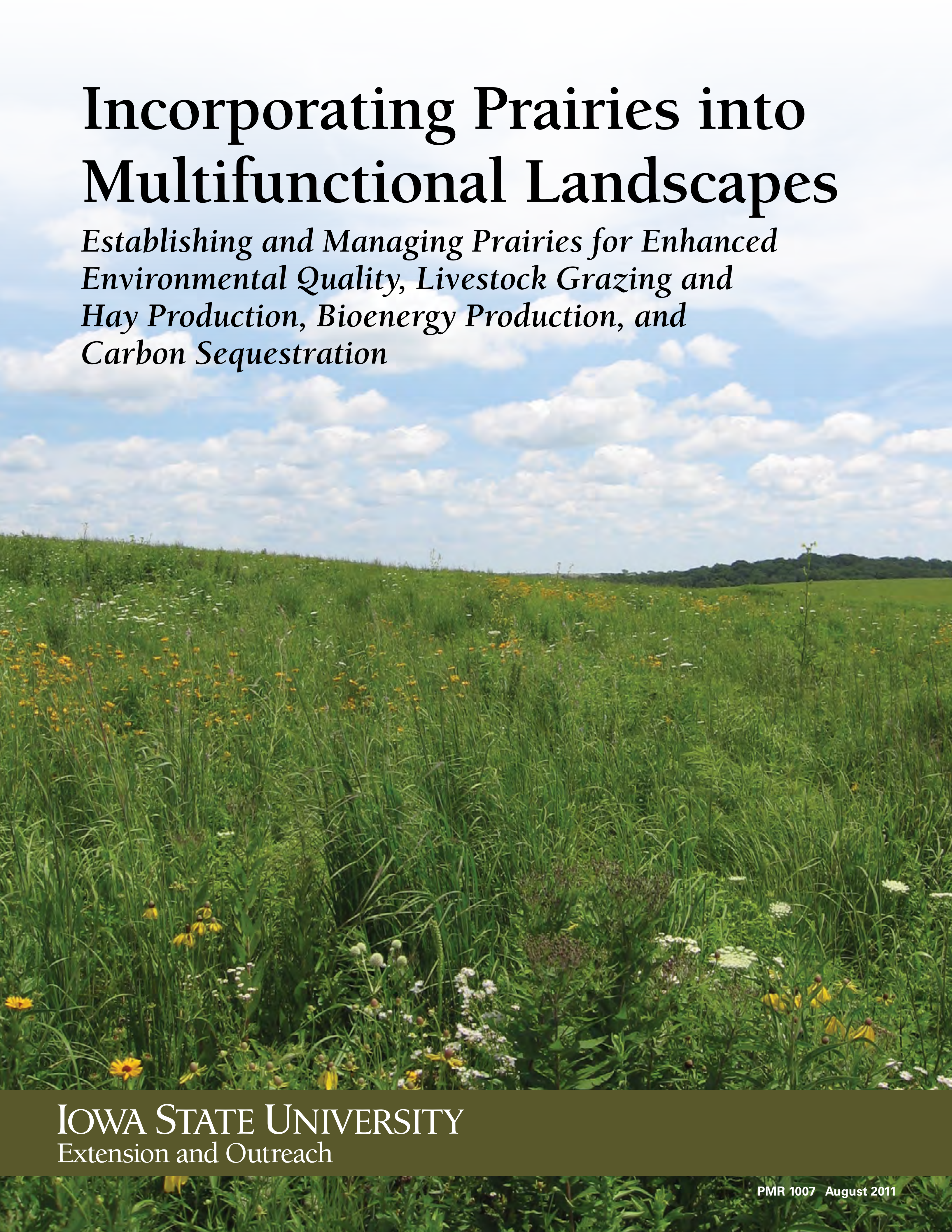

Incorporating Prairies into Multifunctional Landscapes

Establishing and Managing Prairies for Enhanced Environmental Quality, Livestock Grazing and Hay Production, Bioenergy Production, and Carbon Sequestration

IOWA STATE UNIVERSITY
Extension and Outreach

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Contents

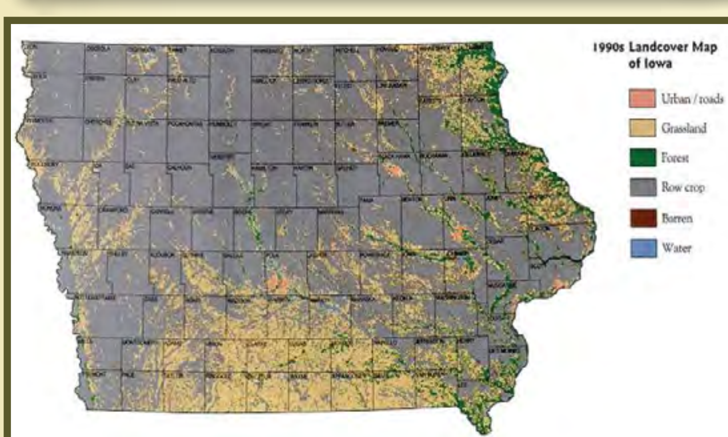
What Is a Prairie?

A prairie is a type of grassland that contains mostly perennial plants. Before European settlement, most of the central United States was covered with prairies. Prairies are generally classified based on the height of the dominant grasses and include tallgrass, mixed-grass, and shortgrass prairies. More than 95% of all tallgrass prairies have been eliminated primarily due to conversion of the land for agriculture, whereas approximately 40% of the shortgrass prairies remain because the land is too dry for non-irrigated agriculture, but is suitable for livestock grazing. Iowa is an extreme example of tallgrass prairie loss; less than 0.1% of the prairie remains today in the state (Samson and Knopf 1994).

Although tallgrass prairie regions receive sufficient precipitation to support trees, trees were historically excluded from prairies because of fire and ruminant grazing. Prairie vegetation is adapted to fire; the aboveground vegetation dies, but the plants are able to grow back rapidly from the roots. Although some species of tree, such as bur oak, are tolerant of fire at maturity, most tree seedlings are intolerant of fire. Disturbance by ruminants such as trampling, grazing, and wallowing also negatively affect tree seedling establishment. Removal of disturbances to tallgrass prairies can result in invasion by trees. Once established, the trees shade the prairie plants, which are adapted to full-sun conditions.

Tallgrass prairies are a threatened ecosystem: less than 5% remain.

Prairie plants have extensive root systems. Soils under established prairies can contain more than 10 tons of roots per acre with most of the roots occurring as a dense mat within the top foot of soil and some roots growing to depths of more than 8 feet (Weaver 1919). The root systems of prairie plants produced the Mollisol soils that are found under prairies. Mollisols have high concentrations of organic matter in the surface horizon, which are often 2 to 3 feet deep. The deep, organic-matter-rich surface horizon gives Mollisols high inherent fertility. It is the high fertility of the soils produced by tallgrass prairies that makes the land desirable for conversion to agriculture.



Landcover maps of Iowa in 1850 and 1990 from the Iowa DNR. Note that the "grassland" category in the 1990 landcover map represents primarily pastures rather than prairie.

Wetlands as a Part of Prairie Systems

Wetlands were once a prominent part of prairie landscapes, especially in the prairie pothole region of the north central United States. Wetlands are ecosystems that contain standing water or saturated soil either permanently or seasonally. Although shallow ponds often come to mind when thinking about wetlands, most wetlands do not have standing water throughout the year. These seasonal wetlands are called ephemeral wetlands. Almost all of the wetlands in the tallgrass prairie region have been eliminated through the use of subsurface drainage tiles and drainage ditches. For example, almost 90% of the wetlands have been drained in Iowa (Mitsch and Gosselink 2000). Locations of former wetlands can easily be seen in the "wet spots" in agricultural fields. Drained wetlands are highly desirable for agricultural production because the land generally receives sufficient water and the soils are high in organic matter. Yet functioning wetlands provide a myriad of critical ecosystem services, such as groundwater recharge, nitrate removal through denitrification, flood control, carbon sequestration, and animal habitat. Unlike row crops that are not adapted to growing under saturated soil conditions, wetland plants thrive under these conditions, making wetlands one of the most productive ecosystems.

How Do Prairies Differ from Other Grass Systems?

There are many different types of non-prairie grass systems, such as pastures, grassed waterways, and riparian buffers. Pastures are generally seeded with non-native cool-season grasses, such as orchardgrass, timothy grass, and smooth bromegrass, that are nutritious for livestock. Cool-season grasses begin growing early in the spring, have higher protein concentrations than warm-season grasses, and have strong re-growth after grazing. Grassed waterways are used to reduce soil erosion and water pollution in row-crop systems, and are generally composed of the same cool-season grasses as pastures. Riparian buffers can contain prairie species, but are often dominated by non-native grasses such as reed canary grass.

Prairies differ from these systems in two main ways. First, prairies are often dominated by warm-season grasses. Warm-season grasses are likely not used in some of the above mentioned grass systems because warm-season grasses are generally slower establishing than cool-season grasses. Warm-season grasses also have lower protein concentrations than cool-season grasses. Second, prairies contain forbs (AKA wildflowers). Some pastures may contain forage legumes, but prairies contain a diverse array of leguminous and non-leguminous forbs. The forbs are particularly important as food sources for insects and wildlife.

How Can Prairies Benefit My Farm?

Incorporating prairies back onto the landscape can provide numerous ecosystem services. These services are functions provided by ecosystems that are desirable to humans, such as waste decomposition and water purification. Other ecosystem services provided by prairies include soil conservation, nutrient retention, habitat for animals, and hydrologic stabilization. The extent to which an ecosystem service is provided by a prairie depends, however, on the size and location of the prairie (see page 7 for ways prairies can be incorporated into landscapes).

Prairies Reduce Soil Erosion

There is almost no erosion from land covered with prairie vegetation because the dense network of prairie roots is incredibly efficient at holding the soil in place. In addition to preventing soil erosion directly under the prairie, prairies can also be used to reduce the amount of soil erosion in the larger landscape. Patches or strips of prairie can be interspersed with row crops to reduce the amount of soil erosion from the system. Placing strips of prairie on only 10% of the area of a watershed has been found to reduce sediment loss by 90–95% when compared to watersheds with 100% annual row crops (Helmers et al. unpublished). This demonstrates that even relatively small patches of prairies can greatly reduce the amount of soil erosion. It is important to note, however, that while prairie strips can reduce the amount of soil leaving a watershed, they may not affect the amount of soil erosion taking place in row-cropped areas adjacent to the strips.

Prairies Reduce Nutrient Pollution

Nutrient pollution refers to the contamination of water bodies by excess nutrients, particularly nitrogen and phosphorus. All of the lakes and rivers in the Corn Belt and Northern Great Plains region have higher nitrogen concentrations now than before the expansion of row-crop agriculture, and approximately 90% of the lakes and rivers in the same region also have higher phosphorus concentrations (Dodds et al. 2009). Nitrogen and phosphorus are pollutants in water bodies because they lead to excessive algal growth, which shades out submerged plants and can cause hypoxic zones (AKA dead zones). Annual row crops are prone to nutrient losses because plants are not growing early in the spring when nitrogen and phosphorus are most susceptible to moving into water bodies through leaching and soil erosion, respectively.

Because most prairie plants are perennials, they begin growing early in the spring. The deep, actively-growing roots of the prairie plants are able to take up nitrogen as it is leached through the soil from higher on the landscape. For example, 50% lower nitrate concentrations were found in streams from a row-crop agriculture dominated watershed with 25% prairie vegetation than a similar watershed without significant prairie vegetation (Schilling and Spooner 2006). Phosphorus, on the other hand, is primarily transported to water bodies attached to soil particles. Therefore reducing soil erosion by incorporating prairies into agricultural landscapes contributes to reductions in phosphorus pollution.

Prairies Increase the Number of Beneficial Insects

Beneficial insects are insects that perform an ecosystem service. Two ecosystem services provided by insects in agricultural landscapes are pollination and suppression of pest insects.

Pollination

Pollination occurs when the pollen produced in the stamen (the male portion of a flower) is released and fertilizes the pistil (the female portion of the flower). Pollen is most frequently transferred from the stamen to the pistil via insects; almost 90% of all flowering plants are pollinated by insects. Wind- and self-pollinated plants, on the other hand, do not require insects for pollination. Grasses, including corn, are one group of plants that do not require insect pollinators, but most other plants, including almost all fruit and vegetable crops, are insect pollinated. Therefore maintaining healthy pollinator populations is necessary for maintaining plant diversity and fruit and vegetable yields. (Note – Although soybeans are not wind pollinated, soybean plants are usually self pollinated and do not require a pollinator.)

Prairies provide insect pollinator habitat and food sources (pollen and nectar). Desirable insect habitat varies among species, but generally, prairies provide habitat for pollinators by having standing aboveground biomass year round. The prairie biomass helps moderate the microclimate around the insects. Prairie forbs are important in providing food sources for insects. Having a diversity of forbs that flower throughout the growing season is necessary to ensure that the pollinators persist.

Suppression Of Pest Insects

Insects that prey upon pest insects are called natural enemies. Increasing the number and types of natural enemies present in and around agricultural systems can help reduce the damage caused by insect pests and can reduce the amount of pesticide that needs to be applied to a crop. It has been estimated that native natural enemies save commodity farmers in the United States about $4.5 billion annually on pest control (Losey and Vaughn 2006). The benefits provided by natural enemies can be increased by increasing the year round food and habitat for these desirable insects. Just like insect pollinators, natural enemies need to be provided with persistent habitat and food resources. Although natural enemies eat pest insects, the pest insects are usually only present for part of the growing season. The natural enemies need other food sources, such as pollen and nectar from forbs, for the rest of the growing season.

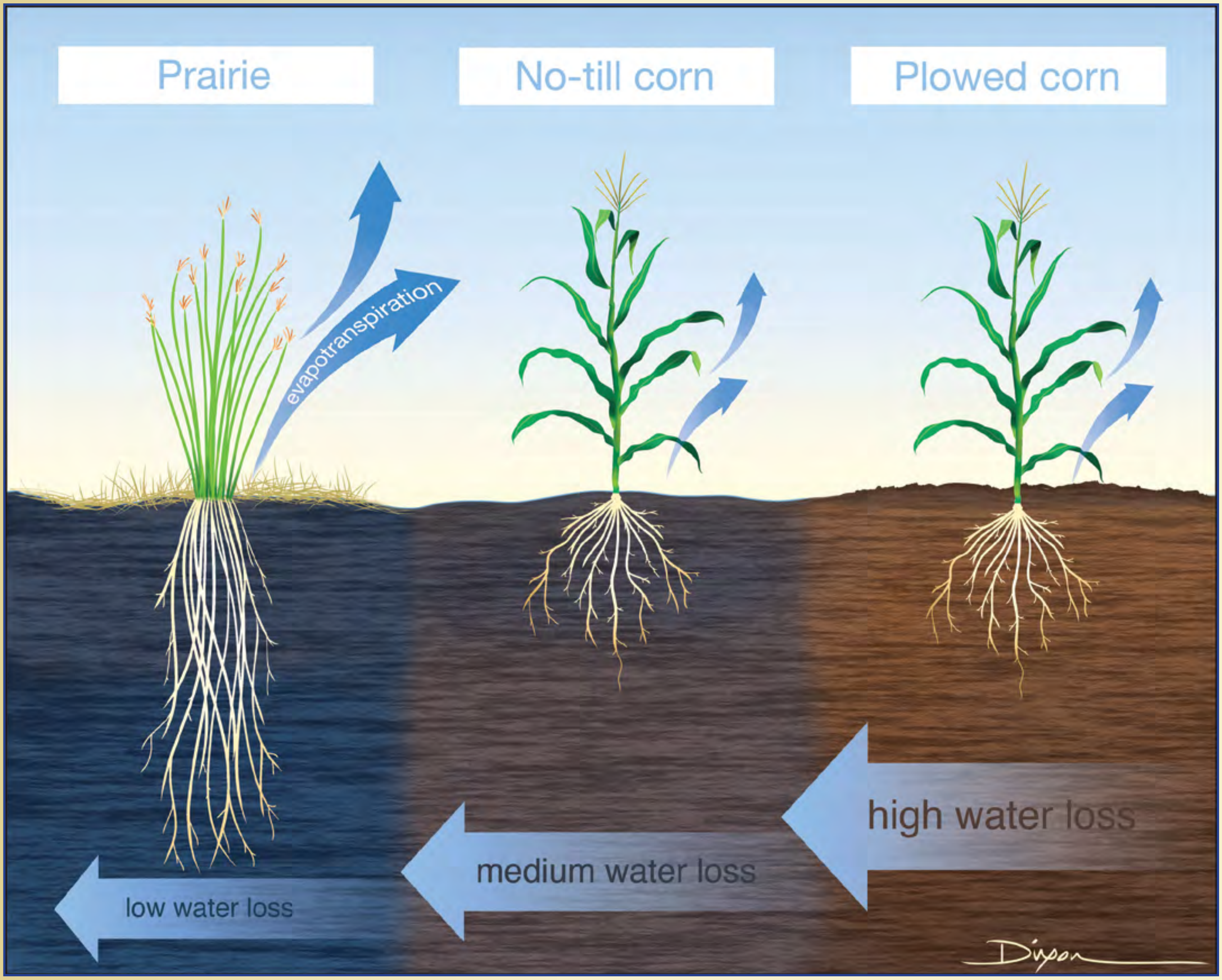
Prairies Provide Habitat for Wildlife and Songbirds

Using prairies as habitat for wildlife and songbirds is one of the most common reasons for prairie reconstructions. In fact, many of the government programs that provide subsidies for habitat restoration such as the Conservation Reserve Program (CRP) and Wildlife Habitat Incentives Program (WHIP) emphasize the importance of using perennial vegetation including prairies for wildlife habitat. The development of the seeding mixes often specifically considers the food and habitat requirements of one or more wildlife or songbird species.

Individuals who reconstruct prairies for wildlife and songbird habitat may do so to provide themselves with habitat for hunting and bird watching. Yet there is a large market for providing hunting and bird watching habitat for others. In the United States in 2006, hunters, fishers, and birdwatchers spent more than $122 billion pursuing these activities (USFWS 2006).

Prairies Help Stabilize the Hydrology of a Watershed

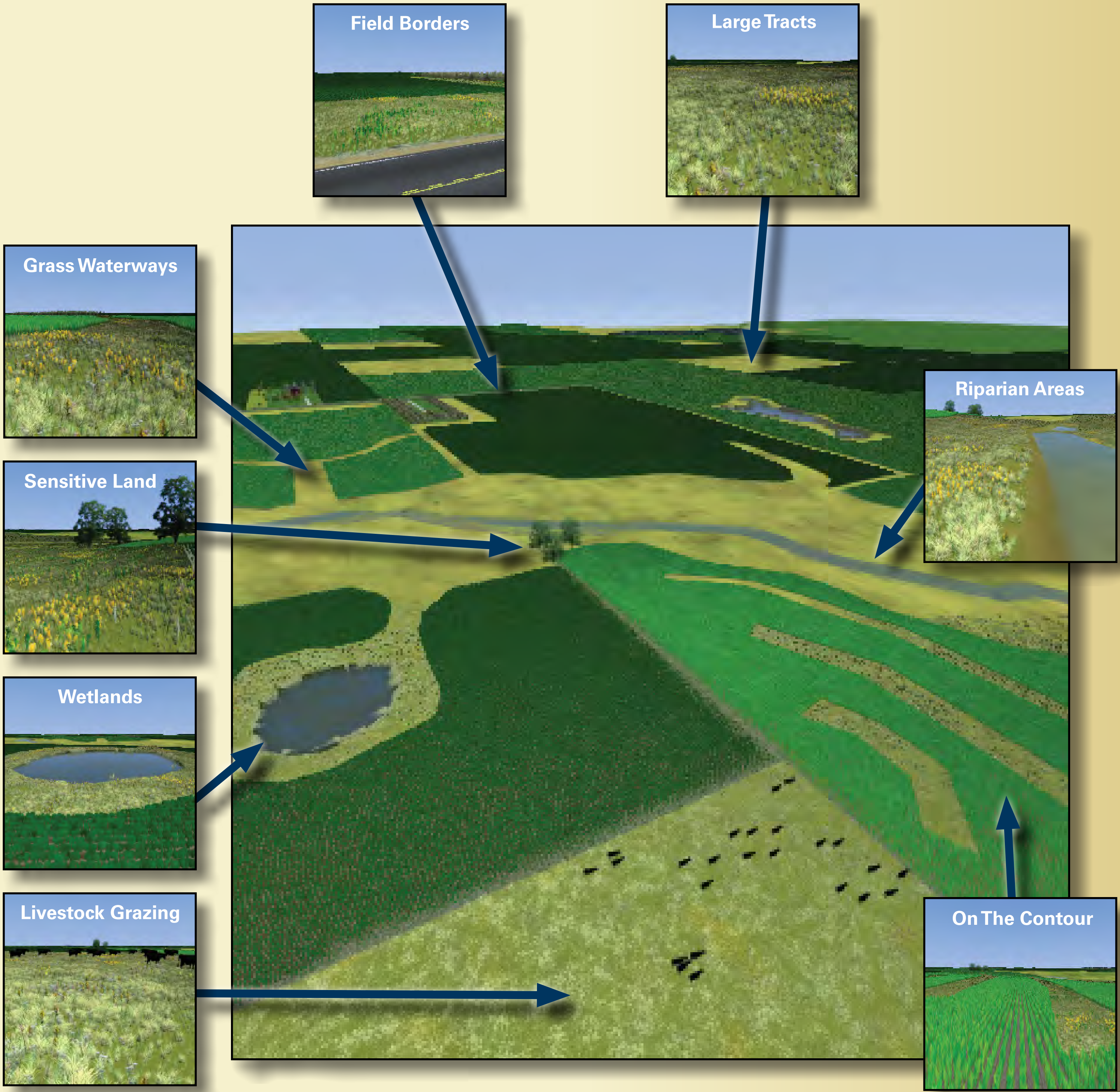
Water moves at the scale of watersheds. A watershed, also called a catchment, is the area of land that naturally drains into one water body – including rivers, lakes, and wetlands. Incorporating prairies, including wetlands, into a watershed can stabilize the hydrology of the watershed by reducing periods of peak water flow and increasing the amount of water held in the soil. Prairies increase the porosity of the soil by increasing the amount of soil organic matter and by having extensive root systems. This makes the soil under prairies act like a sponge. When it rains, the soil is able to take up and hold large amounts of water. Between rainfall events, the soil is then able to more slowly release the water than soil with poorer porosity. Soils under row-crop production are more prone to surface water runoff and water seeping below the plant rooting zone, which reduces the water supply for growing plants and increases the magnitude of changes in the flow of nearby water bodies.



Hydrologic relationships among a restored prairie, corn without tillage, and corn following chisel plowing. Prairie systems hold more water in the soil and have greater evapotranspiration rates than corn systems, thereby reducing the amount of water lost below the plant rooting zone. Between the corn systems, soils in no-till production hold more water and lose less water below the plant rooting zone than soils that have recently been chisel plowed. Data based on Brye et al. (2000); figure by A. L. Dixon.

How Can Prairies Be Incorporated into Farms?

Before European settlement, prairies usually existed in large contiguous blocks of thousands of acres. Restoring large block prairies on any one farm, however, is probably unlikely. Prairies can be incorporated into the landscape in numerous ways (see below). Prairies can be useful additions to the landscape from scales of less than an acre to hundreds of acres.



Photorealistic visualization of multiple uses for prairies in multifunctional landscapes. Figure by G. L. D. Larsen.

How Are Prairies Established and Managed?

Because there are very few remaining prairies, there is no prairie seed bank in the soil in most places. In Iowa, for example, less than 0.01% of the original prairie remains as remnant prairies and most of the prairie was converted into agricultural production by early in the 1900s. In order to reconstruct prairies, prairie seed needs to be added and weeds need to be controlled. Once a prairie is established, prairie plants are competitive with other non-prairie species, but most prairie plants are slow to establish. Because of this, the establishment phase of prairies is one of the most important phases in prairie reconstruction.

Government subsidies are available to offset up to 90% of the establishment costs.

Complete prairie establishment may take up to four years, but establishment may be much more rapid if the soil seed bank is small. On the following pages, the three main steps of establishing a prairie are described in greater detail. These steps are site preparation, selection of an appropriate seed mix, and seeding and weed management. For more complete information regarding the process of establishing a prairie, see the resource list on page 23.

Prairie Establishment Costs

Expenses	Price ($/acre)
Land rent	$100 – 335[1]
Seed costs	$45 – 1500[2]
Site preparation (per management)	
Tillage	$8 – 20
Herbicide (product + application)	$3 – 13[3]
Seeding costs (prairie drill + cultipacking)	$10 – 50[4]
Weed management/mowing (per mow)	$8 – 27[3]

[1]Edwards et al. 2009a
[2]Duffy 2007, Prairie Moon 2009
[3]Edwards et al. 2009b
[4]Blomgren Seed and Habitat Services, personal communication

Comparison Among Most Common Prairie Seeding Times

Time of seeding	*Pre-seeding Tillage*	*Plant favored*	*Notes*
Frost Seeding			
February and March	No	Early germinating plants (cool-season grasses, some forbs, some legumes)	Seed stratification occurs during freeze-thaw cycles, which also work seeds into the soil
Spring Seeding			
April, May, and June	Yes	Later germinating species (especially warm-season grasses)	Spring herbicide application or tillage can be used to kill first flush of weed seedlings
Dormant Seeding			
November and December	No	Early germinating plants (cool-season grasses, some forbs, some legumes)	Seeding occurs when temperatures are reliably lower than are necessary for seed germination

Site Preparation

Appropriate site preparation is necessary to kill existing vegetation, diminish the soil seed and bud banks, and make the soil conducive to prairie seed germination and establishment. The location of the site for the prairie restoration will likely be chosen based on land availability and the proposed use for the prairie. Sites with no perennial vegetation and a minimal soil seed bank are ideal, and preparation is most difficult for sites with established perennial vegetation with an extensive soil seed bank.

The easiest site to prepare is land that has been previously used for tilled annual row crops, especially soybean. The soybean stubble will provide some soil cover, but will decompose readily. The weeds that are most prevalent in tilled annual row crops are annual weeds, and annual weeds are not competitive with prairie plants over multiple years. Furthermore, the weed seed bank under row crops is likely to be small because of the frequent management (tillage and/or herbicides) used to control weeds. If the weed pressure is low, almost no site preparation is needed. The prairie seed can be no-till drilled into the soil or spread over soil after light tillage. If the weed pressure is high, depleting the seed bank is useful. This can be accomplished by using multiple rounds of secondary tillage to expose the weed seeds, encourage weed germination, and kill weed seedlings. The secondary tillage should occur in the spring following crop harvest, and two to three rounds of secondary tillage should be sufficient to reduce the seed bank.

Unlike row-crop systems that include tillage, the weed seed and bud banks under no-till systems often have more perennial species. Perennial weeds can be more competitive with prairie plants than annual weeds because of their persistence once established. The more the perennial weed seeds and plants, which are the source of the bud bank, can be removed from the site, the more rapidly the prairie will establish. The perennial weeds can be killed using either herbicides or tillage. The number of perennial weed seeds in the seed bank can be reduced by multiple rounds of secondary tillage or by spraying herbicides after the weeds have germinated the following spring. If secondary tillage is used, additional weed seeds that had become buried in the soil may be moved to the soil surface and have favorable conditions for germination and establishment.

Land that is currently under perennial vegetation, such as pastures and abandoned fields, requires the most diligent site preparation because the established perennial plants will generally out compete the establishing prairie seedlings. It is important that the established plants are killed before the prairie is seeded. Broad spectrum herbicides, such as glyphosate, are usually successful at killing the established plants. Tillage is less likely to be effective at killing the perennial plants. Although many of the shoots of the plants will die after tillage, the plants' rhizomes may be broken and spread, which could increase the bud bank. The weed seed bank is also likely to be large, and repeated tillage or herbicide spraying can be used to kill emerging weed seedlings. Preparation of a site with existing perennial vegetation will take almost one year. Spraying herbicides in the fall followed by repeated herbicide applications or tillage the following year will greatly reduce the weed pressure and encourage rapid prairie establishment.

What Equipment Will I Need?

(Not all will be needed for all restorations)

- Tillage equipment (e.g. field cultivator)
- Herbicide spraying equipment
- Prairie seed drill or broadcast seeder
- Cultipacker
- Mower with cut height up to 10"

TOP: Tilled ground ready for seeding
BOTTOM: Seeded and cultipacked tilled prairie

Selection of Seeding Mixes

As prairie restorations have become more widespread, prairie seed prices have ecreased and the availability of seed has increased. The cost of prairie seed mixes can vary by orders of magnitude depending on the source of the seed and the number of species in the seed mix. The source of the seed refers to the location where the seed came from. Seed source can be most variable for prairie plants that have a wide range. Switchgrass, for example, is found throughout the United States, and sources for switchgrass seed can range from Texas to North Dakota. It is ideal to select prairie seed from a source close to the site of the prairie restoration or from a source with similar environmental conditions, such as day length and precipitation.

Prairie seed can also be sold as custom seed mixes or bulk-harvested seed mixes. Custom seed mixes are multi-species mixtures in which the seed from each species is harvested separately and the desired quantity of each species is added to the seed mix. Custom seed mixes provide greater flexibility in the identity and amount of species present in the seed mix. Furthermore, the seed of each species can be harvested at the time of peak seed maturity for that species. Bulk-harvested seed mixes are produced when a prairie is harvested with machinery such as a combine or brush stripper and all of the seeds that are collected are sold as one mix. Bulk-harvesting prairies is often more economical than custom mixing seed mixes, and bulk-harvested seed mixes contain seed quantities and species combinations that actually occurred in the harvested prairie.

The richness of species and amount of each species present in seed mixes is highly variable. The composition of the species mix will vary depending on the desired use of the prairie. Some "prairie" seed mixes contain only grasses, but forbs (i.e., wildflowers) are necessary in order to have a prairie rather than a stand of grasses. Grass seed is generally more inexpensive than forb seed. Therefore seed mixes tend to be cheaper when fewer forbs are used. The most basic seeding mix for the Conservation Reserve Program (CRP) contains only two forb species that comprise less than 5% of the seed mix, and these mixes often cost less than \$100 per acre. Alternatively, forb-rich seed mixes that include rare species can cost over \$1,500 per acre. There are a large number of moderate-diversity prairie seed mixes that cost less than \$200 per acre. The source and harvest method also affect seed-mix prices.

Before planting a prairie seed mix, it is important to determine whether any of the seeds require pre-treatment or beneficial microbes (such as rhizobia or mycorrhizae). Pre-treatment refers to a process that the seeds must go through before they are ready to germinate. Common pre-treatments for prairie seeds include cold, moist stratification; alternating cold-moist and warm-moist periods; and scarification. Some companies perform all of the pre-treatments on the seed before selling the seed mix, whereas other seeds are sold as the seeds were harvested from the field. Many of the pre-treatments required will occur naturally if the prairie seeds are exposed to the freeze-thaw cycles of winter. Therefore appropriate seed pre-treatment is most important when the prairie is seeded in the spring. Beneficial microbes include rhizobia bacteria that form root nodules and perform nitrogen fixation in legumes and mycorrhizal fungi that form symbiotic relationships with the roots of many prairie plants. Most soils will contain rhizobia and mycorrhizae, but if the soil has been heavily disturbed with chemicals or has had the topsoil removed, adding rhizobial and mycorrhizal inoculums, which can be purchased with the prairie seed mixes, will ensure that there are sufficient beneficial microbes present.

Prairie Seeding and Early Management

Prairies can be planted either by hand or by using mechanical seeding equipment, but mechanical seeding equipment is necessary for most plantings that are larger than one acre. Broadcast seeders such as manure spreaders can be used to seed large areas. One disadvantage of broadcast seeders is that smooth seeds may fall into the broadcaster more rapidly than fluffy seeds resulting in uneven spreading of the prairie seed across the site. Prairie drill seeders, such as Truax® drills, are specifically designed for planting prairie seed. The drills have two sets of seed boxes so that the smooth seed can be separated from the fluffy seed, which promotes more even seed distribution.

Unlike crop seeds, which have been bred to be larger than seed from their native progenitors, most prairie seed is relatively small, and the seeds must be placed near the soil surface. The above-mentioned seeding methods all place the prairie seeds at or near the soil surface. Yet the seeds must have good seed-to-soil contact to allow the seeds to establish successfully. If the prairie is seeded in the spring, a cultipacker can be used after seeding to press the seeds into the soil surface. If the prairie is seeded between November and March, the freeze-thaw cycles in the soil will work the seed sufficiently far into the soil for good seed-to-soil contact.

Prairie seedlings establish much more slowly than many other, less conservative plants. Most prairie seedlings invest a great deal of energy in producing roots rather than shoots, which makes prairie seedlings very susceptible to being out competed for light by weeds. One of the best methods to prevent the prairie seedlings from being out competed for light is frequent mowing throughout the first growing season. The prairie should be mowed every time the weeds are taller than approximately 12″ and the mower should be set to a cut height of approximately 6″. If weed pressure is high, the prairie can be mowed during the second growing season also, but the cut height during the second year should be 8″ to 10″.

Fire is another effective weed control method in establishing prairies because prairie plants have evolved to tolerate fire whereas many weed species have not. Prairies can be burned as soon as the spring of the second growing season if sufficient dead biomass is present to fuel the fire. Spring fires are often used for weed control because many weeds begin growing immediately in the spring whereas many of the prairie plants, such as the warm-season grasses, begin growing later in the spring. Fire is an important management tool throughout the life of the prairie, particularly if the prairie does not have other types of disturbance, such as mowing or grazing. Without regular disturbance, woody vegetation will begin to invade the prairie.

How Will the Prairie Affect My Crops?

Will the Prairie Plants Become Weeds?

No, most prairie plants will not become weeds in crop fields where annual crops are grown. Prairie plants can be competitive once they become established, but as discussed on page 11, most prairie plants generally take multiple years to become established. Therefore on land that is regularly tilled or where herbicide is applied at least annually, it is unlikely that the prairie plants will become established. Prairie plants have the potential, however, to become established in no-till fields if herbicides are not used. Prairie plants generally need full sun, and are unlikely to become established under a closed crop canopy.

Will the Prairie Harbor Problematic Weeds?

Prairies may harbor some problematic weeds. During the establishment years of a prairie, the prairie is likely to contain many annual weeds, such as foxtail, lambsquarters, horseweed, velvetleaf, and ragweed (giant and common), all of which are weeds in annual cropping systems. If the prairie is mowed frequently during the establishment years, the amount of annual weed seed that is produced and spread to the neighboring cropland can be minimized. If the weed seed bank is low on the site where the prairie is established, the potential for weed seed spread is even lower. As the prairie becomes established – after the first or second year depending on the existing seed bank – the number of annual weeds will greatly decrease, and the prairie should no longer be a source of annual weeds for neighboring cropland.

During the establishment years and beyond, the prairie may be susceptible to invasion by perennial weeds, which could then spread into neighboring cropland, but perennial weeds are generally well controlled in annual row crops through herbicide applications and tillage. One of the most problematic perennial weeds in prairies is Canada thistle, which is a noxious weed throughout almost all of the United States. Canada thistle is a highly competitive plant that can tolerate a wide range of conditions, and because it is a perennial, Canada thistle can compete with prairie plants. The best management strategy to control Canada thistle is to eliminate all established plants before planting the prairie. This may include repeated herbicide sprays or tillage (see page 9). Mowing during the establishment years of a prairie is also an effective way to control Canada thistle. After a prairie is established, spot spraying with herbicides is an effective strategy for suppressing Canada thistle.

The size and shape of the prairie will also affect the weediness of the prairie (see page 7 for descriptions of different prairie configurations). Prairie edges are weedier than the interiors of prairies. Therefore long and narrow strips of prairies will be mostly edge and will tend to have more weeds because the transition zone between land managed for annual row-crop production and the prairie will likely be frequently disturbed through tillage and herbicide spraying.

Will the Prairie Be a Source of Diseases or Pests?

Planting prairies around row crops will generally be beneficial to the crop by increasing the number of natural enemies (see page 5). It is unlikely that the prairie would be a source of crop diseases (bacteria, viruses, or fungi). Many bacteria and viruses are very host specific and are unlikely to be able to infect both the prairie plants and row crops. The change in plant structure between a crop field and prairie would likely be beneficial for reducing the humidity that often leads to fungal diseases in row crops. The prairie could potentially provide habitat for crop pests, particularly stalk borers and grasshoppers, but the effect of the pests on the crop would likely be limited to the first few rows adjacent to the prairie (R. Pope personal communication).

Will Management of the Prairie Conflict with Management of Crops?

Established prairies require little management, but depending on the desired use for the prairie, some management may be needed (see pages 14-21 for a discussion of profit-gaining uses of prairies). During the establishment year(s) of the prairie, however, the site will need to be prepared and the prairie will need to be seeded and managed (see pages 8-11). There is, however, a great deal of flexibility in the timing of these activities.

What If I Decide I Don't Want the Prairie? Can I Get Rid of the Prairie?

Converting a prairie back to row crops is relatively easy. Herbicides, such as glyphosate, will kill the prairie plants, and the land could then be either tilled or used for no-till crop production. Some prairie seeds may germinate in subsequent years, but as described previously, the seedlings can be easily killed with tillage or herbicides. Prairie plants produce extensive root systems, however, and have a large amount of internal nutrient (especially nitrogen) cycling. Therefore additional fertilizer may need to be applied the year after the prairie is eliminated until the prairie roots begin to decompose and the nutrients become available for the crop.

Although it is easy to get rid of a prairie, almost all of the cost in having a prairie is incurred during the establishment year(s) (see page 8). Many of the government programs that provide cost sharing for prairie establishment require the landowner to commit to leaving the land in prairie for a specified number of years (ranging from 10 years to a permanent easement). If the prairie is removed before that time, the landowner must repay all or part of the cost-sharing allotment.

It is important to remember that the prairie will look weedy during the establishment year(s). Decisions to remove the prairie should be delayed until after the third growing season.

Why Prairies? Why Now?

There are likely to be significant changes in agriculture in the near future due to changes in fossil-fuel prices and availability, pollution regulation, and climatic factors. Annual row-crop agriculture is heavily dependent on inexpensive fossil-fuel energy for fuel for machinery and grain drying and fertilizer and pesticide production. As fossil fuels become more limiting, different – and likely more expensive – energy sources will have to be used, which will decrease the profitability of row crops. If greenhouse gas emissions and nitrogen and phosphorus pollution become increasingly regulated, the production and leakage of these compounds into the environment from annual row crops will introduce new costs for farmers. Global climate change will also affect agricultural practices by altering the climate, but potentially more importantly by increasing the frequency of extreme weather events, such as flooding, drought, and untimely frosts.

Diverse prairies are more resilient systems than monocultures of annual row crops. Resilience refers to the ability of a system to resist damage from adverse conditions and rebound rapidly if the system is damaged. Diverse prairies are able to resist damage from potentially adverse conditions because multiple species are present at all times. Therefore if one particular species is damaged – by disease for example – other species are present to become more abundant as the affected species declines. Monocultures lack this feature because it is likely that all plants will be affected by the adverse condition similarly as all plants are the same species. Prairies also rebound rapidly from damage. For example, if the aboveground parts of the plants are damaged, the roots contain large stores of energy from which new aboveground biomass can be produced. Most prairie plants are much more conservative than annual row crops; they have extensive stores of resources belowground rather than investing most of their energy into aboveground biomass production.

Soil under row-crop production (left) and remnant prairie (right).

Can Prairies Be Used as Part of Multifunctional Landscapes?

The deep, rich soils produced by the prairie have been the cause of the near extinction of the prairie; most of the tallgrass prairie has been converted into agriculture. In some drier parts of the country that have mixed- and shortgrass prairies, however, the prairies have remained because the land is more conducive to grazing than row-crop production. Therefore there is a long history of using prairies for large-scale, profit-gaining purposes, but using tallgrass prairies for profit-gaining uses has not been adopted on a large scale because higher productivity can be obtained with annual row crops using intensive management and large inputs of fertilizer and pesticides.

There are multiple profit-gaining uses for tallgrass prairies that are environmentally beneficial and may become economically competitive with annual row crops in light of future changes in agriculture (see "Why Prairies? Why Now?"). The following three profit-gaining uses for prairies will be discussed:

- Livestock grazing and hay production (pages 16-17)
- Biomass feedstock production (pages 18-19)
- Carbon sequestration (pages 20-21)

Using Prairies for Livestock Grazing and Hay Production

What Is It?

Tallgrass prairies evolved with fire and ruminant, especially bison, grazing. These disturbances prevented the prairie from becoming dominated by woody vegetation. Bison grazing also helped maintain prairie diversity because bison preferentially eat warm-season grasses, which are the dominant prairie plants (Collins et al. 1998). It is likely that the historic patterns of fire and bison grazing were patchy and sporadic. Grazing livestock or haying the prairie can act as effective substitutes for fire and bison grazing, and both can be managed to be patchy and sporadic.

Grazing livestock on prairie in rotational or high-intensity grazing systems can be an effective means of maintaining prairie diversity while producing high-quality livestock meat or dairy products. In rotational and high-intensity grazing, livestock are moved frequently, from multiple times per day to once per one or two days, through small paddocks of prairie. The livestock consume most of the available standing biomass while in the paddock, but the paddock is then allowed to regrow without any livestock disturbance for multiple weeks to a whole year. These forms of grazing are management intensive, but closely mimic historic prairie disturbances.

Producing prairie hay is another method of producing a valuable product while still maintaining prairie diversity. Prairie hay can receive price premiums because the legumes and forbs in the prairie provide trace nutrients that may not be found in other hays. Determining when to harvest a prairie for hay is a compromise between maximum forage quality and maximum forage quantity. Peak prairie forage quality occurs in June, whereas maximum aboveground biomass occurs early August. It is recommended for prairie hay to be harvested in mid- to late July, and for prairie hay to only be harvested once per year in order to maintain the vigor of the prairie in subsequent years.

Economics - Costs (Livestock Grazing) For haying estimates see page 18.

Expenses	Price ($/acre)
Land rent	
Land currently in row crops	$147 – 201[1]
Land currently in pasture	$35 – 77[1]
Calf purchase (@ $1.08/pound for 525 pound calf; 1.4 calves/acre stocking rate)[2]	$802[3]
Fertilization	
Nitrogen (@ $0.68/pound from 0 – 150 pounds N/acre)	$0 – 102[4]
Phosphate (@ $0.90/pound from 0 – 50 pounds phosphate/acre)	$0 – 45[4]
Potash (@ $0.72/pound from 0 – 50 pounds potash/acre)	$0 – 36[4]
Application	$2 – 18[5]
Infrastructure	$9[3]
Other non-pasture costs[6]	$16[3]
Labor (@ $14/hour and 1 hour/calf)	$20[3]

[1]Edwards et al. 2009a
[2]Includes a 1% death loss rate
[3]Ellis et al. 2009
[4]Duffy and Smith 2009
[5]Edwards et al. 2009b
[6]Includes veterinary and fixed and variable machinery and equipment costs

What Would a Grazing Prairie Look Like?

Although prairies in the tallgrass prairie region are named for the conspicuous warm-season grasses that are often dominant, the composition and productivity of prairies can vary greatly. The desirable species composition of a prairie will depend on the location of and planned use for that prairie. The effects of the management of the prairie, such as livestock grazing or haying, also need to be considered when planning the species composition in order to ensure that species tolerant of the particular management regime are chosen.

If a prairie is used for rotational or high-intensity grazing, the prairie essentially becomes a set of mini-prairies, which are the paddocks, because different prairie species will be desirable in different paddocks. Grasses will likely be dominant components of all of the paddocks because grasses are highly productive and are desirable forages for livestock, but the relative amounts of cool-season grasses versus warm-season grasses will depend on the desired grazing time for the paddock. Native cool-season grasses generally have higher re-growth rates after grazing than warm-season grasses, and the growth of cool-season grasses is greater than that of warm-season grasses in the spring and fall. Therefore, some paddocks should be planted with higher concentrations of cool-season grasses than might otherwise be used in a prairie reconstruction, and those paddocks can be grazed in the spring and fall. The remaining paddocks can be planted with a mix dominated by warm-season grass, and those paddocks can be grazed in the summer. The paddock grazing order should be changed yearly so that the same paddock is not being grazed at the same time every year. Paddocks should not be grazed more than two times in any one year and generally should be grazed only once per year, especially those paddocks dominated by warm-season grasses.

In prairies that are hayed, the composition of the prairie may be more variable, and the expected market for the hay may be important in determining the species composition. For example, big bluestem can be a particularly desirable component in horse hay. Although harvesting the prairie in mid- to late July is desirable, the exact harvesting date of the prairie can also be variable in order to maintain prairie diversity. The prairie should not be harvested after early August, however, in order to allow the plants to produce sufficient carbohydrate storage reserves for the winter.

Fertilization, specifically nitrogen fertilization, can be used to increase the productivity of the prairie and increase the nutrient concentrations in the plant tissues; although annual fertilization is not necessary in managing prairies for grazing or haying. For grazing in particular, many of the nutrients, including most of the phosphorus and potassium and some of the nitrogen that the animals remove, are recycled back to the prairie through the animals' urine and manure. Annual fertilization may be strategically used, however, for specific or short-term objectives with few long-term, adverse effects on the prairie. High rates of fertilization over a long period of time may lead to a decline in legume and forb concentrations because the grasses are likely to out compete the legumes and forbs when nutrient availability is high.

Economics - Gain (Livestock Grazing) ***For haying estimates see page 19.***

Income	**Price ($/acre)**
Yearling steer	
1 pound daily weight gain/calf (for 150 days @ $0.70 – 1.00/pound)	$662 – 945
2 pound daily weight gain/calf (for 150 days @ $0.70 – 1.00/pound)	$809 – 1155

Using Prairies to Produce Biomass Feedstocks

What Is It?

Feedstock is a general term that describes a raw material used to create a product. In this case, the feedstock is plant biomass. Plants, including prairie plants, are composed primarily of energy-dense structural compounds that are not readily digestible by animals, including humans, but can be used to produce energy if broken down correctly. These compounds are cellulose, hemicelluloses, and lignin and generally account for more than 75% of prairie plant biomass. Prairie biomass can be used as a feedstock for either direct combustion or conversion into a biofuel.

Prairie biomass can be burned by direct combustion for heat and/or electricity generation. One proposed method of producing electricity from prairie biomass is to burn the biomass with coal (called co-firing) in existing coal power plants. Co-firing switchgrass, a warm-season prairie grass, with coal was demonstrated at a previously all coal-fired power plant in Chariton Valley, Iowa in 2006. For smaller scale heat generation, prairie biomass can also be pelletized and used for home heating in stoves similar to wood- and corn-pellet stoves.

A proposed future use of prairie biomass is for conversion into biofuels. Biofuel is a general term used to describe all fuels produced from recently living plant material. Different types of biofuels can be produced as liquid transportation fuels such as corn-grain ethanol, biodiesel, cellulosic ethanol, synthesis gas, and bio-oil. Approximately 95% of the biofuel produced in the United States in 2008 was corn-grain ethanol, which is produced when microbes ferment the starch contained in corn kernels into ethanol. The remainder of the biofuel produced in the United States in 2008 was biodiesel, which is produced from oils, primarily soybean oil in the United States.

A dollar for dollar government subsidy matching program has been proposed for feedstock prices up to $45/ton (Harte 2008).

Cellulosic ethanol is not being produced on a commercial scale in the United States yet, but in passing the Energy Independence and Security Act of 2007, the U.S. Congress mandated the production of 16 billion gallons of cellulosic ethanol by 2022. Cellulosic ethanol is similar to corn-based ethanol in that plant material is ultimately converted into liquid fuel. Cellulose, however, is harder to break down than starch

Economics - Costs

Expenses	Price ($/acre)
Land rent	
Land currently in row crops	$147 – 201[1]
Land currently producing grass hay	$60 – 138[1]
Fertilization	
Nitrogen (@ $0.68/pound from 0 – 150 pounds N/acre)	$0 – 102[2]
Phosphate (@ $0.90/pound from 0 – 50 pounds phosphate/acre)	$0 – 45[2]
Potash (@ $0.72/pound from 0 – 130 pounds potash/acre)	$0 – 94[2]
Application	$2 – 18[3]
Harvest costs	
Mow/conditioning	$8 – 17[3]
Raking	$2 – 10[3]
Baling[4]	$59 – 139[3]
Removing from the field (@ $3.00/bale)	$18 – 45[3]

[1]Edwards et al. 2009a
[2]Duffy and Smith 2009
[3]Edwards et al. 2009b
[4]Assuming large square bales @ 950 lbs/bale; @ $9.40/bale from 3 – 7 ton/acre

due to its chemical structure and the relatively small number of microorganisms that can attack and digest it. Other biofuels that are more similar to gasoline or diesel can be produced from synthesis gas or bio-oil, which are produced when lignin, cellulose, and hemicelluloses in plant material are combusted at high temperatures. Synthesis gas and bio-oil are also not yet produced on a commercial scale, though similar technologies for converting coal to liquid fuels have been used in some countries for decades.

What Would a Bioenergy Feedstock Producing Prairie Look Like?

Three interrelated characteristics of prairies managed for biomass feedstock production are high warm-season grass dominance, high productivity, and low nutrient concentrations in harvested biomass. Biomass used for direct combustion or to produce biofuels should be as dry as possible because energy is used to transport and remove the water from the biomass, and wet biomass is susceptible to decomposition. In prairie systems in which the goal is to produce large amounts of dry biomass, a single harvest after the plants have senesced is ideal. Warm-season prairie grasses, such as switchgrass, Indiangrass, and big bluestem, are the most productive group of plants in this type of system. Therefore a seeding mix that contains mostly warm-season grasses (more than 75%) will help establish the desired prairie composition. Using plants that contain relatively low tissue nutrient concentrations in the harvested biomass is beneficial because nutrients in the harvested biomass are waste products when the biomass is being used to produce energy, and keeping the plant nutrients in the field reduces fertilizer requirements. Prairie plants translocate nitrogen from aboveground biomass to the roots and leach phosphorus and potassium into the soil via rainfall at the end of the growing season, which makes the harvested biomass relatively nutrient poor and the nutrients available for the plants to use in subsequent growing seasons (Samson et al. 2005).

Occasional fertilization may be desirable in prairies grown for biomass production because nutrients will be removed from the prairie with each harvest. Fertilization, particularly nitrogen fertilization, will also increase the productivity of the prairie, but it can decrease the species diversity of the prairie. There is generally a linear increase in harvestable biomass of warm-season prairie grasses with increasing nitrogen fertilization up to approximately 100 lbs N/acre (Heggenstaller et al. 2009). The composition of the prairie will affect the amount of nutrients harvested each year. For example, cool-season grasses can contain twice as much nitrogen in the harvested biomass as warm-season grasses.

Economics - Gain

Income	**Price ($/acre)**
Biomass	
Prairie producing 3 ton/acre (@ $15 – 45/ton)	$45 – 135
Prairie producing 7 ton/acre (@ $15 – 45/ton)	$105 – 315

Using Prairies to Sequester Carbon

What Is It?

Carbon sequestration is removing carbon from the atmosphere – usually as carbon dioxide (CO_2) – and storing it for long periods of time. The CO_2 can be removed from the atmosphere by plants and animals and stored belowground or in water. For example, plants remove CO_2 from the atmosphere in order to perform photosynthesis (the CO_2 is converted into sugars). Some of the sugars are used by the plant during metabolism, but some of the sugars are used to produce roots. When the roots die, microbes decompose some of the dead roots and release the carbon as CO_2 again, but some of the carbon is not decomposed and remains belowground for tens to hundreds of years.

Carbon sequestration is of great interest because atmospheric CO_2 concentrations are increasing and are contributing to global climate change (in addition to other greenhouse gasses such as methane and nitrous oxide). Governments around the world have or are beginning to implement policies to reduce greenhouse gas emissions and increase the amount of carbon sequestered. In the European Union there is a mandatory cap-and-trade greenhouse gas trading system in which companies that emit greenhouse gasses are given a maximum level of greenhouse gas emissions. If the companies emit more greenhouse gasses than they are allowed to emit, they must either invest in technologies to reduce their emission or buy emission credits from an organization or company that is either sequestering carbon or emitting greenhouse gasses below their maximum level. The United States has a voluntary cap-and-trade system, but legislation is currently being proposed that would make participation in the cap-and-trade market mandatory.

An Example – Carbon Credits for Wetlands

Wetlands can sequester large amounts of carbon. Dead plants (fallen aboveground parts and roots) decompose slowly in wetlands because wetlands are often anoxic (without oxygen) and decomposition is very slow when oxygen is absent. If a farm field was converted to a wetland, the amount of carbon stored in the wetland would increase – the wetland would be sequestering carbon. The carbon that is being sequestered can then be sold to a company that is emitting more greenhouse gasses then it is allowed to emit.

Economics - Costs

Expenses	Price ($/acre)
Land rent	
Land currently in row crops	$147 – 201[1]
Land currently producing grass hay	$60 – 138[1]
Land currently in pasture	$35 – 77[1]
Fertilization	$0 – 102[2]
Nitrogen (@ $0.68/pound from 0 – 100 pounds N/acre)	$0 – 68[2]
Application	$2 – 18[3]

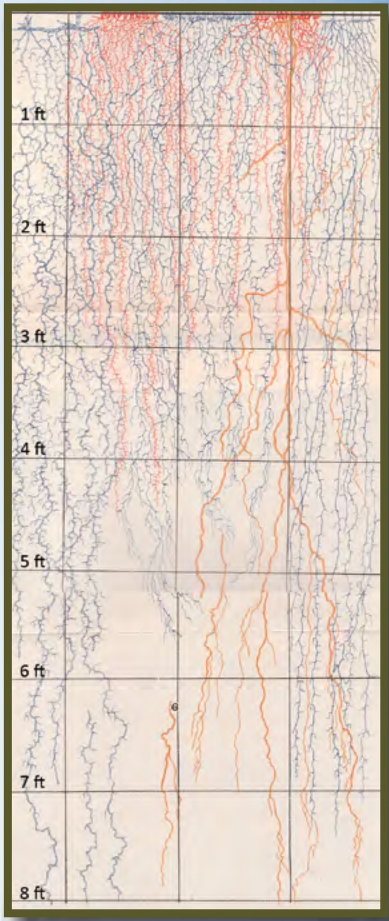
[1]Edwards et al. 2009a
[2]Duffy and Smith 2009
[3]Edwards et al. 2009b

What Would a Carbon Sequestering Prairie Look Like?

Not all prairies sequester carbon, but most of them do. The deep, organic-matter rich topsoils that are produced under prairies are the result of thousands of years of carbon sequestration. At some point, however, the amount of CO_2 released from the soil through decomposition is equal to the amount of new roots added to the soil. Many of the remnant prairies (prairies that have never been plowed) have reached this state of equilibrium, but remnant prairies make up less than 0.01% of the prairies in the tallgrass prairie region, so there is great potential for carbon sequestration under most prairies. Soil that was produced under prairies but has been converted to row-crop agriculture may contain only 10% to 70% of the carbon stored belowground compared with soil that has continuously grown prairie. Reconstructing prairies onto these soils can result in significant carbon sequestration for decades. Rates of carbon sequestration vary widely under different prairies, but average carbon sequestration rates are approximately 1 ton/acre•year (Piñeiro et al. 2009).

The composition of the prairie also affects the amount of carbon that is sequestered belowground. Prairies that produce a high yield aboveground often produce more roots than lower yielding prairies, and the amount of roots produced is the driving factor in determining the amount of carbon that is available to potentially be sequestered. Prairie grasses, particularly warm-season prairie grasses, produce more roots than most prairie forbs. Therefore prairies dominated by warm-season grasses have the potential to sequester more carbon than those dominated by forbs. Furthermore, the roots of warm-season grasses contain fewer nutrients (especially nitrogen) than cool-season grasses or forbs, making them decompose more slowly and remain in the soil longer.

Fertilizing prairies with nitrogen increases aboveground biomass production, but whether fertilization increases root production compared to unfertilized prairies is more variable. Furthermore, nitrogen fertilization leads to higher nitrogen concentrations in the roots, which may increase the decomposition rate of the roots. Although more research is needed, it does not appear that fertilizing prairies with nitrogen is an effective means of increasing the amount of carbon sequestered by prairies.



Line drawing of warm-season grass, cool-season grass, legume, and forb roots to 8 foot depth by J. E. Weaver.

Economics - Gain

Income	Price ($/acre)
Carbon credits (@ 0.93 ton CO_2/acre)	$2 – 28[1]

[1]CO2 sequestration rates from Piñeiro et al. (2009); prices from CCX (2009) and Nordhaus (2008)

Conclusions

The soil formed by tallgrass prairies is among the most agriculturally productive soil in the world. Because of its high inherent productivity nearly all of the tallgrass prairies have been plowed under and converted into cropland. Yet re-incorporating prairies back into landscapes dominated by row-crop agriculture can provide both short- and long-term benefits.

Prairies provide numerous ecosystem services that currently do not provide direct economic benefits to farmers and landowners. Some of the ecosystem services provided by prairies that were discussed previously are:

- reductions in soil erosion
- reductions in nutrient pollution
- enhancement of beneficial insects
- enhancement of wildlife and bird habitat
- stabilization of the hydrology of watersheds

There are some products and services that prairies provide, however, that are likely to have direct economic value in the near future such as:

- providing food for livestock
- producing biomass for conversion into biofuels or for direct combustion
- sequestering carbon

Incorporating prairies into multifunctional landscapes is one method of potentially gaining income from the prairies while receiving the numerous "free" ecosystem services that the prairies provide.

What Other Resources Are Available to Me?

Prairie Restoration Handbooks

- *The Tallgrass Restoration Handbook for Prairies, Savannas, and Woodlands* edited by Stephen Packard and Cornelia F. Mutel. There are two editions of this book both published by First Island Press; the first edition was published in 1997, the second edition was published in 2005. This is a comprehensive book (464 pages) on prairie, savanna, and woodland restorations. It provides both theoretical and practical perspectives on restorations.
- *A Practical Guide to Prairie Reconstruction* by Carl Kurtz was published in 2001 by the University of Iowa Press. This is a much shorter book (57 pages), and focuses on the preparation and management needed to restore prairies.

Plant Identification Books (for both prairie plants and weeds)

- *Tallgrass Prairie Wildflowers: A Field Guide* by Doug Ladd with photos by Frank Oberle was published in 1995 by Falcon Publishing, Inc. This prairie plant identification book contains color photos of 295 species with a full page description of each species.
- *Wildflowers: Northeastern/North-central North America* by Roger Tory Peterson and Margaret McKenny with illustrations by Roger Tory Peterson. This book is part of the Peterson Field Guide Series and is published by the Houghton Mifflin Company. The most recent version is from 1996. This book contains more than 1,000 species with some color photos and many line drawings.
- *Weeds of the Northeast* by Richard H. Uva, Joseph C. Neal, and Joseph M. DiTomaso was published in 1997 by Cornell University Press. Although the focus of this book is weeds in the Northeastern U.S., many of the 299 weed species described in this book are common in the midwestern U.S. and in prairie restorations.
- *Wetland Plants and Plant Communities of Minnesota and Wisconsin* by Steve D. Eggers and Donald M. Reed was most recently published in 1997 by the U.S. Army Corps of Engineers in the St. Paul District. This book has color photos and line drawings of 144 wetland plant species that are common to midwestern wetlands.

Useful Websites for Prairie Restorations

- The Iowa Natural Resource Conservation Service (NRCS) has an online "Native Grass Seeding Calculator" that allows users to design prairie seeding mixes. It assists in selecting appropriate species for the site characteristics and provides seeding cost estimates. The calculator is available at the bottom of the "Iowa NRCS Technical Resources" webpage: http://www.ia.nrcs.usda.gov/technical/
- The United State Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) maintains the "PLANTS Database" which provides photographs and distribution maps of nearly all of the plants in the U.S. The database is available at: http://plants.usda.gov/

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