National Fish, Wildlife and Plants Climate Adaptation Strategy

Grassland Ecosystems

Photo: NPS

Disclaimer

The information in this Grassland Ecosystems Background Paper was developed by the Grassland, Shrubland, Desert, and Tundra Technical Team of the National Fish, Wildlife and Plants Climate Adaptation Strategy (hereafter *Strategy*), and was used as source material for the full *Strategy* document. It was informally reviewed by a group of experts selected by the Team. While not an official report, this Grassland Ecosystems Background Paper is available as an additional resource that provides more detailed information regarding climate change impacts, adaptation strategies, and actions for U.S. grassland ecosystems and the species they support. These papers have been edited by the Management Team for length, style, and content, and the Management Team accepts responsibility for any omissions or errors.

Table of Contents

Introduction

Over the past decade, there have been increasing calls for action by government and non-governmental entities to better understand and address the impacts of climate change on natural resources and the communities that depend on them. These calls helped lay the foundation for development of the National Fish, Wildlife and Plants Climate Adaptation Strategy (hereafter *Strategy*).

In 2009, Congress asked the Council on Environmental Quality (CEQ) and the Department of the Interior (DOI) to develop a national, government-wide climate adaptation strategy for fish, wildlife, plants, and related ecological processes. This request was included in the Fiscal Year 2010 Department of the Interior, Environment and Related Agencies Appropriations Act Conference Report. The U.S. Fish and Wildlife Service (FWS) and CEQ then invited the National Oceanic and Atmospheric Administration (NOAA) and state wildlife agencies, with the New York State Division of Fish, Wildlife, and Marine Resources as their lead representative, to co-lead the development of the *Strategy*.

A Steering Committee was established to lead this effort and it includes representatives from 16 federal agencies with management authorities for fish, wildlife, plants, or habitat as well as representatives from five state fish and wildlife agencies and two tribal commissions. The Steering Committee charged a small Management Team including representatives of the FWS, NOAA, Association of Fish and Wildlife Agencies (representing the states) and Great Lakes Indian Fish and Wildlife Commission to oversee the day-to-day development of the *Strategy*.

In March of 2011, the Management Team invited more than 90 natural resource professionals (both researchers and managers) from federal, state, and tribal agencies to form five Technical Teams centered around a major ecosystem type. These teams, which were co-chaired by federal, state, and I most instances, tribal representatives, worked over the next eight months to provide technical information on climate change impacts and to collectively develop the strategies and actions for adapting to climate change. The five ecosystem technical teams are: Inland Waters, Coastal, Marine, Forests, and a fifth team comprising four ecosystems: Grasslands, Shrublands, Deserts, and Arctic Tundra.

This Background Paper focuses on grassland systems, including information about these systems, existing stressors, impacts from climate change, and several case studies highlighting particular impacts or adaptation efforts. Information from this Background Paper informed discussion of grassland impacts and adaptation measures in the full *Strategy*, and was used to develop the Goals, Strategies, and Actions presented in that document and repeated here. This Background Paper is intended to provide additional background information and technical details relevant to grassland systems, and to summarize those approaches most relevant to managers of these areas and the species they support. Some of the material presented herein overlaps with that for other ecosystem types, particularly regarding cross-cutting issues.

The ultimate goal of the *Strategy* is to inspire and enable natural resource professionals, legislators, and other decision makers to take action to adapt to a changing climate. Those actions are vital to preserving the nation's ecosystems and natural resources—as well as the human uses and values that the natural world provides. The *Strategy* explains the challenges ahead and offers a guide to sensible actions that can be taken now, in spite of uncertainties over the precise impacts of climate change on living resources. It further provides guidance on longer-term actions most likely to promote natural resource adaptation to climate change. The *Strategy* also describes mechanisms to foster collaboration among all levels of government, conservation organizations, and private landowners.

Federal, state, and tribal governments and conservation partners are encouraged to look for areas of overlap between this Background Paper, the *Strategy* itself, and other planning and implementation efforts. These groups are also encouraged to identify new efforts that are being planned by their respective agencies or organizations and to work collaboratively to reduce the impacts of climate change on grassland fish, wildlife, and plants.

Grassland Ecosystem Description

Grassland ecosystems are dominated by grasses and forbs (broad-leafed herbaceous plants) (Knopf 1995). They are disturbance-dependent ecosystems characterized by a climate that shows distinct wet and dry seasonal patterns, where summers are hot and winters are usually extremely cold (Smith 1973). Grasslands transition toward desert or shrublands in the drier regions of the West and Southwest, and integrate into temperate forest along the coast in the Mid-Atlantic region. A majority of the native grasslands in the northeast were confined to the coast, and history suggests these were not a product of agricultural development (Vickery and Dunwiddie 1997).

At the time of European settlement, interior grasslands were the most expansive ecosystem in North America (Anderson 1982). Historically, the northern temperate grasslands of the United States and Canada comprised almost 600,000 square miles, and covered a region from south-central Saskatchewan to central Texas and from the Palouse region of eastern Washington and Oregon to Illinois (Shelford 1963). Today, grasslands (including grazing lands) cover only about 27 percent (614 million acres) of the conterminous United States, and occur mostly between the upper Midwest to the Rocky Mountains and from Canada to the central Gulf Coast (Nickerson et al 2011). In the northeast, more than 90 percent of the coastal grasslands have been lost (Noss et al. 1995) and now, grasslands in this region include hayfields, fallow fields, pastures, airports and military bases (Shriver et al. 2005). Today, the native grassland ecosystem is the most endangered system in the country, declining at a faster rate than any other ecosystem (Noss et al 1995).

Grassland ecosystems play an important role in the provisioning of our national economy, as these now form the heart of our nation’s agricultural landscape. Tallgrass and mid-grass prairie in particular have been used as major agricultural areas, while shortgrass prairie is widely used for livestock grazing. Agricultural practices have also created grassland, pasture, or hayfield habitat important to grassland-dependent plants and animals, covering 135 million acres in the continental United States (a significant portion in the East) (CCSP 2008). Many of those agricultural practices continue to maintain potential grassland habitat (Milchunas et al. 1988). A substantial majority of U.S. grasslands are privately held (more than 70 percent), with agriculture as the dominant use of these lands (Lukowski et al. 2006).

Another important function of grasslands is their ability to store carbon (Mosier et al. 1991, Heinz Center 2008). More than two-thirds of grassland carbon is stored below ground, and the amount stored can be affected by changes in fire frequency, grazing intensity, plant cover, and land use. Increases in the amount of carbon stored in grassland soils could help offset some emissions of carbon dioxide that drive global warming (CCSP 2008). Grassland ecosystems are also important for maintaining hydrological and nutrient cycling services both for terrestrial and aquatic ecosystems. When grasslands are converted to cropland, nutrients and sediment leaving the site increase, threatening degradation to adjacent down slope aquatic ecosystems (CCSP 2008).

There are three major classes of western grasslands, named for the height of the dominant species: tall-, shrot-, and mixed-grass prairies. Historically, tallgrass prairies covered over 240 million acres, although today, only a remnant of native prairie remains (Smith 1992). Tallgrass prairies make up the easternmost section of the North American grasslands. Currently, tallgrass prairie is the most endangered ecosystem in the United States, with approximately one percent remaining (what most Americans recognize as the “corn belt” is where tallgrass prairie was historically found) (Rickletts et al. 1999). The shortgrass prairie, composed of short grasses and forbs, is the westernmost and driest of the grasslands and is now used for cattle grazing. Mixed grass prairie composed of vegetation of medium height is found in the central part of the United States. It is estimated that between 20 to 30 percent of the mixed and shortgrass prairie has been lost (Gauthier et al. 2010). In the East, grasslands include both native grasses and non-native European hay grasses, and are maintained by both agricultural practices and other management activities (e.g., airports).

Shallow, ephemeral wetlands known as prairie potholes and playas dot the Great Plains, including areas of tall-, mixed- and shortgrass prairies. These wetlands play an important role in the functioning of grasslands in the Great Plains by serving as a water supply and a source of recharge to the Ogallala Aquifer (a shallow water table in the Great Plains) (Scanlon et al. 2007). They also create unique microclimates among the grasslands that support diverse wildlife and plant communities, including stopover habitat for many migratory species. The prairie pothole region is considered a “duck factory,” supporting more than 50 percent of the nation’s waterfowl (Johnson et al 2005).

While typical native grassland vegetation is very diverse and includes many grass species mixed with a wide variety of forbs, species richness and composition varies with topography and geographic location. Grass species include both tufted and rhizomatous species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and wildrye (*Elymus* spp.), among others. Forbs include ickseed (*Coreopsis* sp.), wild bergamot (*Monarda fistulosa*), prairie blue-eyed grass (*Sisyrinchium campestre*), and goldenrod (*Solidago* spp.), among others (Kline 1997).

Grasslands support a diversity of species, including many endemic and grassland-dependent species. Forty-eight percent of grassland-breeding bird species are of conservation concern, including four with endangered populations (NABCI 2011). Twelve bird species are considered to be endemic to grasslands (NPWRC 2006). As a guild, grassland birds are declining at a greater rate than any other group (Sauer et al. 2011). Insects are abundant in grasslands, and many species including several butterflies are endemic. Grazing mammals, including prairie dogs (*Cynomys* spp.), pronghorn antelope (*Antilocapra americana*), bison (*Bison bison*) and mule deer (*Odocoileus hemionus*), continue to maintain habitat in some regions. Several grassland species such as prairie dogs and grasshoppers are considered pests, but these animals also play an important role in controlling vegetation in check by grazing. Removal of prairie dog colonies has resulted in an increase in shrub density and decrease in biodiversity (Ceballos et al. 2010). Almost one-fifth of native grassland and shrubland animal species are considered to be at risk (Heinz Center 2008).

Existing Stressors

The greatest single existing stressor on grassland ecosystems in the United States is conversion, primarily for agricultural production, but also for development. Past and current economic incentives are important factors driving landowners to convert grasslands to croplands, because there are fewer incentives to maintain natural habitat. Additionally, when the soils and climate are conducive to cropping (or when irrigation potential exists), there is less market incentive for agricultural practices such as grazing and haying that leave grasslands intact and provide suitable habitat for a variety of species while conserving accumulated carbon in prairie soils. The diversity, habitat specificity, and area sensitivity of species make further losses in the extent of grasslands a major threat to species conservation (Davis 2004, NPWRC 2006, Hamre et al. 2010).

The spread of invasive species in grasslands through various mechanisms is an additional existing stressor. Invasive plants species are the greatest threat to grassland function by altering disturbance processes, such as fire regimes, diminishing the quality of feed for livestock and/or wildlife, and displacing native plants thereby changing the vegetation structure adversely impacting nesting birds and pollinators. For example, cheatgrass (*Bromus tectorum*), along with other exotic annual bromes, has dominated many acres of western rangelands and grasslands. Its distribution now includes all of the United States and much of Canada (Mosely et al 1999). Bio-fuel production and associated economic incentives may exacerbate the establishment and spread of invasive grasses, because the characteristics considered ideal for biofuel feedstock are those associated with invasive species (e.g. growing quickly and forming a monoculture). This may create the potential for conflicts between goals of energy independence and maintaining ecological integrity. Switch grass (*Panicum virgatum*), for example, may spread throughout grassland systems when planted outside of its normal range to supplement farm income (Tillman et al. 2006, Hellman et al. 2008). Also, the non-native perennial silvergrass (*Miscanthus* spp.) which grows quickly, reproduces by rhizomes, and provides a high yield, has the potential to become an invasive species that would be difficult to control (Raghu et al. 2006). Additionally, the development of green energy in the form of wind and solar could create additional pressure on this already endangered ecosystem.

Impacts of Climate Change on Grassland Systems

Grassland function is tied directly to temperature, precipitation, and soil moisture. Climate change will affect the goods and services that grassland areas provide, including carbon storage, nitrate filtration, water quality, crop yield, and forage for livestock and wildlife. Likely impacts are summarized in Table 1.

Table 1: Expected Climate Change Impacts on Grassland Ecosystems (USGCRP 2009 and IPCC AR4 2007)

Major Changes Associated With Increasing Levels of Greenhouse Gases (GHGs)	Major Impact on Grasslands
Increased atmospheric CO_2:	Changes in ratios of C3 to C4 plants, increased C:N ratios
Increased temperatures:	Spread of non-native pests, such as fire ants
Melting ice/snow	Reduced snowpack changes water flows
Changing precipitation patterns:	Invasion of non-native grasses and pests, species range shifting
Drying conditions/drought:	Decline in prairie pothole wetlands, loss of nesting habitat

The most direct impact to grasslands from climate change will be the increase in atmospheric carbon dioxide. Plants utilize sunlight, water, and carbon dioxide to create biomass through either C4 or C3 photosynthesis. While C3 grasses (e.g., cheatgrass) may stand to benefit from increased atmospheric carbon dioxide, C4 grasses are more efficient at using water under hot, dry conditions, and may respond favorably to increased water stress and lower soil moisture conditions. One carbon dioxide enrichment experiment on shortgrass prairie in Colorado showed a 20-fold increase in cover of a C3 shrub as C4 grass cover declined (Morgan et al. 2007). However, a more recent report shows an advantage for C4 over C3 grasses in a future CO_2-enriched, warmer environment for the Wyoming mixed-grass prairie (Morgan et al. 2007). The future distribution of these species will no doubt be influenced by the interaction of carbon dioxide, available moisture, and temperature. These interactions may produce grassland communities with altered species composition of both vegetation and in the animals that depend on that vegetation.

Increased carbon dioxide levels may also affect other variables in the grassland system. For example, forage quality may decline due to increases in carbon (C) to nitrogen (N) ratios of plant material, resulting in lower crude protein content (Milchunas et al. 2005). In general, herbivores must eat more vegetation to achieve the same nutrition when crude protein levels are low (Jones 1997) potentially resulting in overgrazing or the inability of the system to support populations of herbivores.

In recent decades, average temperatures have increased throughout the northern Great Plains, with cold days occurring less often and hot days more often (DeGaetano and Allen 2002). Precipitation has increased overall (Lettenmaier et al. 2008). Future changes projected for the Great Plains include:

1. Increasing average annual temperatures, with the largest increases in the more northern part of the Great Plains. Projections range from approximate 1.5 to 6 degrees Fahrenheit (°F) by mid-century and 2.5 to 13 °F by the end of the century (relative to the 1960-1979 baseline period);
2. More frequent extreme events such as heat waves, droughts, and heavy rains; and

3. Wetter conditions north of the Texas panhandle (USGCRP 2009).

The projected increases in precipitation are unlikely to be sufficient to offset overall decreases in soil moisture and water availability, due to increased temperature and water utilization by plants as well as aquifer depletion (USGCRP 2009).

Climate change is also expected to stress the sensitive prairie pothole habitat with increasing temperatures and changing rainfall patterns, which will alter rates of evaporation, recharge, and runoff in these lake systems (Matthews 2008). Recent modeling predicts that the prairie pothole region of the Great Plains will be a much less resilient ecosystem, with western areas (mostly in Canada) likely becoming dryer and eastern areas (mostly in the United States) having fewer functional wetlands. These changes are likely to reduce nesting habitat, and limit the system's ability to continue to support historic levels of waterfowl and other native wetland-dependent species (Johnson et al. 2010).

Agriculture is a fundamental component within the grassland system matrix, and is also sensitive to climate changes. In the case of crop production, research suggests that the response of crop plants to increasing CO_2 is varied and therefore, difficult to determine winners and losers (Taub 2010). The same stressors that affect grasslands affect agriculture, and can decrease crop yields (Ziska and George 2004). Increased precipitation is unlikely to be sufficient to offset decreasing soil moisture and water availability due to rising temperatures and aquifer depletion. Also, grasslands could face increased pressure for the conversion of more acres of native grasslands to agriculture to meet increasing demand for agricultural products, as per a scenario of decreasing yields in the future. However, increasing yields could also adversely affect grasslands as conversion may occur to offset decreasing yields in other regions.

LESSER PRAIRIE-CHICKEN IN A CHANGING CLIMATE

The lesser prairie-chicken (*Tympanuchus pallidicinctus*), which resides mainly in the grasslands of the southern Great Plains region, is a species in trouble. The conversion of native rangelands to cropland, decline in habitat quality due to herbicide use, petroleum and mineral extraction activities, and excessive grazing of rangelands by livestock have all contributed to a significant decline in population leading to its Candidate status under the federal ESA (NRCS 1999).

Photo: AFWA

Climate change is expected to make the bird's plight worse. Climate change models project that temperatures in the lesser prairie-chicken's range will climb by about 5 °F and that precipitation will decrease by more than one inch per year by 2060 (USGCRP 2009). Such changes would likely harm the lesser prairie-chicken's chances of survival.

The good news is that simple management steps can make a big difference. Under existing U.S. Department of Agriculture conservation programs, farmers and ranchers are paid to take land out of production to create wildlife habitat. In fact, a landscape-scale geospatial analysis has shown that restoring native prairie grasses and sagebrush on 10 percent of land enrolled in the Conservation Reserve Program, if properly targeted, could offset the projected population decline of lesser prairie-chicken from climate change (McLachlan et al. 2011).

Climate change is likely to combine with other existing stressors to further increase the vulnerability of grasslands to pests, invasive species, and loss of native species. Changes in temperature and precipitation affect the composition and diversity of native animals and plants through altering their breeding patterns, water and food supply, and habitat availability (Lettenmaier et al. 2008). For example, populations of some non-native pests better adapted to a warmer climate are projected to increase, such as red imported fire ants (*Solenopsis invicta*) as well as native insects that may be able to reproduce more quickly (Dukes and Mooney 1999). These types of cumulative and potentially synergistic interactions between climate change and existing stressors are potentially critical but not yet well understood.

Some grassland species, many of which already are stressed by habitat fragmentation, could experience significant range shifts as their suitable habitat moves in response to climate change. Grassland species with narrow ranges and greater habitat specificity will likely be at greater risk as habitat shifts. Range reductions and loss of abundance of some species may occur, and may be severe enough to threaten some species with extinction over all or significant portions of their ranges. One example is the regal fritillary butterfly (*Speyeria idalia*), already declining due to habitat loss, degradation, and fragmentation (Swengel and Swengel 1998). This species may be further threatened by climate impacts due to habitat and range contraction as well as the loss of a specific host plant and change in vegetation structure (Swengel and Swengel 1998). However, there are species that may benefit from range changes. Those species include those with wide distributions and those that are generalists (Julliad et al. 2003).

Climate Adaptation Strategies and Actions for Grassland Systems

The National Fish, Wildlife and Plants Climate Adaptation Strategy identifies seven primary Goals to help fish, wildlife, plants and ecosystems cope with the impacts of climate change. As discussed in the Introduction, these Goals were developed collectively by diverse teams of federal, state, and tribal technical experts, based on existing research and understanding regarding the needs of fish, wildlife and plants in the face of climate change. Each Goal identifies a set of initial Strategies and Actions that should be taken or initiated over the next five to ten years.

Actions listed here were derived from those Technical Team submissions determined to be most applicable to grassland systems. Numbers that correspond to the full *Strategy* document are designated by *Strategy* (S) and the Action number (e.g., 1.1.1).

GOAL 1: Conserve habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically-connected network of terrestrial, freshwater, coastal, and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife, and plants under changed conditions.

Actions:

— A: Identify and map high priority areas for conservation using information on species distributions (current and projected), habitat classification, land cover, and geophysical settings (including areas of rapid change and slow change). (**S 1.1.1**)

Strategy 1.2: Secure appropriate conservation status on areas identified in Action 1.1.1 to complete an ecologically-connected network of public and private conservation areas that will be resilient to climate change and support a broad range of species under changed conditions.

Actions:

— A: Work with partners at landscape scales to maximize use of existing conservation programs (e.g., easement, management, mitigation), particularly the conservation titles of the Farm Bill, the private lands programs focused on endangered species, and other federal and state private lands incentive programs to conserve private lands of high conservation value, to enhance habitat values and maintain working landscapes under climate change. (**S 1.2.4**)

— B: Identify and pursue opportunities to increase conservation of priority lands and waters by working with managers of existing public lands such as military installations or state lands managed for purposes other than conservation. (**S 1.2.5**)

Strategy 1.3: Restore habitat features where necessary and practicable to maintain ecosystem function and processes and resiliency to climate change.

Actions:

— A: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function. (**S 1.3.2**)

— B: Restore natural disturbance regimes as appropriate, including instituting human-assisted disturbance (e.g., prescribed fire) to augment natural processes and mimic natural patterns and recurrence for specific ecological systems. (**S 1.3.4**)

Strategy 1.4: Conserve, restore, and as appropriate and practicable, establish new ecological connections among conservation areas to facilitate fish, wildlife, and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— A: Assess and prioritize critical connectivity gaps and needs across current conservation areas, including areas likely to serve as refugia in a changing climate.(**S 1.4.2**)

— B: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches. (S 1.4.3)

— C: Assess existing barriers or structures that impede movement and dispersal within and among habitats to increase natural ecosystem resilience to climate change, and where necessary, consider the redesign or mitigation of these structures. (**S 1.4.5**)

— D: Provide landowners and stakeholder groups with incentives to maximize use of existing conservation programs, such as the conservation titles of the Farm Bill and landowner tools under the ESA, to protect private lands of high connectivity value under climate change. (**S 1.4.6**)

ROLLING EASEMENTS AND THE CONSERVATION RESERVE PROGRAM

The vast majority of the historical extent of tall-, short-, and mixed-grass prairies is now privately owned. Accordingly, the key to survival of grassland ecosystems is the degree to which agencies and organizations can convince landowners to restore the ecological integrity of their fields in this region and keep restored grasslands out of crop production for a prolonged period. The case for doing so is strengthened when landowners receive cost-share for the restoration activities and compensation for the foregone returns to crop production. In general, agriculturalproducers tend to find long-term contracts more appealing than permanent easements. Such long-term, yet temporary arrangements are essentially “rolling” easements, essential for adaptive management of a dynamic process.

The Conservation Reserve Program (CRP) is precisely such a program. Under the CRP, the U.S. Department of Agriculture establishes contracts with agricultural producers to retire highly erodible and other environmentally sensitive cropland and pasture. During the 10- to 15-year CRP contract period, farmland is converted to grass, trees, wildlife cover, or other conservation uses providing environmental benefits, including surface water quality improvement, wildlife habitat creation, carbon sequestration, preservation of soil productivity, protection of groundwater quality, and reduction of offsite wind erosion damages. The program was established by the Food Security Act of 1985, and amended and reauthorized by each subsequent Farm Bill. As a result, there are a variety of types of CRP. Participants in the original form of CRP (general signup CRP) receive annual rental payments during the contract period and half the cost of establishing conservation covers. Additional incentives are available for more targeted, recent forms of CRP, such as the Conservation Reserve Enhancement Program.

Although fields enrolled in CRP are unlikely to be returned to their pre-sod busting condition, the impact of CRP enrollment on wildlife and other ecosystem services is well established: The CRP was identified as a ‘Reason for Hope’ for grassland birds in the ‘State of the Birds’ report, which documented serious declines in grassland birds (NABCI 2011). Researchers found CRP to have a large impact on grassland bird populations, including two birds designated as species of continental importance by Partners in Flight (Sprague’s Pipit and Lesser and Greater Prairie Chicken). CRP is also associated with a net increase of about 2 million additional ducks per year (30 percent increase in duck production) since 1992 in North Dakota, South Dakota, and Northeastern Montana (Reynolds et. al. 2001). Further, an array of ecosystem services are found to be favorably impacted by restoration of grassland-wetland complexes by CRP in the Prairie Pothole and Playa Lakes regions.

Depending on how CRP actually manifests on a field, it can affect the landscape in a variety of ways relevant to climate change. For example, when used to re-establish native grassland species, CRP will disproportionately impact carbon sequestration (as a result of below ground biomass). When used to restore prairie potholes and playa lakes, CRP will make rainfall more available to vegetation and wildlife that depend on it. Increased retention times will moderate water stress in a climate changed environment. When used to establish buffers, filter strips, and other linear practices, connectivity is increased.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species, habitat, and land and water management plans, programs and practices to consider climate change and support adaptation.

Actions:

— A: Incorporate climate change considerations into existing and new management plans and practices using the best available science regarding projected climate changes and trends, vulnerability and risk assessments, and scenario planning. (**S 2.1.1**)

— B: Identify species and habitats particularly vulnerable to transition under climate change (e.g., cool season to warm season grasslands) and develop management strategies and approaches for adaptation. (**S 2.1.3**)

— C: Review and revise as necessary techniques to maintain or mimic natural disturbance regimes and to protect vulnerable habitats. (**S 2.1.5**)

— D: Develop cattle grazing practices that function in ecosystems with reduced rainfall and increasing temperature.

— E: Participate in USDA/NRCS state technical committees to encourage incorporation of climate change into species status assessments and within future federal Farm Bill programs.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— A: Use vulnerability and risk assessments to design and implement management actions at species to ecosystem scales. (**S 2.2.1**)

— B: Develop criteria and guidelines for the use of translocation, assisted migration, and captive breeding as climate adaptation strategies. (**S 2.2.2**)

— C: Where appropriate, actively manage populations (e.g., using harvest limits, seasons, translocation, captive breeding, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions. (**S 2.2.3**)

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

— A: Protect and maintain high quality native seed sources including identifying areas for seed collection across elevational and latitudinal ranges of target species. (**S 2.3.2**)

— B: Develop protocols for use of propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species. (**S 2.3.3**)

— C: Seed bank, develop, and deploy as appropriate plant materials for restoration that will be resilient in response to climate change. (**S 2.3.4**)

DEVELOPMENT OF GRASSLAND FOCAL AREAS IN NEW JERSEY

Photo: NJ DFW

Intensive agricultural practices and increased urban sprawl have resulted in the decline of grassland bird species throughout the Northeast. Private landowners are the key to protecting sustainable populations of grassland birds in this region. To increase efficiency and effectiveness, the NJ Habitat Incentive Team (NJ HIT) was created; members were from state, federal, and non-profit organizations. The mission of the NJ HIT is to effect wildlife habitat enhancement and creation on private and public lands by increasing enrollment in state and federal conservation programs through coordinated partnerships.

One of the first actions the Team undertook was the development of grassland focal areas in New Jersey. The model and resulting map allowed the Team to identify areas that could support sustainable grassland bird populations and target landowners within those focal areas giving them priority for funding opportunities.

To create the grassland focal areas, the Team selected the following GIS variables:

- Potential grassland patches in New Jersey's Landscape
- Project's grassland layer that are 500+ acres
- Grassland patches that were 1⁄4 mile to open space
- Grassland patches that were 1⁄2 mile to identified preserved farmland
- Grassland patches that are valued by a endangered or threatened species

The grassland patches are then "valued" based on those variables (see map). The higher the number, the greater number of variables that grassland patch contains indicating a more "valuable" patch for grassland birds. Staff could overlay the model on aerial photos to determine the number of variables each grassland area contained allowing them to better see the value of that particular field or farm.

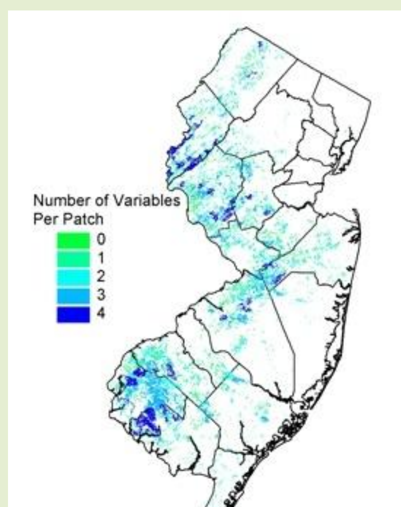

Figure: NJ DFW

In the face of climate change, this tool will become more important to identify and target areas critical for grassland bird assemblages. This model could also be used for a variety of species and habitats; with coordination, it would be possible to develop focal areas at a regional scale. New Jersey is working on including species modeling as a next step to allow staff to target management specific to species' needs. The Team is also planning on conducting focal area maps for emergent wetlands. As land managers grapple with management needs in a changing climate, this tool could be used to identify refugia, corridor development, and areas important in range limits.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change awareness and capacity of natural resource managers and enhance their professional capacity to design, implement, and evaluate fish, wildlife, and plant adaptation programs.

Actions:

— A: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers. (**S 3.1.2**)

— B: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability and risk assessments, scenario planning, decision support tools, and adaptive management). (**S 3.1.3**)

— C: Encourage use of interagency personnel agreements and interagency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop interagency communities of practice about climate change adaptation. (**S 3.1.5**)

— D: Increase scientific and management capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to species. (**S 3.1.7**)

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national, and international scales across state, federal, and tribal natural resource agencies and private conservation organizations.

Actions:

— A: Identify and address conflicting management objectives within and among federal, state, and tribal conservation agencies and private landowners, and seek to align policies and approaches wherever possible. (**S 3.2.2**)

— B: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge and principles into climate adaptation plans and decision-making. (**S 3.2.4**)

Strategy 3.3: Review existing federal, state and tribal legal, regulatory and policy frameworks that provide the jurisdictional framework for conservation of fish, wildlife, and plants to identify opportunities to improve, where appropriate, their utility to address climate change impacts.

Actions:

— A: Review existing legal, regulatory and policy frameworks that govern protection and restoration of habitats and ecosystem services and identify opportunities to improve, where appropriate, their utility to address climate change impacts. (**S 3.3.1**)

Strategy 3.4: Optimize use of existing fish, wildlife, and plant conservation funding sources to design, deliver, and evaluate climate adaptation programs.

Actions:

- A: Prioritize funding for land and water protection programs that incorporate climate change considerations. (**S 3.4.1**)
- B: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards. (**S 3.4.2**)
- C: Collaborate with agricultural interests and businesses to identify potential impacts of climate change on crop production and identify conservation strategies that will maintain or improve ecosystem services through programs within the Conservation Title of the Farm Bill and other vehicles. (**S 3.4.4**)

GOAL 4: Support adaptive management in a changing climate through integrated observation and monitoring and use of decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation, and information systems to detect and describe climate impacts on fish, wildlife, plants, and ecosystems.

Actions:

- A: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools related to fish, wildlife, and plant observation, inventory, and monitoring. (**S 4.1.2**)
- B: Work through existing distributed efforts (e.g., National Climate Assessment (NCA), National Estuarine Research Reserve System -wide monitoring program, State Natural Heritage Programs, National Wildlife Refuge System, National Park Service) to support integrated national observation and information systems that inform climate adaptation. (**S 4.1.4**)
- C: Expand and develop as necessary networks of places for integrated climate change inventory, monitoring, research, and education. (**S 4.1.5**)

Strategy 4.2: Identify, develop, and employ decision support tools for managing under uncertainty (e.g., vulnerability and risk assessments, scenario planning, strategic habitat conservation approaches, and adaptive management evaluation systems) via dialogue with scientists, managers (of natural resources and other sectors), and stakeholders.

Actions:

- A: Conduct risk assessments to identify key climate change hazards and assess potential consequences for grassland fish, wildlife and plants.
- B: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible future scenarios associated with climate phenomena likely to significantly impact fish, wildlife, and plants. (**S 4.2.2**)
- C: Conduct vulnerability and risk assessments for priority species (threatened and endangered species, species of greatest conservation need, species of socioeconomic and cultural significance). (**S 4.2.4**)
- D: Ensure the availability of and provide guidance for decision support tools (e.g., NOAA's Digital Coast, etc.) that assist federal, state, local, and tribal resource managers and planners in effectively managing fish, wildlife, and plants in a changing climate. (**S 4.2.7**)

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Identify knowledge gaps and define research priorities via a collaborative process among federal, state, and tribal resource managers and research scientists working with the National Science Foundation (NSF), USGCRP, National Climate Assessment (NCA), USDA Extension, Cooperative Ecosystem Study Units (CESUs), Climate Science Centers (CSCs), LCCs, Migratory Bird Joint Ventures (JVs), and Regional Integrated Sciences and Assessments (RISAs).

Actions:

- A: Increase coordination and communication between resource managers and researchers through existing forums (e.g., NSF, USGCRP, NCA, USDA, CESUs, CSCs, LCCs, JVs, RISAs, and others) to ensure research is connected to management needs. (**S 5.1.1**)
- B: Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change. (**S 5.1.2**)
- C: Prioritize research on questions relevant to managers of near-term risk environments (e.g., low-lying islands and glaciated areas) or highly vulnerable species. (**S 5.1.6**)

Strategy 5.2: Conduct research into ecological aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems, working through existing partnerships or new collaborations as needed (e.g., USGCRP, NCA, CSCs, RISAs, and others).

Actions:

- A: Support basic research on life histories and food web dynamics of fish, wildlife, and plants to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds. (**S 5.2.2**)
- B: Identify and address priority climate change knowledge gaps and needs (e.g., species adaptive capacity; risk/rewards of assisted migration; climate change synergy with existing stressors; etc.). (**S 5.2.3**)
- C: Accelerate research on establishing the value of ecosystem services and potential impacts from climate change such as loss of pollution abatement or flood attenuation, etc. (**S 5.2.4**)
- D: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change. (**S 5.2.5**)
- E: Increase understanding of the adaptive capacity of grassland communities and species under climate change.

Strategy 5.3: Advance understanding of climate change impacts and species and ecosystem responses through modeling.

Actions:

- A: Improve modeling of climate change impacts on vulnerable species, including projected future distributions and the probability of persistence. (**S 5.3.2**)
- B: Develop models that integrate the potential effects of climate and non-climate stressors on vulnerable species. (**S 5.3.3**)

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally- and culturally-appropriate scales.

Strategy 6.2: Engage the public through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions..

GOAL 7: Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

Strategy 7.1: Slow and reverse habitat loss and fragmentation.

Actions:

— A: Work with farmers and ranchers to apply the incentive programs in the Conservation Title of the Farm Bill as well as the landowner tools under the ESA and other programs to minimize conversion of habitats, restore marginal agricultural lands to habitat, and increase riparian buffer zones. (**S 7.1.2**)

— B: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts and to promote habitat conservation or restoration in desirable locations. (**S 7.1.5**)

— C: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded areas. (**S 7.1.7**)

— D: Support land trusts and farmland and ranchland preservation programs as a way to sustain habitat values on working landscapes.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land/ocean-use planning, water resource planning, pollution abatement, and the implementation of best management practices.

Actions:

— A: Work with local and regional land-use, water resource, and coastal and marine spatial planners to identify potentially conflicting needs and opportunities to minimize ecosystem degradation resulting from development and land and water use. (**S 7.2.1**)

— B: Work with farmers and ranchers to develop and implement livestock management practices to reduce and reverse habitat degradation and to protect regeneration of vegetation. (**S 7.2.2**)

— C: Reduce impacts of impervious surfaces and stormwater runoff in urban areas to improve water quality, groundwater recharge, and hydrologic function. (**S 7.2.6**)

Strategy 7.3: Use, evaluate, and as necessary, improve existing programs to prevent, control, and eradicate invasive species and manage pathogens.

Actions:

— A: Employ a multiple barriers approach to detect and contain incoming and established invasive species, including monitoring at points of origin and points of entry for shipments of goods and materials into the United States and for trans-shipment within the country. Utilize education, regulation, and risk management tools (e.g., the Hazard Analysis and Critical Control Point process) to address. (**S 7.3.1**)

- B: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to natural ecosystems. (**S 7.3.3**)
- C: Monitor pathogens associated with fish, wildlife, and plant species for increased understanding of distributions and to minimize introduction into new areas. (**S 7.3.6**)

COASTAL HABITAT CONSERVATION ON AGRICULTURAL LANDS

Enhanced management of agricultural wetlands along our coasts represents an important opportunity to accommodate waterbirds displaced by wetland loss from sea-level rise.

For example, the wet coastal prairie along the Gulf Coast of Texas and Louisiana is extremely important for wetland wildlife, as are farmland such as rice fields which also provide wet, early successional habitat. But rising sea levels are expected to inundate many of these lands. Conservation programs authorized under the Farm Bill such as the Wildlife Habitat Incentives Program, Environmental Quality Incentives Program, and Wetlands Reserve Program are able to compensate landowners willing to amend tillage and flooding practices to accommodate targeted waterbirds such as fall-migrating shorebirds and wintering and spring-migrating waterfowl. These programs work with landowners to ensure critical wildlife habitat on private lands is not lost when species need it most.

Another approach is to proactively protect land that lies next to important coastal wetlands. In Pacific Northwest estuaries, Ducks Unlimited is leading an effort to protect farmland adjacent to tidal wetlands to allow for future marsh migration inland by purchasing easements (development rights) from a willing farmer. Restoring wetlands on lands like farmlands that have not been filled and developed with buildings and hard infrastructure is a cost effective and feasible adaptation strategy.

Literature Cited

Anderson, R.C. 1982. An evolutionary model summarizing the roles of fire, climate and grazing animals in the origin and maintenance of grasslands: An end paper. *In* Grasses and Grasslands: Systematics and Ecology. J. Estes, R. Tyrl, and J. Brunken (eds.). University of Oklahoma Press, Norman, OK. pp. 297-308.

CCSP (U.S. Climate Change Science Program). 2008. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P. Backlund, A. Janetos,D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman,G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, R. Shaw. U.S. Department of Agriculture, Washington, DC., USA, 362 pp.

Ceballos, G., A. Davidson, R. List, J. Pacheco, P. Manzaon-Fischer, G. Santos-Barrera, and Cruzado. 2010. Rapid decline of a grassland system and its ecological and conservation implications. PloSOne 5:1-12.

Davis, S. 2004. Area sensititivy in grassland passerines: effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in souther Saskatchewan. The Auk 121:1130-1145.

DeGaetano, A.T., and R.J. Allen. 2002. Trends in twentieth-century temperature extremes across the United States. Journal of Climate 15(22):3188-3205.

Dukes, J.S., and H.A. Mooney. 1999. Does global change increase the success of biological invaders? Trends in Ecology & Evolution 14(4):135-139.

Gauthier, D.A., A. Lafon, T. Toombs, J. Hoth, J. Fernandes, N. Flynn, S. Gibbes, M. Griffis, T. Isshiki, S. Killian, L. Palombi, N. Rujanavech, S. Tonsky, and M. Tondro. 2010. Renewable energy in the California desert, mechanisms for evaluating solar development on public lands. School of Natural Resources and Environment, University of Michigan, M.S. Thesis, S. Yaffee, Advisor. 363 pp.

Hamre, L.N., A. Edvardsen, and K. Rydgren. 2010. Plant species richness, composition and habitat specificity in a Norwegian agricultural landscape. Agriculture, Ecosystems and Environment.138:189-196.

Heinz Center (The H. John Heinz III Center for Science, Economics and the Environment). 2008. The State of the Nations Ecosystems. Island Press, Washington, D.C.

Hellman, J.J., J.E. Byers, B.G. Bierwagen, and J.S. Dukes. 2008. Five potential consequences of climate change for invasive species. Conservation Biology 22(3):534-543.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (AR4). Core Writing Team, R.K. Pachauri and A. Reisinger (eds.). IPCC, Geneva, Switzerland, 104 pp.

Johnson, W.C., B. Werner, G.R. Guntenspergen, R.A. Voldseth, B. Millett, D.E. Naugle, M. Tulbure, R.W.H. Carroll, J. Tracy, and C. Olawsky. 2010. Prairie Wetland Complexes as Landscape Functional Units in a Changing Climate. Bioscience 60(2):128-140.

Johnson, W.C., B.V. Millett, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen, and D.E. Naugle. 2005. Vulnerablility of northern prairie wetlands to climate change. Bioscience 55(10):863-872.

Jones, M. B. 1997. The impacts of global climate change on grassland ecosystems. Proceedings XVIII IGC, Winnepeg, MB.

Julliard, R., F. Iguet and D. Couvet. 2003. Common birds facing global changes: what makes a species at risk? Global Change Biology 10:148-154.

Kline, V.M. 1997. Orchards of oak and a sea of grass. *In* Packard, S. and C.F. Mutel. 1997. The tallgrass prairie handbook: for prairies, savannas and woodlands. Island Press, Washington, D.C.

Knopf, F.L. 1995. Perspectives on grazing nongame bird habitats. *In* Rangeland Wildlife, Society of Range Management. P.R. Krausman (ed.).

Lettenmaier, D., D. Major, L. Poff, and S. Running. 2008: Water resources. In: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States.

Lubowski, R.N, M. Versteby, S. Bucholtz, A. Baez, and M.J. Roberts. 2006. Major Uses of Land in the United States, 2002. Economic Research Service, U.S. Department of Agriculture. Economic Information Bulletin No. (EIB-14), 54 pp.

Matthews, J. 2008. Anthropogenic Climate Change in the Playa Lakes Joint Venture Region: Understanding Impacts, Discerning Trends, and Developing Responses. Playa Lakes Joint Venture, Lafayette, CO, 40 pp.

McLachlan, M., A. Bartuszevige, and D. Pool. 2011. Evaluating the potential of the conservation reserve program to offset projected impacts of climate change on the lesser prairie-chicken (*Tympanuchus pallidicinctus*). USDA Natural Resources Conservation Service and USDA Farm Service Agency. 50 pp.

Milchunas, D.G., O.E. Sala, and W.K. Lauenroth. 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. Am. Naut. 132:87-106.

Milchunas, D.G., A.R. Mosier, J.A. Morgan, D.R. LeCain, J.Y King and J.A. Nelson. 2005. Elevated CO2 and defoliation effects on a shortgrass steppe: forage quality versus quantity for ruminants. Agriculture, Ecosystems and Environment 111:166-184.

Morgan, J.A., D.G. Milchunas, D.R. LeCain, M. West, and A.R. Mosier. 2007. Carbon dioxide enrichment alters plant community structure and accelerates shrub growth in the shortgrass steppe. Proceedings of the National Academy of Sciences of the United States of America 104(37):14724-14729.

Mosier, A.R., D. Schimel, D. Valentine, K. Bronson and W. Parton. 1991. Methane and nitrous oxide fluxes in native, fertilized and cultivated grasslands. Nature 350:330-332.

Mosely, J C., S.C. Bunting, and M.E. Manoukian. 1999. Cheatgrass. *In* Biology and management of noxious rangeland weeds. R.L. Sheley and J.K. Petroff (eds.). Corvallis, OR: Oregon State University Press: 175-188.

NABCI (North American Bird Conservation Initiative), U.S. Committee. 2011. The State of the Birds 2011 Report on Public Lands and Waters. U.S. Department of Interior: Washington, DC. 48 pp.

Nickerson, C., R. Ebel, A. Borchers, and F. Carriazo. 2011. Major Uses of Land in the United States, 2007. EIB-89. U.S. Dept. Agr., Econ. Res. Serv. Dec.

NPWRC (Northern Prairie Wildlife Research Center). 2006. Regional trends of biological resources – Grasslands. USGS. Accessed on November 4, 2011.

Noss, R.F., E.T. LaRoe III, and J.M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. U.S. Department of the Interior, National BiologicalService, Biological Science Report 28. 71 pp.

NRCS (Natural Resources Conservation Service). 1999. Lesser Prairie-Chicken (Tympanuchus pallidicinctus). Fish and Wildlife Habitat Management Leaflet 6.

Raghu, S., R.C. Anderson, C.C. Daehler, A.S. Davis, R.N. Wiedenmann, D. Simberloff, and R.N. Mack. 2006. Adding biofuels to the invasive species fire? Science 313:1742.

Reynolds, R.E., T.L. Shaffer, R.W. Renner, W.E. Newton, and B.D.J. Batt. 2001. Impact of the conservation reserve program on duck recruitment in the U.S. Prairie Pothole Region. Journal of Wildlife Management 65(4):765-780.

Rickletts, T.H., E. Einerstein, D.M. Olsen, C.J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P.T. Hurley, K.M. Carney, R. Abell, and S. Walters. 1999. Terrestrial ecoregions of North America. Island Press, Washington D.C., and Covello, California, USA.

Sauer, J.R., J.E. Hines, J. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2009. Version 3.23.2011 USGS Patuxent Wildlife Research Center, Laurel, MD.

Scanlon, B., R. Reedy, and J. Tachovsky. 2007. Semiarid unsaturated zone chloride profiles: archives of past land use change impacts on water resources in the southern High Plains, United States. WaterResources Research 43: W06423.

Shelford, V.E. 1963. The ecology of North America. University of Illinois Press, Urbana, 610 pp.

Shriver, W.G., A.L. Jones, P.E. Vickery, A. Weik, and J. Wells. 2005. The distribution and abundance of obligate grassland birds breeding in New England and New York. USDA forest Service Gen. Tech. Rep. PSW-GRT-191:511-518.

Smith, D.D. 1992. Tallgrass prairie settlement: prelude to the demise of the tallgrass ecosystem. *In* Proceedings of the twelfth North American Prairie Conference: recapturing a vanishing heritage, 5-9 August 1990. D.D. Smith and C. A. Jacobs (eds.). University of Northern Iowa, Cedar Falls. pp 195-199.

Smith, F.M. 1973. Abiotic functions in grassland ecosystems. Analysis of Structure, Function, and Utilization of Grassland Ecosystems, Vol. 2. A Progress Report (Principal investigator, G. M. Van Dyne), US/IBP Grassland Biome, Colorado State University, Fort Collins, Colorado. pp. 29-96.

Swengel, A.B. and S.R. Swengel. 1998. Highlight Box: Tall-grass Prairie Butterflies and Birds. 446-447 pp. In M. J. Mac, P. A. Opler, C. E. Puckett Haecker, and P. D. Doran, eds. Status and Trends of the Nation's Biological Resources, Vol. 2. Jamestown, ND: Northern Prairie Wildlife Research Center Online.

Taub, D. 2010. Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants. Nature Education Knowledge 1:21.

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

USGCRP (United States Global Change Research Program). 2009. Global Climate Change Impacts in the United States. T.R. Karl, J.M. Melillo, and T.C. Peterson (eds.). Cambridge University Press.

Vickery, P.D., and P.W. Dunwiddie (eds.). 1997. Grasslands of northeastern North America: ecology and conservation of native and agricultural landscapes. Massachusetts Audubon Society, Lincoln, Massachusetts, USA.

Ziska, L. and K. George. 2004. Rising carbon dioxide and invasive, noxious plants: potential threats and consequences. World Resource Review 16:427-447.

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