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J. E. Mitchell

USDA Forest Service, Rocky Mountain Research Station

Svata M. Louda

University of Nebraska - Lincoln, slouda1@unl.edu

B. Gillam

USDA Forest Service

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**BACKGROUND AND SYNOPSIS: SYMPOSIUM
ON THE GREAT PLAINS GRASSLANDS
AT THE MILLENNIUM**

J. E. Mitchell

*USDA Forest Service, Rocky Mountain Research Station
2150 Centre Ave.
Fort Collins, CO 80526-1891
johnm@lamar.colostate.edu*

S. M. Louda

*School of Biological Sciences
University of Nebraska
Lincoln, NE 68588-0118*

and

B. Gillam

*Director of Range Management
USDA Forest Service
Washington, DC 20090-6090*

ABSTRACT—Research on biodiversity, landscape ecology, grazing management, greenhouse gas effects, control of invasive species, riparian ecology, sustainable development, and related fields is forging a new and broader understanding of the Great Plains and its grassland ecosystems. This research documents dramatic changes that are taking place across the Great Plains and their consequences. First, we review the factors that led to the January 1999 symposium, “Great Plains at the Millennium,” sponsored by the USDA Agricultural Research Service, USDA Forest Service, Ecological Society of America, Society for Range Management, as well as the Center for Grassland Studies and the Center for Great Plains Studies at the University of Nebraska. Then, we highlight the primary themes developed by the speakers. The funding for this special issue was provided by grants from the USDA Agricultural Research Service and USDA Forest Service.

Introduction

In recent years, the on-going involvement of several governmental agencies and external organizations in the management of Great Plains

grasslands has been supplemented by increased efforts to address important, emerging issues in the Great Plains. In recognition of these developments, USDA Forest Service convened a "National Grasslands Management Review Team" in November 1995. Their task was to examine the effectiveness of management in National Grasslands. Two actions resulting from this national review were the formation of a National Grasslands Council, chartered by the Forest Service and the Natural Resources Conservation Service in 1996, and a call for the development of a research agenda to assist grasslands managers in the Great Plains.

The purpose of the National Grasslands Council is to provide conservation leadership for the National Grasslands that are managed by the Forest Service and to promote cooperation among groups interested in grassland management. The council is composed of members nominated from the three branches of the Forest Service (National Forest System; Research; State and Private Forestry) and the Natural Resources Conservation Service, plus the Director of Range Management for the Forest Service. This Council advises Forest Service leaders on national grasslands policy and budget. In addition, the Council facilitates communication and coordination of activities across grassland ownership boundaries, an increasingly important responsibility of both managers and scientists (Butler 1995, Mitchell and Wallace 1998).

The call for the development of a Great Plains research agenda recognized that prioritization of research and cooperation with University researchers would achieve a better scientific base from which to make management decisions. Moreover, the National Grasslands Council was well positioned to coordinate such a research program to promote the quality of grassland resource management in the USA. Subsequently, the task of assessing research needs for grasslands ecosystems was assigned to the Rocky Mountain Research Station of the Forest Service.

The assessment task specifically included consideration of research needs for the management of prairie dogs, threatened and endangered species, wildlife cover, invasive species and woody draws, including the use of prescribed fire. A committee of grassland scientists and project leaders commenced work on an action plan to implement this directive in late 1996. However, they quickly realized that research priorities could not be established without a comprehensive inventory of the current state of knowledge on grassland ecosystems within their socioeconomic context.

The decision was made to organize a symposium on the state-of-the-art in grassland research, including major areas of active research and important

research findings to date. With the Rocky Mountain Research Station taking the lead, a cooperative agreement to hold such a symposium was developed. The cosponsors of the symposium were: USDA Agricultural Research Service, Ecological Society of America, Society for Range Management, plus the Center for Grassland Studies and the Center for Great Plains Studies at the University of Nebraska. This symposium, titled "Great Plains Grasslands at the Millennium," was held during the 52nd Annual Meeting of the Society for Range Management in Omaha, Nebraska, on 24-25 February 1999. At the meeting, the symposium was coordinated by the Rocky Mountain Research Station and the Sustainable Biosphere Initiative Program (Lubchenco et al. 1991) of the Ecological Society of America. The results are presented here.

Previous Assessments of Grasslands Research

Few syntheses have been published covering the status of knowledge on the Great Plains grasslands. However, some compilations of contemporary research on specific aspects of grassland ecosystems, such as productivity and use of fire, have been published. For example, Sims and colleagues (1978a, b, c, d) published a widely-cited series of papers integrating work done on the structure and function of North American grasslands under the auspices of the Grassland Biome, US International Biological Program.

One of the more comprehensive publications coming out of the International Biological Program on grasslands covered productivity, responses to stress, bioenergetics, nitrogen dynamics, grazing effects, and interactions among these factors (French 1979). After the International Biological Program ended, long-term research was continued by another National Science Foundation program, Long-Term Ecological Research. This long-term ecological research network consists of 21 sites representing diverse ecosystems and research thrusts. Two sites, the Konza Prairie in Kansas and the Shortgrass Steppe in Colorado, are situated within the Great Plains grasslands. One of the most significant conceptual advances incorporated into this long-term research program is the inclusion of spatial and temporal variation as important research directions (Epstein et al. 1998). The results of ongoing work carried out at these grassland sites are summarized, in part, in the Feature Article of this special issue.

Additionally, a symposium was held in 1991 to assess the ecological ramifications of livestock grazing in western physiographic regions at the American Institute of Biological Sciences annual meeting in San Antonio,

Texas. It considered some of the historical, evolutionary, physiological, ecological and management issues, including an extensive review of livestock herbivory in the Great Plains (Lauenroth et al. 1994).

These appraisals of Great Plains grasslands (above) did not consider socioeconomic issues and interactions. Yet, from a management standpoint, the social and economic system within which resource management decisions are made is important. This socioeconomic context may be viewed as representing an added level of integration above the ecosystem, because the goal of management is manifested at this level (Cooper 1969).

Another symposium that included sociological and economic development issues was held in April 1993 in Kansas City, Missouri. This symposium, titled: "Conservation of Great Plains Ecosystems: Current Science, Future Options," was organized by: US Environmental Protection Agency, Western Governors' Association, US Fish and Wildlife Service and Center for Agriculture and Rural Development at Iowa State University. Discussions of sociological and economic development issues identified several problematic economic attributes of the Great Plains, related primarily to a narrow economic base reliant upon agriculture and energy. Overlapping problem areas, involving factors affecting commercial agriculture, quality of rural life and rural sociological development, had been recognized before (Great Plains Resource Economics Committee 1967). However, conservation issues facing grassland managers have not been incorporated into discussions at economics-based symposia (Johnson and Bouzaher 1995).

Great Plains Grasslands at the Millennium Symposium

The symposium, which provided the papers contributed to this special issue, constituted the first comprehensive attempt to provide grassland managers with the scientific information needed to help them plan, covering everything from local grazing allotments to management of entire national grasslands or regions. This meeting expressly afforded an initial opportunity to jointly review the state-of-the-art in grasslands of: 1) biodiversity and impacts to biodiversity, 2) wildlife and recreation, 3) grazing and riparian ecology, and 4) institutional and economic frameworks for the sustainable development of rural communities.

Welcome and Introduction. In his welcome James Saveland, Assistant Director for Research of the Rocky Mountain Research Station emphasized the importance of considering all scientific fields affecting grasslands. He stressed the necessity of collaboration between research and management,

along with the need to integrate the biological, physical and social sciences when summarizing scientific knowledge for natural resource managers. Dr. Saveland suggested that principles of organizational learning, where institutions can learn from mistakes made by different parts of the institution, may act as a model for successful communication between research and management. He emphasized the need for science to follow an adaptive strategy in order to take advantage of effective organizational learning mechanisms (Argyris 1993).

Guy McPherson expanded upon ways to improve the linkage between science and management (Table 1). Scientists focus on general principles and on understanding relationships in ecological, social or economic systems. In contrast, management is necessarily objective- and site-specific. He argued, however, that both endeavors will benefit with increased understanding and appreciation for each other's goals. He suggested ways in which such understanding and appreciation could be developed, increasing the understanding that science and management of natural resources are complementary endeavors.

Setting the Stage. W.K. Lauenroth, I.C. Burke, and M.P. Gutmann set the stage for the symposium by providing an overview of the Great Plains grasslands and land use patterns. Lauenroth emphasized the importance of this region from a global perspective. The Great Plains encompasses one of the largest contiguous areas of grassland worldwide, and it has exceptionally uniform gradients of topography, climate, and social culture. As such, it has attracted more intense study than any other grassland in the world. Primary productivity is closely correlated with precipitation, as with other arid and semi-arid regions. However, soil texture and nitrogen are important modifying factors in this region. Land use patterns can be predicted with reasonable accuracy using climatic and soils statistics. Burke stressed the long-term, regional consequences of contrasting land-use practices on carbon storage and possible climate change. Lauenroth and Burke combined their efforts in the Feature Article (p. 223-59) in this issue.

In addition, C. Owensby reviewed CO₂, nitrogen and climate change in the central grassland region (Table 1). His analyses suggest that primary production in grassland ecosystems under elevated CO₂ will likely increase in plant communities that are subjected to frequent drought stress; however, because of lower leaf nitrogen concentrations and higher fiber content on average, decreased ruminant intake and increased insect herbivory are likely as CO₂ concentrations increase.

Biodiversity. Several contributors highlighted the contribution of a heterogeneous landscape to the maintenance of biological diversity. Grazing and other management practices can be used to promote heterogeneity, and thus help sustain ecosystem processes that enhance both community and species diversity (e.g., Collins et al. 1998).

C.H. Sieg reviewed the statistics on grassland lost (96-99% tallgrass; 60-100% mixed grass depending on region; 20-86% shortgrass), and the fragmentation and degradation of the remaining tracts, suggesting the biological integrity has been eroded where measured (p. 277-313). She challenged grassland managers to put the science to work to reverse past trends, diversity management, and restore processes underlying diversity and function in Great Plains ecosystems. However, returning to perceived pre-European settlement conditions was challenged as a viable option, in part, by the evidence presented by D. Flores that native Americans had a long history of anthropogenic management and disturbance of the Great Plains (pp. 343-55).

In reviewing changes in grassland bird populations, J.R. Herkert reviewed four ways in which habitat fragmentation impacts these populations. He argued that our understanding of the effects of habitat fragmentation on grassland birds has increased over the last 10-20 years, but much remains to be learned. M. Carter of the Colorado Bird Observatory highlighted the influence of land management outside the Great Plains region in the patterns of ground-nesting birds in the grasslands (Table 1). He explained how non-governmental groups such as "Partners in Flight" and his organization work to promote cooperation across state and national borders to achieve the common goal of preserving wildlife biodiversity.

F.E. Smeins reviewed the threat posed by invasive plants to biodiversity and ecosystem function in grasslands (Table 1). He suggested that generalizations are still scarce. So, a thorough knowledge of the biology and ecology of the species and processes is essential to prevent invasions and spread. He also suggested more careful screening, improved early warning systems and responses, and new and innovative management strategies will be required to deal with problem species. M.R. Haferkamp and R.K. Heitschmidt provided an update on the impact of an invasive plant (Japanese brome) on a native grass (western wheatgrass) (p. 315-27).

The Nature Conservancy and other non-governmental organizations have been working to protect and enhance biodiversity to the Great Plains by preserving critical native species and ecosystems. Identification and selection of suitable areas have become more deliberate in recent years as proto-

cols for doing so have evolved. S.J. Chaplin discussed how TNC sets priorities for acquiring sites to attain their biodiversity goals (Table 1). And, S. McCanny of Parks Canada addressed the value of long-term rest in grassland conservation.

Managing Grazing and Riparian Ecosystems. Several speakers evaluated grassland grazing by various ungulates. R. K. Heitschmidt introduced the session by proposing that managed grazing is ecologically sustainable, although not always economically viable or socially acceptable (Table 1). He suggested that societal aversion to livestock grazing is linked to a lack of awareness of the Great Plains' evolutionary history. To achieve social tolerance of cattle grazing, Dr. Heitschmidt argued that scientists need to cooperate with managers in organizing and conducting research to help demonstrate the compatibility of properly managed grazing with other values held by society.

Three speakers examined the effects of bison and cattle on grassland ecosystems. Bison have been shown to have differences in physiology and morphology from cattle, but the significance of these differences for both conservation and productivity is still incompletely known. A. A. Steuter found some differences in the influence of bison and cattle on plant community structure of large, mixed grass prairies. He also contrasted herd productivity and animal ecophysiology under typical management regimes that included fire in the bison area (p. 329-42). The fire-bison regime shifted vegetation composition more toward rhizomatous grasses and forbs in the years following a burn. Productivity of unsupplemented bison herds was high.

D.C. Hartnett summarized evidence from a 10-year study of grazing on tallgrass prairie at the Konza Prairie Long-Term Ecological Research site in Kansas (Table 1). The results suggest that grazing can enhance both plant and aboveground invertebrate diversity through physical disturbance and microsite creation as well as by consumer-induced shifts in plant competition. Plant responses to grazers were variable, resulting from interspecific differences in palatability, growth form, phenology, and compensatory growth. Even though bison and cattle differ in aspects of their foraging ecology and non-grazing behaviors, few differences have been found in their effects on plant or invertebrate populations or species diversity in this tallgrass system. He concluded that the results to date suggest that stocking rate, rather than type of grazing animal per se, has the most effect on vegetation structure and composition.

R.G. Hamilton summarized work by Plumb and Dodd (1993), on the relative suitability of bison and cattle for protected area management in the Great Plains. He concluded that bison are more appropriate for large pastures, where fire can be used to achieve desired distribution patterns of grazing animals, than for small reserves (Table 1).

Riparian zones are extremely important in Great Plains grasslands, especially for maintenance of biodiversity (Knopf 1985). In many places riparian areas have been subjected to both physical and biological perturbations resulting from human activities; i.e., irrigation water withdrawals, channelization, grazing, recreation, and urban expansion. Large-scale water diversions and impoundments have altered many Great Plains riverine systems (Miller et al. 1995).

Two speakers addressed riparian zone dynamics. W.C. Johnson provided an overview of the influence of human activities on riparian zone vegetation (p. 357-69). He concluded that, for large rivers, dams and water diversions affect ecological processes more than local land uses, whereas for small streams the reverse is generally true. He suggested that restoration of the different types of systems will require separate methods and approaches.

M.L. Scott summarized the effects of flooding, ice damming, and cattle grazing on recruitment and survival of cottonwood populations along a intensively studied, confined reach of the upper Missouri River in Montana (Table 1). Successful recruitment of cottonwood requires infrequent high flows to establish seedlings in disturbed patches high enough along the riverbank's hydraulic gradient to survive subsequent flooding and ice scour. Grazing reduced these seedling densities, but no more than subsequent mortality factors would have. In addition, both authors discussed the importance of good management and restoration practices to heal the effects of previous improper management.

Socioeconomic Research. K. Cordell reviewed information on recreation potential and impacts in the United States (Table 1). In the 1990's, walking has become the most popular form of outdoor recreation, followed by bird watching and wildlife viewing. The studies show that most recreation takes place close to home, which leaves less populated areas of the Great Plains at a competitive disadvantage for tourism dollars. He suggested that more data are needed on the origins and destinations of recreational trips in the Great Plains.

Expanding capital choices for rural communities in the Great Plains was identified as a concern in previous symposia (above). M. Drabentstott reviewed the economic forces currently shaping the rural Great Plains. He

summarized four ways in which grassland communities can add economic value: Value-added agriculture, tourism, manufacturing, and white-collar services.

J.C. Allen suggested that centralization of government, consolidation in the private sector and agriculture, and an increase in home-based business are leading to shifts in populations that are changing relationships among individuals, communities, and economic sectors of our society (Table 1). He argued that population shifts and changes in the organizational structure of farms, businesses and communities enhance linkages between environmental issues, technological applications, and cultural opportunities for rural development.

J. Vaisey, from the Prairie Farm Rehabilitation Administration, discussed grazing as an integral, sustainable part of the economic and environmental health of Canada's three prairie provinces (p. 371-95). She noted that current environmental issues in Canada, such as biodiversity responses to management of endangered species and increased greenhouse gases and carbon sequestration, will influence the way prairie grasslands are used in the future. Since changes in management will affect individual and community economic sustainability, she contended that all stakeholders must be involved in the decisions. Her final point was that the public needs to recognize both the stewardship efforts and the economic dependence of the landowners in rangeland areas.

C.B. Flora culminated the socioeconomic analyses with a synthesis of how our perception of the landscape can influence rural community goals and community sustainability (pp. 397-419). In rural areas, community goals tend to be healthy ecosystems, social equity, and economic vitality. The resources available to reach these goals include four forms of capital: Human, financial, social, and natural. Resource mobilization to accomplish the goals starts with enumeration of the specific resources within a community. She concluded that varied community perceptions of the best use of the natural capital, comprised of air, soil, water, biodiversity, etc., need to be communicated and resolved for a community to reach its goals of sustainability, equity, and economic vitality.

Synthesis. The two final speakers, M. Peterson and J. Dodd, were asked to highlight and synthesize the symposium information. Both saw a strong link between science and management. Peterson observed that research involves inquiry while management involves application, and she argued without application there can be no real knowledge (Table 1). Dodd called for partnerships to enhance the joint advancement of research and manage-

TABLE 1

Titles and Addresses of Additional Speakers in the "Grasslands at the Millenium" Symposium, 24-26 February 1999, in Omaha, NE

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- Allen, J.C. "Rural community development in the Great Plains." Center for Rural Community Revitalization and Development, University of Nebraska, Lincoln NE 68588 <jallen1@UNL.edu>
- Carter, M.F., "Shortgrass prairie bird conservation - broad approaches for broad landscapes. Colorado Bird Observatory, 13401 Piccadilly Rd., Brighton, CO 80601 <mike.carter@cbobirds.org>
- Chaplin, S.J. "Current landscape: Priorities and locations for biodiversity across the Great Plains." The Nature Conservancy, 1313 5th St., NE, Minneapolis, MN 55414 <schaplin@tnc.org>
- Cordell, H.K. "Recreation potential and impacts." USDA Forest Service, 320 Green St., Athens, GA 30602, <hcordell/srs_athens@fs.fed.us>
- Dodd, J.L. "Comments on the state of our knowledge about Great Plains grasslands." Dept. Animal & Range Science, North Dakota State University, Fargo, ND 58105 <jdodd@ndsuxext.nodak.edu>
- Drabenstott, M. "The value imperative in the economic future of the rural Great Plains." Federal Research Bank Kansas City, 925 Grand Boulevard, Kansas City, MO 64918-0001 <mdrabenstott@frbkc.org>
- Hartnett, D.C., "Population and community level effects of bison and cattle grazing in tall grass prairie." Biology Department, Konza Prairie Research Natural Area, Kansas State University, Manhattan, KS 66506 <dchart@ksu.edu>
- Hamilton, R. "Comparative biodiversity management using bison and cattle." The Nature Conservancy Tallgrass Prairie Preserve, P.O. Box 458, Pawhuska, OK 74056 <bhamilton@tnc.org>
- Heitschmidt, R. "Is livestock grazing a sustainable form of land use in the Great Plains?" Ft. Keogh Livestock and Range Research Laboratory, USDA Agricultural Research Service, RR 1 Box 2021, Miles City, MT 59301-9801 <rod@larl.ars.usda.gov>
- Herkert, J.R. "Effects of habitat fragmentation on grassland birds." Illinois Endangered Specie Protection Board, 524 South Second St., Springfield, IL 62701 <jherkert@dnrmail.state.il.us>
- McCanny, S. "The value of long-term rest in grassland conservation." Parks Canada, Winnipeg, Manitoba, R3B 3E8, Canada.
- McPherson, G.R. "Linking science and management," School of Renewable Natural Resources, Biological Sciences East 325, University of Arizona, Tucson, AZ 85721 <grm@ag.arizona.edu>
- Owensby, C. "CO₂, nitrogen and climate change in the central grassland region. Department of Agronomy, 3016A Throckmorton Hall, Kansas State University, Manhattan, KS 66506-5501. <owensby@ksu.edu>
- Peterson, M. "Comments on the state of our knowledge about Great Plains grasslands," Supervisor, Nebraska National Forest, 125 N. Main St., Chadron, NE 69337 <mpeterson/r2_nebraska@fs.fed.us>
- Saveland, J. "Welcome, and challenge." Rocky Mountain Research Station, USDA, Forest Service, Ft. Collins, CO 80524-8597

- Scott, M.L. "Effects of floods, ice and cattle grazing on cottonwood demographics along the upper Missouri River, Montana, USA." US Geological Survey, Biological Resources Division, 4512 McMurray Ave., Fort Collins, CO 80525 <mike_l_scoti@usgs.gov>
- Smeins, F.E. "Invasive plant species issues in grasslands: A review." Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX 77843-2126 <f-smeins@tamu.edu>

ment principles on the Great Plains (Table 1). Rangeland classification, inventory/ monitoring systems, and management of invasive species were identified as areas urgently needing collaborative effort.

Acknowledgment

Much of the success of the symposium must be attributed to Lori Hidingier of the Ecological Society of America's Sustainable Biosphere Program. Lori worked energetically on all facets of the symposium, and she continues to help bring attention to the important information and conclusions reached by the participants.

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