping in mind that his descriptions relate to problems that may occur with mistakes in management. Utilizing examples of mismanagement to illustrate the unsustainability of livestock grazing or to justify removal of livestock from specific locations has been done (Knopf 1996). It must be remembered that humans have been altering their environments since prehistoric times, perhaps even contributing to the extinction of the Pleistocene megafauna (Martin 1967). Malin (1956) stated that human intervention on ecosystems has been a real and dramatic force of change, but natural changes ("disasters" to human thinking) have always occurred and greatly confound analysis of the causative agents of change. Disturbance is a natural force of most ecosystems (Vavra 1996). Defining what presettlement vegetation composition and providing a pathway to return to that state is in most cases impossible, due to the natural and imposed changes. There have been shifts in climate in some regions even within the past 200-500 years, and vegetation that dominated previously may or may not be adapted to present conditions. Livestock grazing on rangelands varies in its intentional modifications of ecosystems. When accomplished with sustainability in mind, grazing probably lies toward the lower end of the spectrum of modifications, more modifying than hunting-gathering, but less modifying than intensive cropping (Duncan and Jarman 1993). Defining ecosystem changes caused by livestock grazing and developing management plans that minimize those changes is and will be an important aspect of grazing management research. Literature on herbivory by native and domestic species and literature on rangeland ecology and ecosystem science is available and should guide managers and researchers in developing sustainable grazing systems.

One approach to predict the impacts of grazing on plant communities is to consider both the evolutionary history of grazing and the environmental moisture that occurs on the area in question (Milchunas et al. 1988 and Milchunas and Lauenroth 1993). This approach provides an indication of the potential change in plant communities that may occur with different grazing intensities. The plant communities and species present at any given level of grazing then may influence the kinds and amounts of animal, avian, and fish species also present. Sub-humid grasslands with a short history of grazing are the most susceptible to grazing-induced changes, while semiarid rangelands with a long history of grazing are the least. It is interesting to note that the Serengeti Plains of Africa, an area long studied and with a long history of grazing, is considered to be a sub-humid grassland where changes can and do occur rapidly with a cessation of grazing (McNaughton 1984). A few tallgrasses dominate in the absence of grazing and diversity is low. With moderate grazing a mosaic pattern of tall, intermediate, and short grasses occur on specific areas depending on patterns of grazing intensity, and diversity is high. Diversity is low at heavy grazing because shortgrasses dominate (Milchunas et al. 1988). Semiarid rangelands with a short history of grazing are somewhat resistant to changes due to grazing, particularly if management is sensitive to periodic rest or deferment. A severely overgrazed range in eastern Oregon that was treated with moderate grazing and grazing exclusion showed similar improvement in ecological conditions in both treatments from 1937 to 1974 (Sneva et al. 1984).

Hobbs (1996) provides important insights to the influence of ungulates on the modification of ecosystems. Ungulates influence the nitrogen cycle in a complex manner that can cascade throughout the ecosystem and can stabilize or destabilize the composition of plant communities. Net primary production can decrease or increase with ungulate grazing. Ungulates can influence fire regimes by altering the fuels available for combustion. In grasslands, ungulates often reduce the extent, frequency, and intensity of fires. However, in some disturbed grasslands, fire frequency may increase. In shrublands and forests, grazing may increase the likelihood of crown fires, while reducing the likelihood of beneficial underburns. Hobbs (1996) went on to say that ungulates are important agents of change in ecosystems, acting to create spatial heterogeneity, modulate successional processes, and control the switching of ecosystems between alternative states. Jefferies et al. (1994) reported that in resource-limited, early successional environments, ungulate foraging may accelerate or delay succession and increase the turnover rate of nutrients, particularly nitrogen, thereby sustaining net primary production of preferred forage plants.

Impacts on organisms

The previous section dealt with the influence of herbivory at the ecosystem and community levels of organization. Those changes in plant species composition; structure of the vegetation, both vertical and ground cover; soil characteristics and other macro-level changes in turn influence the habitat available for individual fish and wildlife species.

Just as grazing is considered a treatment imposed on a plant community that causes changes in wildlife species present, so too is the removal of grazing a treatment that will cause changes, depending on plant community evolutionary history (Milchunas et al. 1988). Most ecosystems are disturbance based (Vavra 1996). Therefore, there are arrays of wildlife species that occur at specific successional stages following disturbance. Removal of grazing from a plant community with a long evolutionary history of grazing will most likely affect wildlife species present. Morrow et al. (1996) implied that insufficient grazing led to a decline in Attwater's prairie chicken (*Tympanuchus cupido attwateri*) due to the inadequate interspersion of open areas within the grassland structure on a national refuge, which was charged with managing for the bird. However, Holechek et al. (1982) reported that research by others showed that overgrazing was more detrimental than no grazing to Attwater's prairie chicken. Neel (1980) observed that a rest-rotation grazing system improved sage grouse (*Centraocercus urophasianus*) habitat by increasing forb abundance. He also found that moderately grazed meadows were more attractive than ungrazed meadows, but that overgrazed meadows were unused by sage grouse. Urness (1990) identified the reduction or elimination of cattle grazing as one of the causative factors which lead to a decline in the quality of mule deer (*Odocoileus hemionus*) winter range in the Intermountain West of the United States. These examples illustrate the need for vegetation goals and objectives in a grazing program to enhance wildlife species. Recognizing that a lack of grazing can be as detrimental as uncontrolled grazing is an important point that managers need to remember.

Individual wildlife species may require disturbed areas or areas of mid-successional stage for at least a portion of their habitat. The mountain plover (*Charadrius montanus*) nests in fairly overgrazed shortgrass steppes, which were once maintained by bison. It now successfully nests where heavy cattle grazing exists (Graul 1973, 1975). Mule deer in the western United States require winter ranges dominated by palatable shrubs and forbs. Grazing management has been such over the last 25 years that plant succession on these ranges have favored the increase of perennial grasses to the detriment of shrubs and forbs (Urness 1990). The higher ecological condition has resulted in a decline in the quality of the mule deer winter range. Likewise, whitetailed deer (*Odocoileus viginianus*) on the Pacific coast of Costa Rica probably peaked in numbers in the late nineteenth century when native dry tropical forest was converted to shrubland and secondary forest (Irby and Vaughan 1996).

In the United States, one current concern with livestock grazing focuses on the riparian area, the greenbelt adjacent to waterways, and the influences on water quality and quantity. Improper livestock grazing has caused damage to fish habitats by the degradation and removal of riparian vegetation, altering channel morphology, lowering the groundwater table and decreasing summer stream flows; and increasing summer water temperatures and winter icing Armour et al. (1994). Riparian areas are important habitat for many mammalian and avian species (Kauffman and Krueger 1984). However, management schemes can be developed to restore many degraded habitats without exclusion of livestock grazing (Chaney et al. 1990). However, livestock and riparian area management is difficult because streams are variable and complex habitats so that no one management system can be applied to all sites (Elmore and Kaufman 1994).

The previous discussion presented examples of problems that may occur when considering livestock-wildlife relationships. An important concept in developing management plans for wildlife is that of incomplete habitats (Vavra and Sheehy 1996). In most of today's world, wildlife are no longer able to exert preference for habitats or occupy historically used areas because many of the habitats no longer exist, or are altered by the increasing human population. Incomplete habitats exist at spatial, temporal, and ecological scales. Spatially incomplete habitats exist when conversion of habitat to other purposes reduces access to a critical habitat component. Conversion of rangeland to intensive agricultural production and urbanization are two examples. Temporally incomplete habitats exist when a change in the short term creates less than optimum habitat. The presence of livestock is often socially intolerable to many species of wildlife.

Once livestock are removed the habitat is again complete, and wildlife return. Fire causes the temporary destruction of habitat. Likewise, the lack of fire and the proliferation of trees and shrubs can also cause temporarily incomplete habitats until fire and subsequent vegetation re-establishment occur. Ecologically incomplete habitats occur when spatial and temporal components are intact, but a critical qualitative factor formerly present is absent. Removing grazing from an ecosystem that has a long evolutionary history of grazing is an example. Livestock have replaced bison on the Great Plains of the United States, thereby, in theory, retaining an ecologically complete habitat. Any one or combination of incomplete habitats may exist. Livestock grazing management plans must consider the aspects of incomplete habitats if wildlife values are to be enhanced or maintained.

Developing compatible grazing systems

In the development of grazing systems compatible with wildlife two main objectives are usually considered. The first is to simply develop a system that has minimal environmental consequences, that is, one that fits the definition of sustainability (Vavra 1996). The other has specific plant community manipulations in mind, and the livestock are used to develop that plant community through the process of grazing (Seversen and Urness 1994).

The development of sustainable grazing systems usually begins with a change from continuous season-long use, to one where livestock are moved through a given number of pastures creating recurring periods of grazing and deferment. Most systems are designed to provide rest or deferment through the growing season in an effort to sustain plant vigor. In most cases, a change from continuous use to a grazing system will benefit wildlife (Bryant 1982) if stocking rates are not excessive.

On most rangelands the landscape is such that some areas are more preferred by livestock than others due to topography, distance to water, shade, and/or palatability of plant species. Season of use may also influence livestock distribution. The end result is that rangelands are seldom grazed to an even level of utilization. Areas of heavy, moderate, light, and even non-use commonly occur within one pasture (Sheehy and Vavra 1995). Gradients of disturbance and consequent successional status should then occur across the landscape (West 1993), providing an array of habitats. Guthery (1986) reported that bobwhite quail respond favorably to the development of diverse habitats. The key to success is a moderate level of stocking so that residual plant material remains and not all locations within all pastures are grazed heavily. Moderate levels of stocking should also provide the proper level of gain per animal and gain per hectare so that livestock production itself is sustainable (Bement 1969).

In specific instances, livestock grazing systems are designed to manipulate plant communities to enhance the habitat for featured species. The development of these systems probably has its beginnings in the work of Bell (1971) and others who observed that grazing by one species of herbivore can modify vegetation so that individual plant species or communities are more preferred by another species of herbivore. In forests of the interior northwestern United States, Skovlin (1976) observed that elk and mule deer changed both feeding habitat and species composition of the diet in response to cattle grazing. On the Isle of Rhum, Scotland, Gordon (1988) found that red deer production was increased on the area of the island where cattle grazing was reintroduced. More calves were produced per hind in the cattle grazed area.

Severson and Urness (1994) provide an excellent description of the specific vegetation manipulations possible with grazing management. Livestock of various species may be used to alter the composition of the vegetation, increase the productivity of selected plant species, increase the nutritive quality of the forage, and increase the diversity of habitat by altering its structure. Likewise, different species of livestock can be used to the same effect to improve forage conditions for other species of livestock, or even within species enhancement is possible.

Where wild herbivores that prefer shrub and/or forb diets concentrate, they may negatively impact the shrub and forb components of plant communities with a resultant increase in the grass component. The introduction of controlled cattle grazing should result in a decrease in the competitive ability of the grasses and allow increased vigor and reproduction of forbs and shrubs. Timing is critical as cattle may also use the shrubs once the grasses are mature and crude protein content has declined (Lesperance et al. 1970). Urness (1990) found that cattle used grasses more effectively than forbs, while the converse was true of sheep; sheep were borderline in shrub use, and horses used grasses almost exclusively. He also suggested that alternation of cattle and sheep or combined grazing would be the most successful. In the United States this has been demonstrated effectively for a wide variety of large mammals and birds.

The same methodologies employed above may be used to increase the productivity of selected species. Horses and cattle may be used to decrease the vigor of grasses and favor the production of preferred shrubs. Likewise, on ranges where both palatable and non-palatable shrubs occur, goats may be used to improve production of one species over another if differential palatability occurs. Riggs and Urness (1989) found that the root-sprouting Gambel oak brush (*Quercus gambelii*) was effectively controlled by goat browsing, which in turn provided release of big sagebrush (*Artemisia tridentata*) for wintering mule deer. Gambel oak is a strong root sprouter and cannot be controlled with burning, mechanical, or herbicidal means. Limited overlap in forage selection must occur between the treatment animals and the featured species for this approach to be successful.

For animals of similar food habits, the opportunities are more restrictive. However, one species of herbivore may still be used to improve the nutritive quality of the forage available for another (Anderson and Scherzinger 1975). In an early application of this method Hyder and Sneva (1963) used spring cattle grazing to condition crested wheatgrass and improve its nutritive quality for future cattle grazing. The hypothesis proposed by Hyder and Sneva (1963) and Anderson and Scherzinger (1975) was that grazing with cattle intensively for a short-time period in the spring during the boot stage of plant growth provided regrowth of the grasses while soil moisture allowed. Growth of these tillers was arrested by summer heat and drought prior to the development of reproductive stems. Nutrients were fixed in the leaves of these conditioned plants at a higher level than in plants that were ungrazed. Grazing during this period of plant growth is the most potentially damaging to the plant and cannot be done on an annual basis.

Some form of rotation system is needed to provide deferment. Research verification of this hypothesis has been mixed (Pitt 1986, Bryant 1993 and Westenskow-Wall 1994). However, field application of the technique has been successful (Anderson and Scherzinger 1975, Frisina and Morin 1991, and Frisina 1992). Currently the technique is as much art as it is science. Timing of removal of cattle grazing is critical in that sufficient soil moisture must remain to allow regrowth.

A rest rotation system can be employed to accomplish these goals and provide an array of other forage availabilities for wintering wildlife or for use in a dry season. A two-herd, four-pasture rest rotation system provides for different forage availabilities for wildlife after livestock are removed. The pasture grazed in the boot stage, produces high quality forage of somewhat limited production. The rested pasture produces current annual growth and most importantly provides rest and vigor maintenance in the year following the defoliation during the boot stage. The mid- or late-season pasture and the season-long pasture may produce regrowth if sufficient precipitation occurs. This regrowth is of limited production but extremely high quality. The benefit to these two treatments is that current year's growth is removed and will not persist into next year. Persistence of standing litter from one grazing season to the next confounds forage availability and quality for the next grazing season (Vavra and Sheehy 1996) and may alter animal forage selection behavior (Ganskopp et al. 1993).

Livestock grazing can be effectively used to increase diversity of habitat by altering its structure. Previously in this paper, I mentioned the work of Guthery (1986) where grazing at the landscape-level created a variety of utilization levels and improved habitat for bobwhite quail. Cattle grazing is often considered a negative event for waterfowl production (Strassman 1987). However, there is some indication that grazing under controlled systems may actually enhance waterfowl production (Kantrud 1990). Kemp (1975) used cattle in the winter to create trails and open areas in densely vegetated marshes that provided avenues of travel for waterfowl the following spring when water inundated the wetlands. Open areas provided feeding sites for waterfowl because old dead vegetation was removed allowing better access to new spring growth.

Consideration for the future

There is worldwide concern that human-based disruption of ecosystems for food and energy extraction is not sustainable (Vavra 1996). The current generation is using natural resources at historically unprecedented rates and future generations will inherit a much depleted and degraded resource base (Lubchenko et al. 1991 and Bishop 1993). Steinfeld et al. (1996) reported that in the last 35-40 years, large land areas have become degraded. They also mention that 35 percent of the world's land area is used by livestock for grazing. The role of improper livestock grazing in land degradation cannot be ignored. Critics of grazing readily point out failures (Durning and Brough 1991 and Fleischner 1994). In this paper I have tried to discuss some of the problems of the past, the ecological complexity of managing natural systems, and some examples of controlled grazing that provide opportunities for continued livestock production with environmental maintenance or enhancement. The practicality of applying these methods on a global basis across diverse climates and land types is unknown. These examples do provide illustration that methodologies can be developed when specific goals and objectives are in mind.

Leopold (1949) talked about the agents of destruction of America by the invading Europeans. The plow, cow, axe, and fire were used by the settlers to alter landscapes on a continental basis. In this paper I have given examples on how the cow, and other livestock can be used as agents of positive change. Leopold's other agents can also be incorporated into agents of positive change. Many of the ecosystems of the world have periodic fire as a natural component (Pyne 1982). The reintroduction of fire in a prescribed fashion is another tool in the reestablishment of certain plant communities. The plow can be used to reseed degraded rangelands. The axe or logging can be used to thin tree- and shrub-invaded lands prior to burning to reduce fuel loads to prevent extensive fires. In some cases the invasion of woody plants has fire-proofed ranges so that cutting is the only means of removal possible. In many cases, rehabilitation of rangelands will benefit livestock production as well as enhance the wildlife habitat.

Riparian zones pose particular problems because usually there is not the same positive response to a grazing system that will improve uplands (Elmore and Kauffman 1994), particularly if reestablishment of woody vegetation is a goal. Such riparian zones may best be grazed when grasses are immature and most palatable and nutritious. Unfortunately, during this same time period grasses are also most susceptible to grazing damage, so rest or deferment must be incorporated into the system. Deferment of grazing until grasses are mature also means that grazing occurs when grass nutritive quality is low. Grazing animals may then turn to the riparian woody plants as a source of protein causing degradation of the riparian area. This riparian dilemma makes viable livestock management difficult. Possible alternatives do exist, but may mean a change from traditional management (Elmore and Kaufman 1994).

The increasing environmental awareness on a global basis will make our job as livestock grazing managers more difficult. In the United States, broad application of the Endangered Species Act has resulted in the listing of 1,258 species, and the consideration of 3,000 additional species as threatened or endangered. In most cases there is no science-derived information on the habitat needs of these species (Vavra 1997). Unfortunately, government agencies charged with administration of the Act usually make their first attempt at enhancement of these species an action that curtails livestock grazing where it occurs. Misinformation and bias against livestock within portions of the scientific community is a confounding influence (Vavra 1997).

Developing appropriate research and extension programs to address environmental issues, including: wildlife, fish habitat, and endangered species is the challenge that faces us. Funding for these efforts presents the major hurdle. Scientists involved in grazing management research and extension must break from their traditional career paths and pursue these issues as part of their programs (Vavra 1996). Institutions must also recognize this and provide career incentives for scientists in these pursuits.

One very positive aspect of developing new approaches to grazing management exists. At the same time environmentally compatible systems are developed, we can critically look at the efficiency of current systems and make improvements in efficiency of production. In most of the World's grazing systems, tradition and culture play more important roles than efficiency of production. In the United States we commonly graze rangelands when livestock production (average daily gain) is zero or even negative (weight loss) just because that is the way we have always done it. New systems may enhance the environment and provide increased efficiency of production.

What must be developed are management pathways for livestock production based on ecological soundness that provide the essentials of vegetation cover, water-holding capacity, and lack of erosion to the landscape. Grazing treatments for specific habitat considerations can be factored in where objectives dictate. These are not new ideas, but it appears their time has come.

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