Quantifying the Environmental Benefits of the Conservation Reserve Program on Prairie Wetlands: Separating Acts of Nature from Acts of Congress

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Introduction

The global diversity of ecosystems is the result of complex interactions between and among physical, chemical, and biological factors at specific locations. Physical and chemical characteristics are largely determined by events, such as structural (e.g., volcanoes), weathering (e.g., Karst topography), and depositional or erosional (e.g., glacial deposition) processes, that occurred at the landscape level. Landscape formation processes also determine topography, type of parent material available for soil genesis, and the basic hydrologic framework. Although components (e.g., aquatic, terrestrial) of a single ecosystem often are subdivided for evaluation and management, all components were derived from formation events that occurred at a landscape scale. Further, evolution of ecosystems involves the flow of energy and material between ecosystem components at multiple scales; thus, factors such as landscape position (e.g., elevation, slope, aspect), geomorphic processes (e.g., soils, hydrology, water quality), and climate (e.g., precipitation and temperature) continue to influence modern ecosystems. The influence of these abiotic factors on system function cannot be ignored because they are involved in complex feedback loops that define and constrain biotic communities composing an ecosystem and, ultimately, the types and extent of values (e.g., biodiversity, floodwater retention, and carbon sequestration) provided to landowners and society. Thus, evaluation and management of an entire ecosystem, or even a single ecosystem component, must be interpreted within the context of landscape-scale processes.

In systems devoid of human intervention or activity, such "acts of nature" are the only determinants of ecosystem functions and biological communities. However, humans represent a significant component of most systems in the conterminous United States, where anthropogenic activities have significantly altered relationships between the abiotic and biotic components of most ecosystems. In the Great Plains, for example, agriculture has resulted in replacement of native vegetation with crops, nutrient enrichment, soil erosion, and altered hydrology. Initially, such land-use changes occurred as the result of human ingenuity and desire. However, over time government has attempted to influence many of these activities through congressional acts (Fischman, 2003). Hence, we refer to such activities as "acts of Congress." Although modern ecosystems still function within historic constraints defined by specific acts of nature, anthropogenic disturbances resulting from acts of Congress have altered processes that influence biotic community composition, system function, and values provided to society. Therefore, determining the environmental benefits accrued as a result of conservation programs, such as the Conservation Reserve Program (CRP), requires acts of Congress be distinguished from acts of nature.

Widespread concern over global resources has stimulated considerable interest in conducting evaluations of land-use programs in terms of environmental health and the sustainability of modern ecosystems. However, these terms are vague and measuring success tends to be difficult because diverse stakeholders evaluate programs from very different perspectives. In some cases, definitions of success may be unrealistic because of expectations that an ecosystem can be returned to its original condition or managed to optimize a single function or value. Regardless, the response of the entire system to land-use change will result in a mix of positive and negative changes, and depending on stakeholder perspective, will result in success or failure of specific programs or land-use practices. Given the inherent ambiguity of these types of evaluations, we think a paradigm shift is needed to objectively evaluate land-use practices implemented through acts of Congress. Specifically, programs need to be evaluated from a perspective that considers interrelationships of ecosystems, and ecosystem components, in the modern landscape. Further, evaluations of success should be within the context of ecological fit, which we define here as how well specific acts of Congress are integrated with acts of nature. This definition is analogous to one proposed by Aldo Leopold, which states that "an understanding of ecology does not necessarily originate in courses bearing ecological labels; it is quite as likely to be labeled geography, botany, agronomy, history, or economics" (Leopold, 1949). Key to understanding rationale for the method of evaluation we propose is that many acts of nature at specific geographic locations cannot be changed (e.g., basic parent material, climate); hence, success will depend on how well acts of Congress are coordinated with acts of nature. Based on ecological fit, programs would be successful if they result in land-use changes that optimize specific functions, yield

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sustainable habitats, and do not produce unintended and negative impacts on other ecosystem functions valued by society. Again, this is similar to Leopold (1949), who stated "quit thinking about decent land-use as solely an economic problem. Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Although evaluating programs within the context of ecological fit is clearly needed, conducting such evaluations will be daunting because ecosystems are complex and basic processes are interrelated. Thus, multiple aspects of an ecosystem must be evaluated simultaneously to obtain accurate assessments. Although evaluations based on ecological fit will not eliminate the perception of negative change from the perspective of individual stakeholder groups, such evaluations would provide an objective and scientific approach to evaluate programs in relation to stated objectives because functional changes attributable to specific land-uses could be quantified and predicted. Further, it would provide a means to develop new programs that optimize specific ecological functions, minimize unintended outcomes, and bring diverse stakeholder groups closer to consensus.

Applying the Concept of Ecological Fit

The concept of ecological fit requires information from multiple disciplines (e.g., geology, hydrology, biology, economics, agronomy) to be collected or obtained from existing sources to define the acts of nature and acts of Congress impacting the system of interest. Complete information may be lacking in many cases. Although this may hinder complete understanding, it does not preclude an evaluation based on the concept. Further, given that each ecosystem often exhibits unique characteristics, and the types and extents of human perturbations vary greatly, application of ecological fit likely will differ among ecosystems. Therefore, it is neither feasible nor advisable to provide a "cookbook" approach to evaluation of conservation programs. Rather, we provide an annotated example using the Prairie Pothole Region (PPR) to describe a general course of action that could be adapted for other geographic areas.

Formation and Historic Functions of the Prairie Pothole Region

The PPR of North America is approximately 347,490 mi^2 (900,000 km^2) (Phospahala and others, 1974; Mann 1986) and may have contained more than 49 million acres (20 million ha) of wetlands prior to European settlement (Tiner, 1984; Millar, 1989). The PPR was a unique area dominated by a background matrix of prairie interspersed with shallow depressions created by the scouring action of Pleistocene glaciation. Historically, a dynamic midcontinental climate influenced precipitation and temperature patterns, coupled with complex groundwater pathways that determined solute concentrations and transport mechanisms (i.e., import, export), functioned to create and maintain a diversity of wetland and prairie types. Further, a given ecosystem component could undergo significant changes among years. For example, the hydroperiods of a wetland can range from dry to extremely wet, salt concentrations can vary from fresh to nearly 10 times the salinity of the world's oceans (Euliss and others, 1999), and vegetation can fluctuate between facultative upland and obligate wetland species. Despite this harsh abiotic environment, the PPR was extremely productive and the biological communities inhabiting it were well suited to cope with these conditions. However, populations of terrestrial and aquatic biota exhibited dynamic shifts in relation to interannual climate variation. A conceptual model has been developed that simultaneously considers the influence of climate and hydrologic setting on undisturbed wetland biological communities (Euliss and others, 2004; fig. 1).

Agriculture as a Perturbation in the Prairie Pothole Region

The present climate of the PPR remains highly dynamic and characterized by extreme variation. Abundant rainfall can be followed by severe drought and annual temperatures can range from 104 °F to -40 °F (40°F to -40°C). Similarly, groundwater pathways still exert a primary influence on solute concentrations and transport of nutrients. Biological communities still vary in response to these dynamic conditions. For example, the PPR is the most important area in North America for the production of dabbling ducks (Smith, 1995), but annual production varies depending on climatic conditions (Batt and others, 1989). However, agriculture has significantly altered relationships between these and other abiotic features. Extensive areas of native prairie have been converted to agriculture. In North Dakota alone, 68% of the mixed-grass prairie has been converted to agricultural production (Samson and others, 1998). Similarly, it has been estimated that >50% of the wetland area in the United States PPR (Tiner, 1984; Dahl, 1990; Dahl and Johnson, 1991) has been drained for agricultural development. Remaining wetlands, which comprise 23% of the land area in the PPR, are embedded within a predominately agricultural landscape (Euliss and others, 1999) and most are cultivated for agricultural production, especially during drought years (Euliss and others, 2001). In addition to loss, historic processes (e.g., hydrology, fire, herbivory) important for maintaining the integrity of the remaining native communities have been altered, which has led to changes in biotic communities and other ecosystem benefits. For example, the planting of crops in upland areas has altered relations between surface and subsurface water in

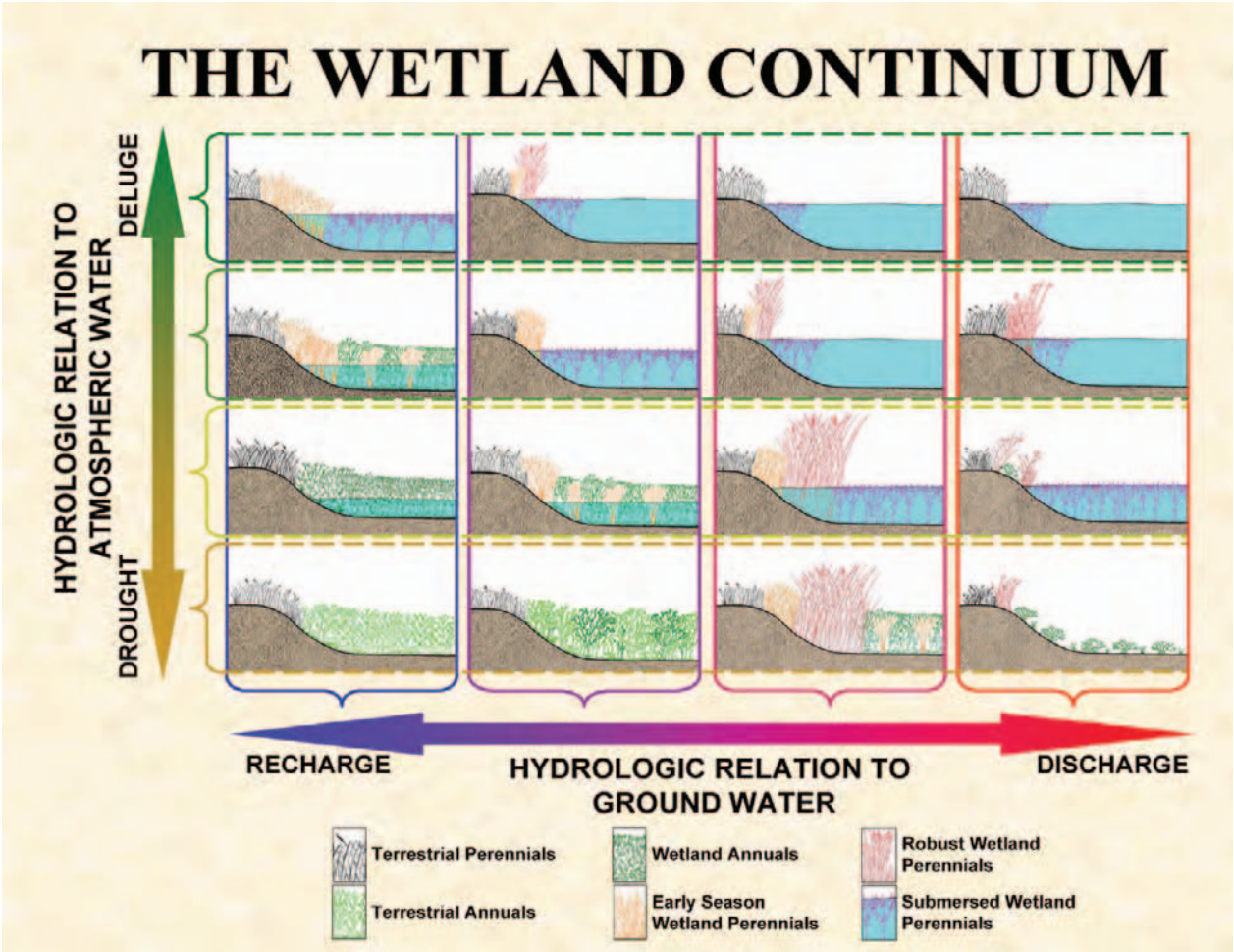

Figure 1. A visual depiction of the wetland continuum. Wetlands located at the recharge end of the hydrological relation to ground water axis recharge ground water but do not receive ground-water discharge. Wetlands at the discharge end of the same axis receive ground-water discharge but do not recharge ground water. Wetlands located between the two extremes are located along the axis based on their relative ratio of ground-water recharge to ground-water discharge. Potential plant communities in wetlands at four discrete points along this axis are depicted. The "hydrological relation to atmospheric water" axis extends from drought to deluge. Again, the plant communities of the same four wetlands are depicted at different points in the drought-deluge cycle to show how community response to climatic change is largely dictated by the hydrologic relation to ground water (from Euliss and others, 2004).

both uplands and wetlands (Euliss and Mushet, 1996). As a result, changes also have occurred in sediment transport (e.g., erosion), nutrient enrichment (e.g., fertilizers), water quality (e.g., agrichemicals), and, ultimately, biotic communities (e.g., vegetation, wildlife). For example, large-scale conversion of prairie to cropland has changed the communities of birds and other animals that rely on grassland habitats (Johnson, 2000). Similarly, wetlands remain an important component of the regional ecosystem, but many important ecological functions (e.g., fish and wildlife habitat, global carbon cycling, flood water retention, water quality improvement, and sediment retention) performed by wetlands (Mitsch and Gosselink, 2000) have been altered to various extents.

Application of Ecological Fit to Restore Prairie Pothole Region Wetlands

Extensive conversion of wetlands and prairie to agricultural fields has stimulated considerable interest in restoring previously farmed uplands and wetlands for conservation (Knutsen and Euliss, 2001). Here, we describe considerations necessary to successfully evaluate environmental benefits of conservation programs (e.g., CRP) only in relation to wetlands, but the same principles apply to uplands as well.

Most wetlands restored are within large blocks of marginal farmland that landowners have voluntarily idled

from production and planted to perennial grassland through conservation programs of the Farm Bill (Food Security Act of 1985; Public Law 99-198, Farm Security and Rural Investment Act of 2002; Public Law 107-171). Wetland restoration typically involves plugging or destruction of drains and relying on natural processes for reestablishment of wetland vegetation. An often reported goal of these restorations is to return farmed wetlands to their original condition. However, although plugging drains will alter the existing hydrology, this single activity will not necessarily result in the emulation of the desired hydroperiod. Further, it is unrealistic to expect this single activity will ensure that other abiotic and biotic features will recover to desired levels. For example, failure to restore sediment dynamics within wetland catchments may hinder the diversity of plant and invertebrate propagules that can emerge from wetland sediments, which is a major factor facilitating the rapid replacement of the biological community within individual wetlands as climate regimes (e.g., acts of nature) fluctuate (see review in Euliss and others, 1999). Therefore, implementing restoration efforts to enhance a single function may represent a poor ecological fit if the restored habitat is not sustainable or it has great potential to produce unintended negative outcomes. In contrast, a good ecological fit would require that all ecological processes be evaluated to determine the impacts of past perturbations. Using the above example, not only would changes in hydrology be evaluated, but also the amount of sediment in wetlands, extent of erosion in uplands, and surface water movement. A primary benefit of evaluating all wetland functions simultaneously is that potential negative outcomes would be identified. Thus, decisions regarding the type of actions to implement would be improved because acts of Congress would be objectively evaluated in relation to complementing acts of nature. Thus, the goal of modern land management is not only to develop practices that insure the long-term sustainable productivity of the Nation's ecosystems, including agroecosystems, but also to develop improved criteria for selection and management to improve ecological fit. This will require an objective evaluation of the types and extent of change in fundamental abiotic features related to ecosystem processes. Although a seemingly impossible task, long-term studies indicate that changes in abiotic and biotic features can be related to natural climate variations (Euliss and others, 2004). Thus, the potential exists to develop a modeling approach that predicts and relates changes in the composition of biological communities to normal climatic variation. Coupled with monitoring information, the operational use of such a model would serve to better integrate science-based evaluations into land management and facilitate formulation of policy by enabling observed variation to be partitioned between acts of nature and acts of Congress.

Conclusions

There are increasing requests to evaluate the success of federal conservation programs in terms of achieving stated goals and quantifying outcomes to facilitate program evaluation and develop more effective environmental policy. Although such programs undoubtedly have had beneficial results, our ability to quantify specific values has been confounded in past evaluations. Therefore, improving existing conservation programs will require developing the capacity to partition changes due to acts of nature from those due to acts of Congress. Accomplishing this task necessitates understanding relations between natural and anthropogenic influences relative to fundamental ecosystem processes and developing a framework (e.g., model) that facilitates monitoring and interpretation of existing programs. The operational use of such a model would serve to better integrate science-based evaluations into land management decisions and contribute to improved policy formulation.

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