Prairie Restoration: Bridging the Past and the Future

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ABSTRACT Tallgrass prairie once dominated most of mid-continent North America. Conversion of this prairie to cropland was rapid and extensive. Today, it is the most decimated ecosystem in North America with less than two percent remaining. Prairie reconstruction began at the University of Wisconsin Arboretum in the 1930s. Thirty years later, exemplary initiatives by a group of highly motivated restorationists in Illinois and Iowa became a part of the legacy of restoration ecology. Their work generated widespread public interest in prairie restoration and initiated the ongoing biennial North American Prairie Conference. Since then, practitioners have made significant advances in reconstruction and remnant restoration procedures and techniques. Prairie restoration is now at a point where practitioners and restoration ecologists can cooperate to develop principles that can be applied in the new century. Increases in the human population and resource consumption are extensively altering ecosystems creating a need for restoration of natural systems. Advances initiated in the twentieth century provide a bridge to prairie restoration in the future. The twenty-first century will likely be recognized as the "restoration century" with tallgrass prairie restoration as a major component.

KEY WORDS prairie biomass, prairie in watersheds, prairie networks, reconstruction, restoration, restoration ecology, tallgrass prairie

An immense 68.4 million hectare landscape of grass, wind and sky once occupied mid-continent North America. It extended westward from the Wabash River to beyond the Missouri River and stretched from southern Manitoba to the coastal prairie of Texas and Louisiana. Tallgrass prairie communities dominated most of Iowa and parts of the other intervening states of Minnesota, Wisconsin, Illinois, Indiana, North and South Dakota, Nebraska, Missouri, Kansas and Oklahoma. The Twenty-third North American Prairie Conference provided opportunities to explore Manitoba remnants of the northern-most reaches of this once vast ecosystem (Samson and Knopf 1994).

Conversion of the tallgrass prairie to cropland was extensive and rapid. More than 90% of the tallgrass was transformed to agriculture in the last 70 years of the nineteenth century. Today, tallgrass prairie is the most decimated ecosystem in North America. Less than two percent of the original tallgrass prairie remains, most on un-tillable land like the shallow, rocky soils of the Flint Hills in eastern Kansas (Smith 2012). States with extensive blacksoil prairie, like Iowa and Illinois, have lost more than 99.9 percent of their prairie ecosystem (Smith 1992). Estimates for Manitoba place the remaining tallgrass prairie at less that 0.1 percent (Joyce and Morgan 1989). Occasional larger pieces persist because they were retained for prairie hay. However most prairie exists as small isolated remnants, tiny islands awash in an agricultural sea, scattered across the landscape in railroad rights-of-way, roadside ditches, old settler cemeteries, or on non-tillable rocky outcrops and out-of-the-way places (Smith 1992). Consequently, most of the former tallgrass prairie landscape no longer has the capability for expeditious adsorption and infiltration of water or soil formation. Nor can it provide habitat for host organisms, exhibit extensive floral displays, or support indigenous cultures.

Unfortunately, the confluence of land, climate, biota and Native American culture that created the tallgrass prairie is gone and will never occur again (Simpson 2008). In addition, the landscape in some extensively cultivated areas has been so modified that natural processes cannot overcome the degradation to allow the recovery of prairie. The scattered remnants that remain are under incessant external stress from disturbances such as herbicides, invasive species, siltation, woody encroachment and modifications of hydrology (Leach and Givnish 1996, Smith et al. 2010). Scientists were slow in realizing that the landscape had been so changed that tallgrass prairie could not recover without human assistance. Society was unaware that a valuable ecosystem was vanishing and assumed no responsibility for its retention. By now, it should be obvious that to retain any vestiges of the tallgrass prairie ecosystem, we must increase our efforts to preserve remnants and reconstruct new prairie areas.

Preservation of remnants must be a priority in any prairie ecosystem recovery plan. It is virtually impossible to recreate an ecosystem as complex and diverse as the pre-settlement prairie. Furthermore, there is abundant evidence that preserving ecosystems is far less expensive than reconstructing them (Cairns 1993). Each year that I am involved in prairie reconstruction, I become a more ardent preservationist. However, prairie preservation alone is not sufficient in meeting the needs of society. Tallgrass prairie should be readily available for people to walk upon to experience, appreciate, know and understand it. The number of prairie remnants is insufficient to accommodate this need and most are not readily accessible. As species diminish in small, isolated prairie

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preserves and the remnants slowly degrade, we may be merely serving as curators of "living museums." Therefore, to retain and better understand this historic ecosystem we must also restore degraded remnants and reconstruct new prairie areas that approximate the pre-settlement prairie.

LAYING THE FOUNDATION

The foundation for prairie restoration was laid by far-sighted individuals like Norman Fassett, Aldo Leopold, G. William Longnecker and Ted Sperry with a remarkable prairie reconstruction project at the University of Wisconsin (UW) Arboretum. Their plan became a reality over a five-year period (1936–1941) as Sperry directed Civilian Conservation Corp crews in planting seed and transplanting plugs from remnants in an area that would later be known as the Curtis Prairie. In the 1950s, John Curtis added monitoring and management research studies to the project. Part of this research was critical in demonstrating the importance of fire in restoration and management of prairies (Jordan 1982, Anderson 2009). Henry Greene continued prairie reconstruction at the Arboretum as he designed and single-handedly completed a second project from 1945–1953. With a thorough knowledge of the soil and moisture requirements for each species and a knack for knowing where to plant them, he established 200 species on a 20–ha sandy soil site using seeds, greenhouse-grown seedlings and transplants. It gained recognition as one of the most successful restored prairies anywhere with diversity comparable to good quality native remnants (Anderson 2009). When I visited the Green Prairie in 1972 and later in the 1980s, I felt that I was walking in a native prairie. It was indeed a treasure, a marvelous recreated prairie.

The UW Arboretum prairie reconstruction is often cited as the origin of environmental restoration. It can certainly be argued that much of restoration ecology's legacy traces back to that project. Fortunately, prairie proved to be a better medium for reconstruction than forest. Prairie vegetation is more amenable to horticultural and agronomic techniques due to its reproducibility on a small scale, and being composed of long-lived herbaceous species that mature rapidly (Jordan and Lubick 2011). Jordan and Lubick (2011) bemoan that the remarkable beginning at the UW Arboretum was followed by an extended period of time in which this type of restoration was generally ignored and faded from sight. Fortunately, during this hiatus, other prairie reconstruction projects were initiated in the Midwest that would emerge as exemplars of prairie restoration.

EXEMPLARY LEGACY PROJECTS

Prairie reconstruction initiatives by Ray Schulenberg (Morton Arboretum, Lisle, IL), Peter Schramm (Knox College, Galesburg, IL), Bob Betz (Fermilab, Batavia, IL) and Paul Christiansen (Cornell College, Mt. Vernon, IA) gained prominence as they built upon information from the UW Arboretum project and tried new techniques and procedures. The success of these projects stimulated much interest in prairies and prairie reconstruction in the late 1960s and 1970s. All were very capable, knowledgeable, highly motivated individuals. Their high visibility enabled them to garner support for their projects and attract converts to prairie restoration. As they interacted with one another and developed awareness of the importance of their projects, they began to define themselves as restorationists. Their work and the questions it raised were key to the emergence of restoration ecology as a new science. The heady "atmosphere" of this era was a causative factor for my infection with the prairie restoration "bug" in the early 1970s (Betz, 1986, Dredze 1998, Jordan and Lubick 2011).

WIDESPREAD PUBLIC INTEREST

With this base of support, Peter Schramm organized and hosted the first Midwest Prairie Conference at Knox College in 1968. This ongoing conference, later renamed the North American Prairie Conference in 1978, has biennially provided opportunities for prairie enthusiasts to gather and exchange knowledge and techniques of prairie restoration. The conference's longevity and strong participant support over the past forty-four years is evidence of the ongoing interest in prairies and prairie restoration.

Interest in and support of prairie reconstruction involves individuals and organizations of many kinds including conservation organizations, corporations, agencies, educational institutions, students, teachers, researchers, public agency personnel and employees of private companies. Businesses that market prairie related products have multiplied and now include native seed growers, nurseries, landscaping, equipment manufacturing and chemical companies. Iowa native seed growers have increased from none in the 1960s to eight or more currently. Prairie plantings have become more common in urban areas as homeowners and corporations increasingly use native prairie plants to landscape their property.

Over time, governmental agencies, conservation organizations and local groups have become more involved with prairies. Private prairie groups such as Nature Manitoba, the Iowa Prairie Network, The Prairie Enthusiasts, Grand Prairie Friends, Wild Ones, and Save the Prairie Society formed to promote prairies, save prairie remnants and contribute to prairie restoration. State and national private non-profit organizations such as The Nature Conservancy, Nature Conservancy Canada, the Audubon Society, Ducks Unlimited (Canada and United States), Pheasants Forever, Alberta Native Plant Council, Native Plant Society of Saskatchewan, Tallgrass Ontario, the Iowa Natural Heritage Foundation and the Missouri Prairie Foundation added prairie restoration and management to their preservation and protection activities. Departments of transportation in several states began to use prairie plants in rights-of-way as a part of their roadside vegetation management programs. Most Iowa counties adopted an integrated roadside vegetation management program based on prairie plantings. Federal agencies such as the U. S. Federal Highway Administration, the USDA-Natural Resources Conservation Service and Environment Canada - Canadian Wildlife Service**,** have financed prairie-related programs. The Conservation Reserve Program (CRP) alone has funded the planting of thousands of acres of prairie species on highly erodible soils of marginal farmland (Jones-Farrand et al. 2007). Cooperative ventures between private conservation groups and agencies have also increased. For example, Nature Manitoba initiated the Tallgrass Prairie Preserve Project that is now jointly supported by Nature Conservancy Canada, the Province of Manitoba and local municipalities. In addition, the Prairie Conservation Action Plan originated by World Wildlife Fund—Wild West Program attributes much of its success in the three prairie provinces of Canada to the involvement of nearly 100 stakeholders (Nernberg and Ingstrup 2005).

ADVANCES BY PRACTITIONERS

In the past forty years, practitioners of prairie restoration have made significant advances in reconstruction procedures and techniques. The following are some of the changes: seeding rates of prairie grasses have been reduced five times or more from a high of 32–45 kg/ha; seed mixtures are now designed with specific amounts of seeds per unit area (*e.g.* x number of seeds/square foot or /square meter) for each species; greater availability of appropriate plant materials allows reconstructionists to include a more complete mixture of species (grasses, forbs, sedges and prairie shrubs) in their plantings; the height of establishment mowing has been reduced and the frequency increased; extensive tilling for site preparation has been replaced with glyphosate application; and more attention is given to drilling depth. Although some reconstruction projects are being fall-seeded, most are still seeded in the spring. The use of western cultivars and nonlocal ecotypes has been much reduced. High quality source-identified seed is more readily available at a reasonable price and is increasingly used in plantings. Unfortunately, uninformed novices can still purchase prairie seed mixtures containing species not endemic to a particular area (Schramm 1970, 1992, Packard and Mutel 1997, Smith et al. 2010).

Many of the advances in prairie restoration procedures and techniques have been the result of trial-and-error or fortuitous experiences involving little use of scientific methodology. Information regarding these procedures and techniques has been anecdotal and disseminated via word-of-mouth by practitioners. Much of the anecdotal, experiential information is valuable, but not always repeatable. This has led to the general opinion that standardized methods cannot be formulated for prairie reconstruction and remnant restoration because of variations in annual and seasonal weather, past history of the site, soils and physiographic differences as well as the impact of adjacent land. Consequently, there is some tension between prairie restoration practitioners and restoration ecologists regarding methodology.

Hobbs and Norton (1996) in discussing a conceptual framework for restoration note, "What is clear is that restoration ecology has largely progressed on an ad hoc, site- and situation-specific basis, with little development of general theory or principles that would allow the transfer of methodologies from one situation to another." I interpret their comments as an observation rather than a criticism. I agree with Anderson (2009) that one of the driving forces for the non-scientific approach taken by some restorationists was a sense of urgency; there was not sufficient time to wait for results of rigorous scientific studies to provide information about how restorations should be done. We all share an urgency stemming from concern for the rapid degradation of the natural landscape. Cabin (2007) comments on that perspective, "Thus, if one's goal is to accomplish ecological restoration as quickly and efficiently as possible, a trial-and-error/intelligent tinkering-type approach might often be better than using more rigorous, data intensive scientific methodology."

COLLABORATION OF PRACTITIONERS AND SCIENTISTS

In my opinion, scientists and practitioners involved in prairie restoration need to work toward a common goal of insuring success in future restorations. The time is now right to do so. The work of practitioners carried us to the bridge into the new century, we now need to proceed on both fronts to take prairie restoration to the new century. This will involve testing techniques of practitioners as they continue to reconstruct and restore prairies to formulate principles of prairie restoration that can then be successfully applied more broadly. Hopefully, this cooperation will be fruitful and contribute to containing further degradation and restore/reconstruct sufficient prairie to maintain a viable landscape.

Clewell and Reiger (1996) suggested that scientists interested in restoration ecology have a responsibility to define the kind of research needed, prior to seeking the support of practitioners and the public for their ideas and approaches. Development of tested general restoration and reconstruction principles would help prevent the perpetuation of mythical planting guidelines, untenable recommendations by agencies regarding seeding time and management, and the uninformed use of cheap, non-native "prairie in a can" seed mixes that create single-season flowering splashes and misrepresent prairie to the public.

Significant strides have been made in prairie preservation and restoration, but much remains to be done. Most early prairie reconstructions focused on prairie plants with little or no consideration of the animals. Anderson (2009) suggested that a more comprehensive community view of prairie restoration is emerging that includes restoration and research of invertebrates, birds, small mammals, large herbivores, burrowing animals, fungi, bacteria and mycorrhizal fungi. Prairie reconstructions and remnant restorations provide a means to test this community approach and enable practitioners and ecologists to work together to develop and test principles and procedures. Knowledge gained could prove to be invaluable in the future as we try to restore ecosystems degraded by increasing numbers of humans and technological capability to extract resources.

BRIDGING TO THE FUTURE

The best hope for retaining the historic tallgrass prairie ecosystem is to restore degraded remnants and reconstruct new areas of high quality prairie with appropriate species. Undoubtedly, remnant prairie restoration and prairie reconstruction will continue to be required in a landscape that is being increasingly modified by humans. These efforts should include some landscape-scale restorations of thousands of acres in extent. Restorationists will need to provide the impetus, expertise, and plant materials to recreate and maintain this historic ecosystem in an increasingly altered landscape.

Though we cannot recreate the original prairie, these restorations and reconstructions provide an opportunity to actively assist in the recovery of a degraded, damaged or destroyed ecosystem. In the process, we will learn much about this vanishing ecosystem. However, we must avoid creating the impression that reconstructed prairies can replace prairie preserves. Planners or developers should not be encouraged to consider mitigating a project by replacing a prairie remnant with a reconstructed prairie. Like Schulenburg, we need to be constantly reminded that we cannot fully recreate the diverse collections of plants, animals and microbes that persist in prairie remnants (Dredze 1998). Schramm's (1992) goal of reconstructing a facsimile of original prairie is reasonable as these reconstructions can assist in soil building, increased water interception and infiltration, habitat improvement and increased biodiversity.

The first half of the twenty-first century will be a critical time in terms of survival of natural areas. During the last half of the twentieth century, the human population more than doubled from 2.5 billion in 1950 to 6.1 billion in 2000. It is projected to rise more than three billion by 2050 and then level off (United Nations 2004), although recent projections indicate a faster growth rate (Weiss 2013). Undoubtedly, extensive alteration of ecosystems will continue as human numbers and resource consumption increase. Consequently, the twenty-first century will likely be known as the restoration century. Tallgrass prairie restoration, both reconstruction and remnant restoration, will be a major part of restoration efforts. The tallgrass prairie is a part of our cultural and biological heritage and provides invaluable ecological services as a functioning ecosystem.

Projects initiated late in the twentieth century are providing a bridge into the twenty-first century. There appears to be increasing recognition of the importance of maintaining prairie remnants, getting more prairie on the land, and taking advantage of the adaptive capabilities of native prairie vegetation (Anderson 2009). The following examples of bridging to the future illustrate the potential for prairie restoration to carry the banner for the "restoration century."

Perennial Polyculture

Wes Jackson, co-founder of the Land Institute, is a great proponent of the long view. He believes agriculture should look to natural ecosystems where mixtures of perennial plants are the rule. A primary focus of the Land Institute for more than three decades has been to utilize perennial crop species to replace or supplement annual crops (Jackson 2008). This new paradigm for agriculture develops sustainable farming as a functional mimic of the prairie ecosystem utilizing a perennial polyculture system involving diverse plantings of perennial grasses, legumes, and composites (Piper 1996, Jackson and Jackson 1999). This revolutionary approach to agriculture permits reduction or elimination of annual tillage of soil facilitating the renewal of topsoil and soil fertility and creating a system largely independent of fossil fuel inputs.

Landscape Scale Prairie Networks

The scale of prairie reconstruction has increased considerably since its inception almost 80 years ago. The size of the early prairie reconstructions was measured in tens of acres. Betz and his group increased the magnitude of reconstruction by a factor of 10 in 1974 as they began a proposed 283-ha planting at Fermi Lab (Betz 1986). Currently, the Fermi Lab Prairie consists of 486 ha. Two decades later much larger reconstructions appeared on the scene. Most prominent were the 3,480-ha prairie and savanna reconstruction and remnant restoration project that began in 1991 at Neal Smith (originally Walnut Creek) National Wildlife Refuge near Des Moines, Iowa (Drobney 1994) , and the multi-community reconstruction and remnant restoration project initiated in 1996 on 7,689 ha at Midewin National Tallgrass Prairie near Joliet, Illinois (Glass and Ulaszek 2003).

Widespread fragmentation of remaining prairie is a primary concern in prairie restoration. As mentioned previously, in many states and provinces much less than 1% of native prairie remains (Sampson and Knopf 1994). Even in areas with more remnant prairie, much of it exists as small, scattered pieces. A challenge for the future is to assemble provincial, state or interstate networks of interconnected pieces. To some degree, parts of such networks are already being constructed. For instance, many governmental agencies (federal, state and county) are committed to programs preserving quality prairie, restoring degraded prairie remnants and reconstructing new prairies (Anderson 2009). If native remnants can be managed or restored to a high degree of biodiversity, they can form a core network to be filled in or surrounded with reconstructed prairies to enlarge the prairie network and provide buffers to the adjacent agricultural lands. This network could be comprised of a mix of county, state and privately owned preserves or conservation plantings of native prairie, federal conservation program plantings, and roadsides with prairie vegetation established as a part of Integrated Roadside Vegetation Management (IRVM) programs. Iowa, probably the most road-intensive state or province in North America, has more than 364,218 ha of roadsides (approximately 2.5% of the state's total acreage). Stimulated by the success of IRVM programs, the Iowa DOT and 85% of the 99 counties are utilizing natives in roadside vegetation management (Smith 2004).

A cooperative network of prairie preserves, restorations and reconstructions was recently proposed. On 30 July 2012, the Minnesota Department of Natural Resources (MNDNR), U.S. Fish and Wildlife and ten conservation groups including The Nature Conservancy, Pheasants Forever, and the Audubon Society announced an ambitious 25-year plan to preserve and restore a portion of the vanishing prairie that once occupied two-thirds of Minnesota. State and federal agencies are combining resources with conservation groups to secure $3.5 billion. The funds will be used to acquire or protect more than 890,000 ha of a network of interconnected native and restored prairies, wetlands and grasslands along the west edge of the state (Marcotty 2012). Tom Landwehr, MNDNR commissioner, noted that only 1% of the state's 10,000 year-old native prairie persists in scattered fragments across the western half of the state. The small amount of prairie that remains is on land too steep or rocky to till. He indicated that the consortium acted because they were concerned that the relentless pressure of development, rising commodity prices and advances in agricultural technology might result in the disappearance of the remaining remnants (Marcotty 2012).

Adding Prairie to Watersheds

The frequency and intensity of flooding is increasing in much of central North America and other regions. For example, in the last two decades, Iowa has experienced two episodes of catastrophic flooding exceeding a flood probability of 1% (100-yr flood) in 1993 and 2008 (Achenbach 2008, Eash 2010). A major cause is that increased conversion of native ecosystems to row crops has changed the basic hydrology of Iowa. Historically, the landscape of the state was covered with prairie, forest, savanna and wetland ecosystems. The canopy cover and extensive root systems of the native vegetation formed a sponge-like vegetation and hydrological system capable of incorporating large quantities of rainfall into the land via interception and infiltration (Stone and Watson 2012). Rather than flowing across the land surface, rainwater percolated through the soil, became part of groundwater storage or re-entered the atmosphere through evapo-transpiration.

Prairie has great capacity for interception and infiltration of rainwater. Prairie vegetation intercepts and holds a considerable portion of the rainfall until it evaporates. The extensive interception of rainwater is a result of the surface area of foliage being 5–20 times greater than the soil surface beneath it (Weaver 1954). A hectare of big bluestem can intercept approximately 131 tons of rainwater during a one-inch rainfall event (Clark 1937). In addition, the extensive root systems of prairie vegetation increase the soil's ability to take up and hold water via infiltration. The roots create air pockets and channels in the soil and provide large quantities of organic matter (Dierks 2011). Organic matter has the ability to hold up to 90% of its weight in water and also cause clumping and aggregation formation that increases soil porosity (Funderberg 2001). Increased water infiltration and stable soil aggregate formation can reduce soil erosion. Calculations of the universal soil loss equation indicate that increasing soil organic matter from 1 to 3 percent can reduce erosion by 20 to 33 percent (Funderberg 2001). Miller and Jastrow (1986) found that water-stable, macro-aggregate levels of soil content were 39% in cropland under continuous corn at Fermilab. Levels in prairie reconstructed on that cropland approached those of a nearby prairie remnant (93% of soil content) by the fifth growing season after planting, and statistically equaled the prairie remnant by the eighth growing season.

Reconstructing prairie in strategically placed locations within watersheds to take advantage of the water retention capabilities of prairie vegetation could effectively slow and/or reduce outflow of water and reduce erosion. Initial results of a watershed study at Neal Smith NWR by a team from Iowa State University indicate that prairie vegetation is effective in capturing both soil and water. They observed that prairie occupying 10% of the watershed would reduce sediment loss by 95% compared to no-till practices (Helmers et al. 2008).

Prairies could be reconstructed within watersheds on highly erodible marginal cropland or interspersed with annual row crops to take advantage of the water holding and soil erosion reduction capabilities of prairie vegetation. If prairie reconstructions in a watershed reduce the height of a flood crest in a downstream urban area by only a few inches, it would save millions of dollars in flood damage and flood recovery.

Prairie Biomass Production

Native prairie species mixtures appear to have great promise as bio-energy feedstock. Perennial prairie plants are carbon negative and produce greater net energy gain than row crops because (1) after initial establishment they require little or no energy input such as cultivation, fertilizer, pesticides and irrigation, (2) they sequester excess CO_2, and (3) the entire above ground portion of the plant is used rather than just the seed. As prairie grows well on non-prime, nutrient-poor agricultural soils, it would not displace food crops from higher quality agricultural land (Long 2008, Tilman et al. 2006) . Although planting prairie for biomass production is not prairie restoration, it is a means to increase prairie on the landscape while providing for an alternative agriculture. Certainly the lessons learned from prairie restoration will be helpful in maximizing biomass production.

The strong interest in using row crops for biofuels along with significant increases in corn production for ethanol has raised environmental concerns regarding the effect of the demand on marginal agricultural land. Converting natural lands or reconverting Conservation Reserve Program (CRP) lands to cropland would unquestionably increase runoff, soil erosion, siltation, and pollution from fertilizers and pesticides, reduce wildlife habitat and threaten biodiversity (Wu and Weber 2012). A sustainable economic crop is needed as a viable alternative to counter the conversion of marginal farmland to row crops. Mixtures of prairie species are such an alternative as they are more diverse than row crops and require low energy input for biomass production (Tilman et al. 2006).

Additional study of the energy conversion benefits and combustion products of plants is needed to fully assess the potential of prairie vegetation for biofuel production. Applied research on its capability as an alternative fuel is underway, but in an early stage. With regards to burning prairie plant material for generating electricity, concerns regarding harvesting, processing, transporting, and storing are being examined. In addition, there is currently no economically feasible method for large scale production of ethanol from the cellulose of prairie plants.

Tilman et al. (2006) demonstrated that mixtures of perennial prairie plants produce significantly greater biomass than monocultures of row crops or native species. The Prairie Power Project of the Tallgrass Prairie Center is designed to verify their work on an applied agricultural scale, and to determine an optimal mixture of prairie plants for maximum production of biomass on non-prime agriculture land while maintaining quality wildlife habitat. The first three years of the six-year project have been completed. The research design compares four different mixtures of prairie species on three soil types. The four treatments were (1) monoculture of switchgrass, (2) five warm season prairie grasses (including switchgrass), (3) sixteen species of warm and cool season grasses (including the five grasses of treatment 2), forbs (including legumes), and sedges, and (4) thirty-two species (including the 16 species of treatment 3) of warm and cool season grasses, forbs (including legumes), and sedges (D. Smith, Tallgrass Prairie Center, unpublished data). This project also will assess carbon sequestration over the six-year period, examine the value of the biomass plantings for wildlife habitat and determine the optimal frequency for harvesting biomass.

Validating mixtures of prairie species as sustainable biomass feedstock for electrical generation would provide a viable alternative to row crops on marginal agriculture land. Exercising this alternative would increase the presence of prairie vegetation in the agricultural landscape and address environmental concerns of our society regarding loss of wildlife habitat, stormwater runoff, erosion, and increased atmospheric carbon dioxide. Not only does prairie biomass production have promise as a carbon negative alternative energy, it could also become a sustainable alternative agriculture in the Midwest. Proving the viability of an alternative energy form like prairie biomass could benefit utility companies and companies generating heat and electricity. Iowa and most, if not all, of the Midwest would benefit from electrical production by prairie biomass. The development of prairie biomass production as a sustainable alternative agriculture would provide another cash crop with the potential for creating a number of agriculturally related jobs. For instance, it would provide increased agricultural income from marginal farmland as well as related employment in custom baling, transporting of biomass to the use-site, and cubing the biomass to prepare for burning. If, as anticipated, prairie biomass proves to be a viable component of utilities' portfolios for electrical generation, the utility companies would gain options and flexibility in electrical production and ability to increase staff. Society would benefit from lower energy costs, more sustainable energy, reduced atmospheric carbon, reduction of water runoff and soil erosion, and increased wildlife habitat.

SUMMARY

One could argue that we need to restore prairie remnants and reconstruct prairies because we perceive that the tallgrass prairie ecosystem and the organisms that inhabit it are unique and beautiful and we realize they will disappear if we do not act (Simpson 2008). I support and applaud restoring portions of the prairie landscape to the way it was before Euro-American settlement, fully aware that we can never achieve a complete replicate of the historic landscape, and knowing that our responsibility is perpetual (Jordan 2003). However, as important as these reconstructions and remnant restorations might be, the resulting living museums will be insufficient to meet the need for prairie in the twenty-first century (e.g., "restoration' century).

Using prairie to address current environmental concerns allows us to incorporate more prairie into the landscape. While not fully replicating prairie, the more utilitarian prairie plantings will provide elements of that ecosystem. Also, the benefits they provide may improve society's perception of their value and increase its support for maintaining and restoring a more natural world to counteract an ever increasing human population and the potential for environmental degradation.

When all is said and done, regardless of the difficult challenges associated with restoring this historic ecosystem or elements of it, the ecological, conservation, economic, educational and cultural rewards are well worth the effort. Prairie restoration, in the future, could be a major contributor to mending the rents in the fabric of our natural systems and, perhaps, contribute to global natural resource conservation efforts.

LITERATURE CITED

Achenbach, J. 2008. Iowa flooding could be an act of man, experts say. Washington Post, 19 June, Washington, D.C., USA.

Anderson, R. 2009. History and progress of ecological restoration in tallgrass prairie, Chapter 13 *in* C. Taylor, J. Taft and C. Warwick, editors. Canaries in the Catbird Seat. INHS Publication 30, Illinois Natural History Survey, Champaign, USA.

Betz, R. 1986. One decade of research in prairie restoration at the Fermi National Accelerator Laboratory (Fermilab) Batavia, Illinois. Pages 179–185 *in* G. Clambey and R. Pemble, editors. Proceedings of the Ninth North American Prairie Conference. Tri-College University Center for Environmental Studies, North Dakota State University, Fargo, USA.

Cabin, R. J. 2007. Science-driven restoration: a square grid in a round earth. Restoration Ecology 15:1–7.

Cairns, J. 1993. Is restoration ecology practical? Restoration Ecology 1:3–7.

Clark, O.R. 1937. Interception of rainfall by herbaceous vegetation. Science 86:591–592.

Clewell, A. F., and J. P. Reiger. 1996. What practitioners need from restoration ecologists. Restoration Ecology 5:350–354.

Dierks, S. 2011. Quantifying prairie and forest impacts on soil water holding capacity and infiltration. Stormwater. <http://www.stormh2o.com/SW/Editorial/Quantifying_Prairie_and_Forest_Impacts_on_Soil_Wat_15583.aspx>. Accessed 6 August 2013.

Dredze, B. 1998. Ray Schulenberg: prairie doc. Chicago Wilderness Magazine Summer. Chicago Wilderness Alliance, Illinois, USA.

Drobney, P. M. 1994. Iowa prairie rebirth: rediscovering natural heritage at Walnut Creek National Wildlife Refuge. Restoration and Management Notes 12:16–22.

Eash, D. 2010. Estimating flood frequency. Pages 71–70 *in* C. Mutel, editor. A watershed year: anatomoy of the Iowa floods of 2008. University of Iowa Press, Iowa City, USA.

Funderberg, E. 2001. What does organic matter do in soil. Ag News and Views. The Samuel Roberts Nobel Foundation. Ardmore, Oklahoma, USA. <www.noble org/ag/soils/organicmatter/>. Accessed 19 November 2012

Glass, W. and E. Ulaszek. 2003. Prairie restoration at Midewin National Tallgrass Prairie. Pages 75–77 *in* S. Fore, editor. Proceedings of the Eighteenth North American Prairie Conference. Truman State University, Kirksville, Missouri, USA.

Helmers, M. J., T. M. Isenhart, M. Dosskey, S. M. Dabney, and J. S. Strock. 2008. Buffers and vegetative filter strips. Pages 43–58 *in* UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop, American Society of Agricultural and Biological Engineers. St. Joseph, Michigan. <http://www.treesearch.fs.fed.us/pubs/30386>. Accessed 18 July 2012.

Hobbs, R. and D. Norton. 1996. Towards a conceptual framework for restoration ecology. Restoration Ecology 3:1–3.

Jackson, W. 2008. The necessity and possibility of an agriculture where nature is the measure. Conservation Biology 22:1372–1381.

Jackson, W. and L. L. Jackson. 1999. Developing high seed yielding perennial polycultures as a mimic of mid-grass prairie. In R. LeFroy, editor. Agriculture as a mimic of natural ecosystems. Kluwer Academic Publishers, Netherlands.

Jones-Farrand, D. T., D. Johnson, L. Burger and M. Ryan. 2007. Grassland establishment for wildlife conservation. Chapter 2 in fish and wildlife response to Farm Bill conservation practices. Technical Review 07–1. The Wildlife Society, Bethesda, Maryland, USA.

Jordan, W. 1982. Look back: a pioneering restoration project turns fifty. Restoration and Management Notes 1:4–10. University of Wisconsin-Madison Arboretum, Madison, USA.

Jordan, W. 2003. The sunflower forest: ecological restoration and the new communication with nature. University of California Press, Berkley, USA.

Jordan, W. and G. Lubick. 2011. Making nature whole: a history of ecological restoration. Island Press, Washington, D.C., USA.

Joyce, J and J. Morgan. 1989. Manitoba's tall-grass prairie conservation project. Pages 71–74 *in* T. Bragg and J. Stubbendieck, editors. Proceedings of the Eleventh North American Prairie Conference. University of Nebraska-Lincoln, Lincoln, USA.

Leach, M. and T. Givnish. 1996. Ecological determinants of species loss in remnant prairies. Science 273:1555–1558.

Long, S. P. 2008. Opportunities for enhancing the productivity of biofeedstocks and minimizing imputs: theory and practice. Pages 109–118 *in* A. Eaglesham, S. Slack and R. Hardy, editiors. Reshaping American agriculture to meet its biofuel and polymer roles. National Agricultural Biotechnology Council, Boyce Thompson Institute, Ithaca, NY, USA.

Marcotty, J. 2012. $3.5 billion plan will protect Minnesota prairie. Star Tribune, 31 July, Minneapolis, Minnesota, USA.

Miller, R. M. and J. Jastrow. 1986. Influence of soil structure supports agricultural role for prairies, prairie restoration. Restoration and Management Notes 4:2.

Nernberg, D. and D. Ingstrup. 2005. Prairie conservation in Canada: the prairie conservation action plan experience. USDA Forest Service, Gen. Tech. Rep. PsW-GTR-1991.

Packard, S. and C. F. Mutel. 1997. The tallgrass restoration handbook for prairies, savannas and woodlands. Island Press, Washington, D.C., USA.

Piper, J. 1996. Natural systems agricultural research. In M. Hackett and S. H. Sohmer, editors. Proceedings of The Ecology of Our Landscape: the Botany of Where We Live symposium, "Exploring the Interfaces Between Plants, People, and the Environment." The Botanical Research Institute, Fort Worth, Texas, USA.

Samson, F. and F. Knopf. 1994. Prairie conservation in North America. Bioscience 44:6:418–421.

Schramm, P. 1970. A practical restoration method for tallgrass prairie. Pages 63–65 *in* P. Schramm, editor. Proceedings of a Symposium on Prairie and Prairie Restoration. Knox College, Galesburg, Illinois, USA.

Schramm, P. 1992. Prairie restoration: a twenty-five year perspective on establishment and management. Pages 195–199 *in* D. D. Smith and C. A. Jacobs, editors. Proceedings of the Twelfth North American Prairie Conference. University of Northern Iowa, Cedar Falls, USA.

Simpson, T. 2008. Recovering nature. Ecological Restoration 26:2:115–119.

Smith, D. D. 1992. Tallgrass prairie settlement: prelude to the demise of the tallgrass ecosystem. Pages 169–177 *in* D. D. Smith and C. A. Jacobs, editors. Proceedings of the Twelth North American Prairie Conference. University of Northern Iowa, Cedar Falls, USA.

Smith, D. D. 1998. Iowa prairie: original extant and loss, preservation and recovery attempts. Journal Iowa Academy of Science 105:94–108

Smith, D. D. 2004. Native Roadside Vegetation: The Iowa Model. Pages 149–156 *in* W. Keammerer and J. Todd, editors. Proceedings High Altitude Revegetation Workshop No. 16. Ft. Collins, CO, USA.

Smith, D. D. 2012. Restoring a national treasure: Investment for the future. Pages 232–237 *in* D. Williams, B. Butler and D. Smith, editors. Proceedings of the Twenty-second North American Prairie Conference. University of Northern Iowa, Cedar Falls, USA.

Smith, D., D. Williams, G. Houseal and K. Henderson. 2010. The Tallgrass Prairie Center guide to prairie restoration in the Upper Midwest. University of Iowa Press, Iowa City, USA.

Stone, L. and B. Watson. 2012. Take watershed approach to reducing flood risks. Cedar Rapids Gazette, 22 January, Cedar Rapids, Iowa, USA.

Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314:1598–1600.

United Nations Population Division. 2004. World population to 2300. United Nations Publication. New York, New York, USA.

Weaver, J. 1954. North American Prairie. Johnsen Publishing Co., Lincoln, Nebraska, USA.

Weiss, K. 2013. Global population growing faster than expected. Los Angeles Times, 10 July, Los Angeles, California, USA.

Wu, J. and B. Weber. 2012. Implications of a reduced conservation reserve program. The conservation crossroads of agriculture. Council on Food, Agriculture and Resource Economics. Washington, D.C., USA.

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