Great Plains

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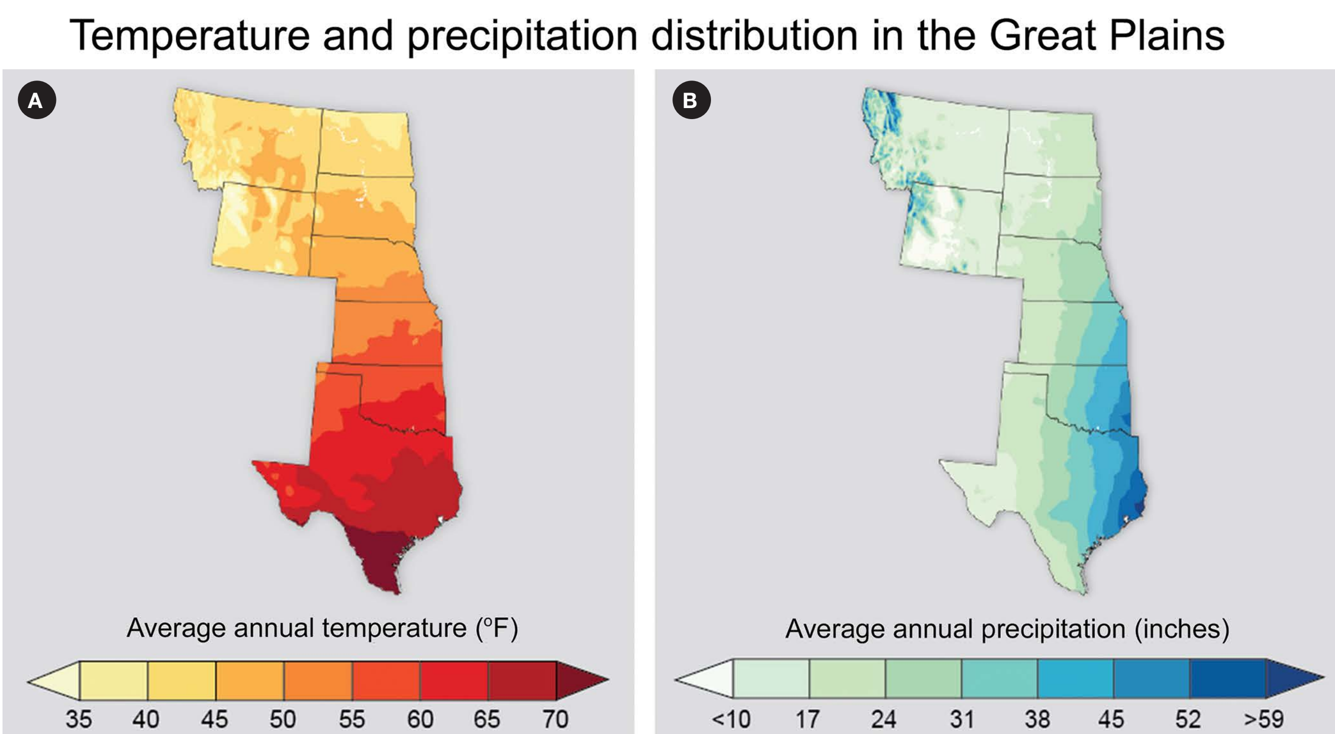
Description of the Region

Extending from Mexico to Canada, the Great Plains Region covers the central midsection of the United States and is divided into the northern Plains (Montana, Nebraska, North Dakota, South Dakota and Wyoming) and the southern Plains (Kansas, Oklahoma, and Texas). This large latitudinal range leads to some of the coldest and hottest average temperatures in the conterminous United States and also to a sharp precipitation gradient from east to west (fig. A.6). The region also experiences multiple climate and weather hazards, including floods, droughts, severe thunderstorms, rapid temperature fluctuations, tornadoes, winter storms, and even hurricanes in the far southeast section (Karl et al. 2009).

Agriculture is the dominant land use in the Great Plains, with more than 80 percent of the region dedicated to cropland, pastureland, and rangeland (Shafer et al. 2014). This sector generates a total market value of about $92 billion, approximately equally split between crop and livestock production (USDA ERS 2012). Agricultural activities range in the northern Plains from crop production, dominated by alfalfa, barley, corn, hay, soybeans, and wheat to livestock production centered on beef cattle along with some dairy cows, hogs, and sheep. In the southern Plains, crop production is centered predominantly on wheat along with corn and cotton, and extensive livestock production is centered on pastureland or rangelands and intensive production in feedlots. Crop production is a mixture of 82 percent dryland and 18 percent irrigated cropland, with 34 and 31 percent of total irrigated cropland in the region occurring in Nebraska and Texas, respectively (USDA NRCS 2013). In the most arid portions, where irrigation is not available and land is not suitable for cultivation, livestock grazing is the predominant operation (Collins et al. 2012).

Figure A.6. The Great Plains Region has a distinct north-south gradient in average temperature patterns (A), with a hotter south and colder north. For precipitation (B), the regional gradient runs east-west, with a wetter east and a much drier west. Averages shown here for the period 1981 to 2010. (Kunkel et al. 2013).



Life in the Great Plains has always been played out against the backdrop of a challenging climate, the massive and extensive drought of the 1930s being a poignant example. Increasing frequency and intensity of extreme weather events, however, is starting to have a greater impact on agriculture and communities within the region. Since 2011, the region has suffered from severe droughts with swings to significant flooding in both the southern and northern Plains, resulting in agricultural losses in the billions of dollars (NOAA 2014). Changes in the overall climate are also ushering in new conditions that will require Great Plains agriculture to adapt. For instance, the average temperature in the Great Plains has already increased roughly 0.83 °C relative to a 1960s and 1970s baseline (Karl et al. 2009). Creating more diverse and resilient farming systems will help mitigate these challenges.

Both positive and negative impacts are predicted for the Great Plains as a result of climate change (Melillo et al. 2014). Although a longer growing season and increased levels of carbon dioxide (CO_2) in the atmosphere may benefit some types of crop production, unusual heat waves, extreme droughts, and floods may offset those benefits (Walthall et al. 2012). Farm diversification and intensification through agroforestry may help offset some of the negative effects of climate change. Before discussing the agroforestry practices that are relevant for the Great Plains, we describe a few of the key threats and challenges that Great Plains agriculture faces as a result of climate change.

Threats and Challenges to Agricultural Production and Community Well-Being

Heat events and droughts are expected to increase in frequency, along with higher temperatures (Kunkel et al. 2013). These conditions can lead to soil erosion by wind, which is a significant threat to both production and human well-being in the region (fig. A.7).

Figure A.7. Dust storm event in southern Lubbock County, TX, on June 18, 2009. (Photo by Scott Van Pelt, USDA Agricultural Research Service).

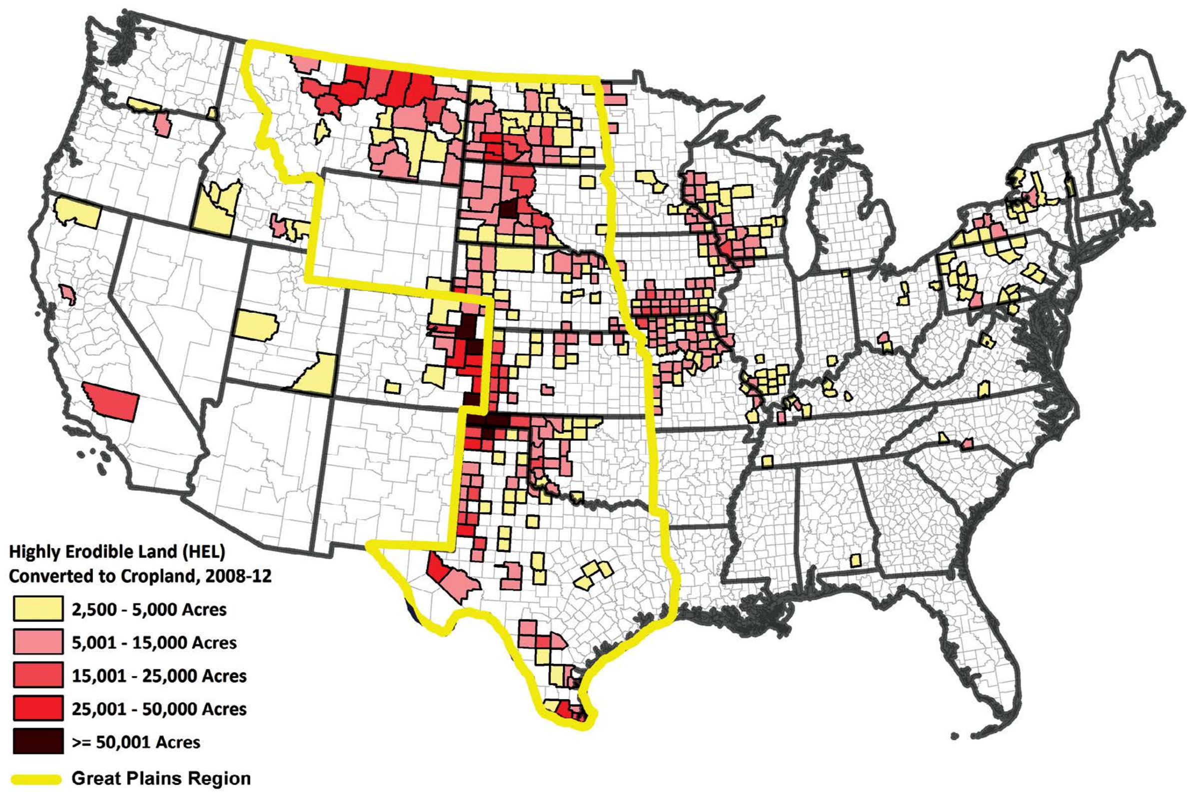
Some of the largest areas of highly erodible soils occur within this region (USDA NRCS 2013), with an increasing portion of these soils being converted to crops (fig. A.8) (Cox and Rundquist 2013). Although best management practices have reduced wind erosion during the past several decades, many areas are still above the tolerable rate for soil loss, and these rates are rising again due to extreme weather events (USDA NRCS 2013). In addition to the loss of soil productivity with wind erosion, human health and safety are also issues. The droughts of 2011 through 2014 have increased blowing dust events throughout the Plains, reducing air quality and contributing to road-related accidents and fatalities (Lincoln Journal Star 2014) and also to asthma and other lung diseases (see the Air Quality section in chapter 2).

The duration of droughts and heat waves is expected to increase in the southern Plains (Kunkel et al. 2013). These changes will impact crop productivity and livestock operations in terms of animal heat stress and obtaining affordable feed (Ojima et al. 2012). Indications are the northern Plains will have higher precipitation and warmer temperatures, creating longer growing seasons (Kunkel et al. 2013) that will continue to facilitate the northward migration of corn and soybean production (Barton and Clark 2014). The northern Plains will remain vulnerable to periodic droughts, however, because much of the projected increase in precipitation is expected to occur in the cooler months, and increasing temperatures will result in higher evapotranspiration during the growing season (Kunkel et al. 2013). In addition, these same conditions are expected to result in a northward spread of insects and weeds (Walthall et al. 2012). Increasing heavy precipitation events in the northern Plains are expected to worsen flooding and runoff events, impacting soil erosion, water quality, and downstream communities (Groisman et al. 2004, Kunkel et al. 2013).

Climate projections indicate that competition for the region's declining water resources will continue to intensify, especially in areas of irrigated corn production in the Great Plains (Barton and Clark 2014). Johnson et al. (1983) predicted this area would need to eventually return to a dryland production system within 15 to 50 years due to water scarcity. With the continued water drawdown occurring in the High Plains aquifer, the long-term outlook for irrigated operations remains uncertain (Brambila 2014, Sophocleous 2010). Given the future climate projections for this area, the need to begin making a transition, at least in part, to production systems less dependent on water seems inevitable.

Because communities in the Great Plains depend highly on farms and ranches, any reductions in agricultural output and income from climate change pose a significant threat to rural economies and vitality. Rural and tribal communities in the region already face challenges because of their remote locations, sparse development, and limited local services, which

Figure A.8. Between 2008 and 2012, 5.3 million acres of previously uncultivated, highly erodible land were planted with row crops. Fully 73 percent of that conversion occurred in 425 hotspot counties identified in this map, with most of the counties being within the Great Plains. (From Cox and Rundquist 2013. Copyright Environmental Working Group, http://www.ewg.org. Reprinted with permission).



only will be exacerbated by climate extremes (Shafer et al. 2014). Working-age people are moving to urban areas, leaving behind a growing percentage of elderly people and diminished economic capacity in rural communities (Ojima et al. 2012). Approximately 80 percent of Great Plains counties have a higher percentage of older residents than the U.S. average (Wilson 2009). Reducing risks to agriculture production will be an important step in maintaining economically viable communities, which underlies community well-being.

Agroforestry as an Opportunity To Build Resilience

Agroforestry first came into widespread use to deal with extreme weather events in the Great Plains during the 1930s. To combat one of the largest wind erosion events in the United States, the 1930s Dust Bowl, more than 200 million trees and shrubs were planted in windbreaks from North Dakota to Texas through the Prairie States Forestry Project (Droze 1977) (see box 2.1). This region continues to be the largest user of this practice because of the preponderance of wind in the region (figs. A.9 and A.10). The protective services of windbreaks to

Figure A.9. Most windbreaks established each year are in the Great Plains Region based on linear feet of windbreak. Data from 2010 are presented because the proportions remained similar across all 4 years. No windbreaks were established in Alaska based on these data. (Data [2008 to 2010] derived from USDA Natural Resources Conservation Service National Practice Summary information).

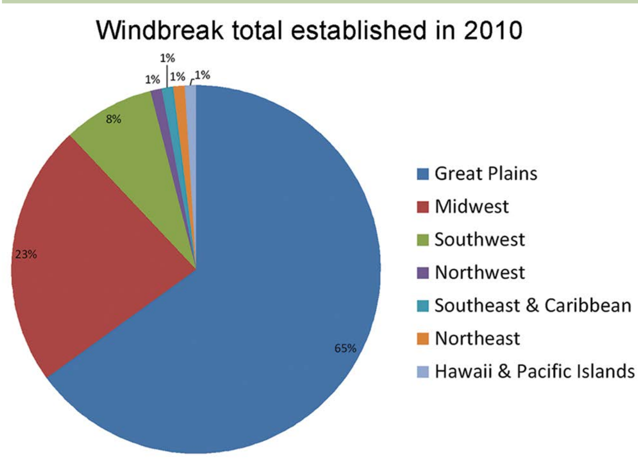
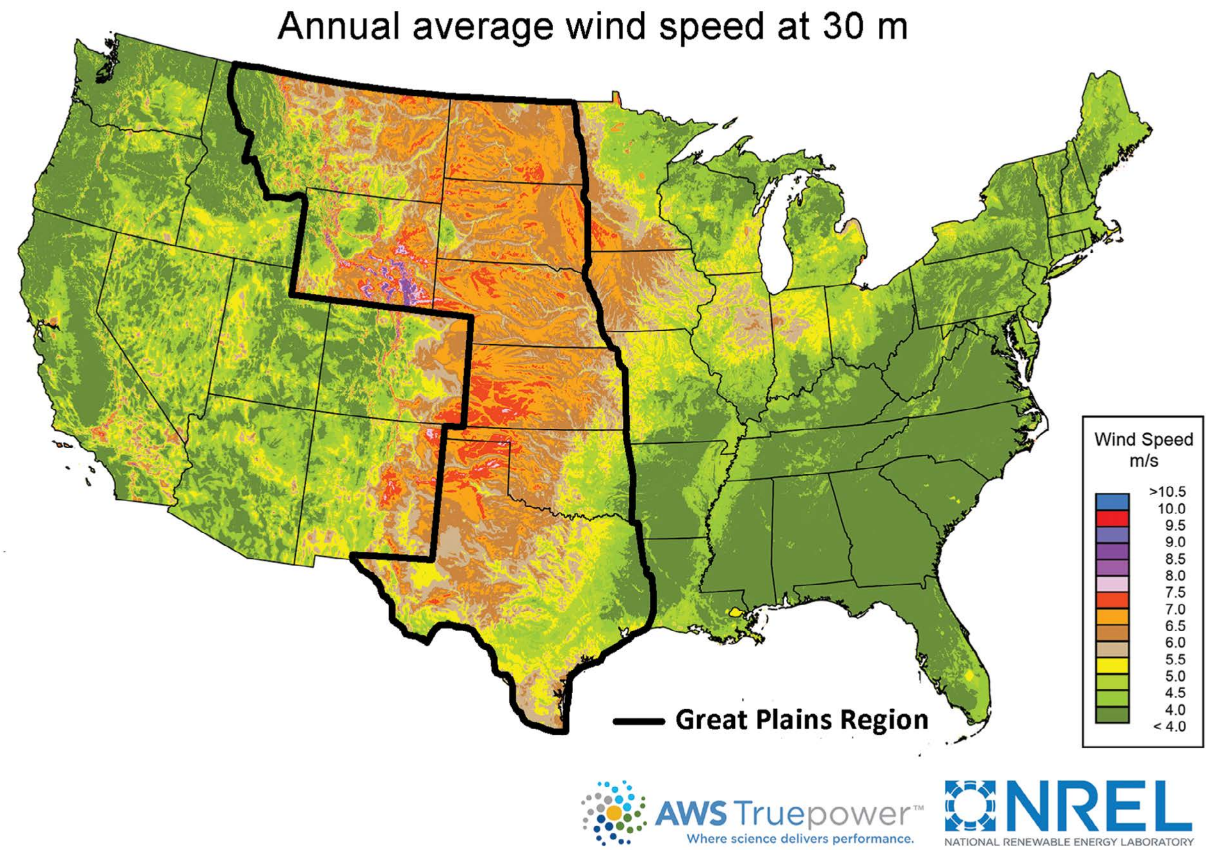


Figure A.10. Wind is a dominant feature in the Great Plains Region, as illustrated by this map, which shows the predicted mean annual wind speeds at a 30-meter height based on model-derived estimates. (Wind resource estimates developed by AWS Truepower, LLC. Map developed by the National Renewable Energy Laboratory).



favorably modify microclimate for crops, livestock, farmsteads, and wildlife remain the primary reason for use in the region (Anderson 1995, Schaefer and Ball 1995) (see also chapter 2). As awareness of water-quality and streambank-stability issues in the Great Plains has emerged, interest in the protective services of riparian forest buffers has also increased. Table A.4 summarizes the agroforestry practices that are most relevant to the Great Plains Region.

Table A.4. Agroforestry practices that have current or potential importance in the Great Plains Region.

Practice	Relevance to Great Plains subregions
Field windbreaks	NGP, SGP
Livestock windbreaks	NGP, SGP
Farmstead windbreaks	NGP
Living snowfences	NGP
Riparian forest buffers	NGP, SGP
Silvopasture	SGP
Incorporating wildlife into agroforestry practice design	NGP, SGP

NGP = northern Great Plains. SGP = southern Great Plains.

Source: Adapted from Anderson (1995) and Schaefer and Ball (1995).

Windbreaks remain a logical choice for building greater resiliency in Great Plains agriculture. Field windbreaks in the Great Plains have the potential to increase irrigation/water use efficiency and, therefore, crop production in this region with a high evapotranspiration demand (Dickey 1988). This function of windbreaks could also be instrumental for making the transition from irrigated to dryland operations where necessary. Modeling efforts using several climate change models for Nebraska indicate that windbreaks may aid production during key points in the growing cycle for nonirrigated corn operations (Easterling et al. 1997). For nearly all levels of climate change, dryland corn yields were greater under sheltered than non-sheltered conditions, with the greatest benefit of shelter under conditions having the maximum precipitation deficiencies and windspeed increases. Modeling results suggested the following three climate change-related benefits of windbreaks on crop yield compared with open fields: (1) night-time cooling of the crop that would counteract daytime temperatures in sheltered fields, thereby lengthening the period to maturation and allowing for greater grain fill and yields; (2) reduction in respiration and increase in net primary productivity due to lower night-time temperatures; and/or (3) reduction in the number of days plants experience water stress due to reduced levels of evapotranspiration.

In the southern Plains, the role of windbreaks may be limited, depending on how severe growing conditions become and with the resultant shifts in profitability. Early windbreak work documented enhanced plant and boll biomass in cotton in Texas under sheltered conditions (Barker et al. 1985). Although windbreaks have also been demonstrated to benefit wheat production and protect soils (Brandle et al. 1984), current use is limited. Additional research and technology transfer efforts are needed to demonstrate windbreaks' biophysical and economic utility to combat current and projected climate impacts on the sustained production of this crop.

In the northern Plains, where snow and winter winds are more prevalent, windbreaks can be used to distribute snow across a field to replenish crucial soil moisture and to insulate fall crops against desiccation by cold, dry winter winds (Scholten 1988). Livestock in the Great Plains experience a high level of thermal stress at both extremes, impacting overall survival, production, and profitability. Windbreaks in the Great Plains can provide critical livestock protection during extreme cold/snow events and also during heat waves (see the Livestock Protection section in chapter 2).

Regarding community well-being, agroforestry plantings in the Great Plains—again, predominantly windbreaks and riparian forest buffers—may offer valuable services. Projected increases in winter and spring precipitation events in the northern Plains and the extreme events being predicted throughout the Plains can result in increased urban flooding, as evidenced in the Red River Valley (ND Forest Service 2010). Waterbreaks, a concept similar to windbreaks but with the primary purpose of modifying flooding impacts, could aid in reducing flood damage (Wallace et al. 2000). In addition, this practice could provide other ecological and economic returns from high-risk floodplain agriculture (Schoeneberger et al. 2012). Woody riparian vegetation can be effective in providing streambank protection during large flood events, such as documented in Kansas during the 1993 floods (Geyer et al. 2000). Properly located windbreaks can reduce home heating and cooling costs by as much as 10 to 40 percent (DeWalle and Heisler 1988). In the northern Plains, windbreaks can be used as cost-effective living snowfences to keep roads cleared and reduce snow removal costs and to also provide greenhouse gas emission mitigation and carbon (C) sequestration (Shaw 1988).

Valuation of services from windbreaks and other agroforestry practices in the Great Plains regarding on-farm and off-farm benefits is limited due to the lack of agroforestry inventory in the Great Plains and elsewhere (Perry et al. 2005). The Great Plains Initiative (GPI) is developing an approach to inventorying nonforest trees, including agroforestry, with future use of the method to extend beyond the Plains (Lister et al. 2012). Using 2009 GPI data, dollar values estimated for the various windbreak services in Nebraska were $9 million in annual gross income from field windbreaks based on improved crop yields, $24 million from energy savings due to farmstead windbreaks and $27 million in energy savings for acreages (Josiah 2016). The value of these services under changing climate would vary, depending on location in the region. These estimates do not include offsite benefits from these systems, such as reducing the cost of dealing with windblown soil removal and increasing C sequestration, two aspects being projected as having great significance under projected climate changes in the Plains. Adaptation strategies in the northern Plains can include using the beneficial microclimate effects of windbreaks on crop growth; on the winter protection of livestock, roads, and farmsteads; and on wildlife, as identified in chapter 2. The findings from Brandle et al. (1992) indicate a targeted windbreak planting program in the Great Plains could potentially provide considerable C contributions through C sequestration in the woody biomass and through indirect C benefits via avoided emissions and fuel savings realized through reduced home heating requirements and equipment usage in the tree-planted area.

Given the flexibility in designing agroforestry systems, options to contribute to production, mitigation, and adaptive services are many. For instance, the incorporation of suitable plant materials within windbreaks or riparian forest buffers could serve as an additional source of biofeedstock for onsite or school/community heating systems. In addition, harvesting biofeedstock from riparian forest buffers can enhance the nutrient-absorbing capacity of the plants, maintaining water-quality functions (Schoeneberger et al. 2012). Center pivot irrigation corners may provide areas for additional tree plantings that can provide wildlife habitat and C sequestration opportunities. The potential to store C in the woody biomass in pivot corners in Nebraska was estimated between 13 to 60 teragrams during a 40-year period from establishment (NE DNR 2001). These materials over time could also be used as biofeedstock for local heat or power generation if markets and infrastructure are available.

Challenges to Agroforestry Adoption

Although the value of agroforestry in the Great Plains has been demonstrated since the 1930s, its adoption in the Great Plains has been limited (Anderson 1995, Schaefer and Ball 1995). A lack of public understanding, institutional infrastructure, and quantitative information is identified as the main obstacle (Anderson 1995, Schaefer and Ball 1995). Reasons for lack of adoption in this region include—

- High cost of establishment and renovations.
- Difficulties/complexities of Farm Bill cost/share assistance programs.
- Lack of compatibility with farm machinery now used in larger scale operations.
- Perceptions that plantings are costing rather than benefiting operations; these costs includes real and perceived competition for water resources (Rasmussen and Shapiro 1990).
- Reluctance by producers to take on the longer management timeframes within a predominantly annual system.
- Limited need to adopt risk-reduction strategies for extreme weather events due to multiple-peril crop insurance (Wright 2014).
- Desire by producers to maximize production when crop prices are high.

Future climate variability and uncertainty will likely necessitate a shift in Great Plains production from maximization of yields per acre to one that can better use renewable resources and sustain production, incomes, natural resources, and communities. Agroforestry in the Great Plains has the potential to contribute to this end (Brandle et al. 1992, Schoeneberger et al. 2012). To increase the adoption of agroforestry in the Great Plains, both on-farm and off-farm valuations of services afforded by these plantings are needed. A study conducted in the northern Plains of Canada indicated windbreaks provided significant returns that extended beyond the individual practice and farm boundaries (Kulshreshtha and Kort 2009). Additional studies like this one will be valuable in providing a broader base of considerations in management decisionmaking.

Despite the benefits of windbreaks in the Great Plains, a big challenge is to keep these practices in place. The declining condition of windbreaks in the region has been identified as a significant issue, and many of these degraded windbreaks are being removed and not replaced because of recent high crop prices (Marttilo-Losure 2013). A nursery responsible for supplying many of the windbreak seedlings in the northern Great Plains has seen a 70-percent decrease in sales from 2002 to 2013 (Knutson 2014). Interest in the practice still exists, however, and two major windbreak workshops—the Great Plains Windbreak Renovation and Innovation Conference and the Southern Plains Windbreak Renovation Workshop—were held in 2012 and 2013. Continued opportunities for exchange of windbreak expertise will be required to modify the design and management of windbreaks and other agroforestry practices to address future conditions. One such effort is an ongoing Great Plains-wide effort to reevaluate the impact of windbreaks on crop yields, given current growing conditions, cultivars, and management practices.

Another challenge facing agroforestry use in the Great Plains is the availability of suitable plant material. Tree and other woody plant species will need to be resilient to the same future weather and climate shifts. Trees in the Great Plains historically have been exposed to numerous pests, diseases, and environmental conditions that hinder planting success, reduce their effectiveness, and limit their long-term survival. Damage in trees planted in the Prairie States Forestry Program was observed most commonly in trees previously stressed by drought (Read 1958). Modeling efforts by Guo et al. (2004) indicate that tree growth in agroforestry-like plantings may be impaired in the region under several climate change scenarios, likely affecting the services desired from these plantings. Findings from Wyckoff and Bowers (2010) suggest shifts in climate along with elevated levels of CO_2 may prompt the expansion of species from the eastern forests into the Plains, potentially increasing new options for suitable plant material.

The number of tree species historically used for agroforestry plantings in the Great Plains is few. Two primary species used in agroforestry plantings throughout the region, Scots pine (*Pinus sylvestris*) and green ash (*Fraxinus pennsylvanica*), are no longer recommended because of diseases and pests, with the recommendation for black walnut (*Juglans nigra*) also becoming questionable with the emergence of thousand cankers disease. Because stress events are expected to increase in the Great Plains, a greater diversity of plant materials and management strategies for creating resilient agroforestry plantings will be required. Although agroforestry alone might not create sufficient pressure for the innovation and production of suitable plant materials, the need for appropriate materials for community forestry, green infrastructure, restoration, and agroforestry should collectively create ample demand.

Key Information Needs

- Develop climate-smart design, planning, and management guidelines for agroforestry systems to better meet the needs and conditions of the Great Plains region.
- Conduct an economic assessment of internal and external benefits, from production to natural recourse conservation, derived over time from agroforestry practices in the Great Plains.
- Identify and produce on a large scale a variety of stress-/pest-/climate-resilient/resistant plant materials for use in the different Great Plains growing zones.

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