Agriculture, transportation and climate change: Considering the future of agricultural freight transport in the Upper Mississippi River Valley

A team of University of Wisconsin-Madison researchers took a closer look at how climate change might impact grain production and transportation in the Upper Mississippi River Valley. They surveyed current literature and interviewed 11 people across the supply chain, from private industry, state and local government, and agricultural and nonprofit organizations in this region. Their work sheds light on ways that climate change might affect agricultural production, markets and transportation in this region.

Agriculture in the Upper Mississippi River Valley watershed is part of the global food trade network; the flow of food from the Illinois-centered corn belt to Louisiana ports is the largest link, in terms of trade volume, between U.S. agricultural production and international markets (Lin et al. 2014). Climate change will impact supply chains and transportation, both directly through impacts on waterways and highways, and indirectly through changes to regional, national and international agricultural production patterns. Further complicating matters is the projection that climate will continue to change significantly over at least the next century, regardless of mitigation efforts. Adapting to these dynamic circumstances requires flexible, responsive protocols and relationships across the food supply chain that originates in this region—from farms in the five states, through grain elevators, trucks and barges, brokers, buyers, regulators, and global markets. A systemic shift in the transportation sector is needed to support efforts to adapt to a changing climate. In addition, the transportation sector will likely be asked to reduce emissions. The transportation sector is the second-biggest source of greenhouse gas (GHG) emissions in the United States, accounting for a third of CO_2 emitted through the burning of fossil fuel in 2011 (U.S. Department of State 2014).

Agricultural regions worldwide are contending with weather extremes and market upsets. Global food security depends on the resilience of farms in every region around the world. In the near term, farmers in the Upper Mississippi River Valley region will continue to export dairy, grains and specialty crops, while simultaneously contending with extreme weather. Increased volatility in natural systems may increase volatility in markets and intensify pressure on already fragile transportation systems and supply chains. As it stands, truck transportation is expected to continue to provide the majority of agricultural freight movement, even though GHG emissions from trucks are of concern.

Policies—both administrative and legislative—that support crop diversification as a public good may increase food system resilience. Farmers in the Upper Mississippi River Valley who integrate their production of commodity grain with more fruits and vegetables or perennial pastures for livestock may sell these crops to domestic rather than global markets. While such market shifts may enhance regional and environmental resilience, they could reduce the amount of grain available for international trade. Targeting public investment to meet changing transportation and infrastructure needs for regional food systems is recommended. This will entail support for rural and urban road infrastructure, attention to freight optimization, and investment in reorganizing how food flows within and between regions and countries.

Direct and indirect impacts

Predictions of the direct impact of climate change on agricultural transportation differ based on assumptions and variables such as the length of shipping seasons on the Mississippi River and Great Lakes, water levels in the Great Lakes, shipping cost comparisons between different trade modes and routes, and grain production in other exporting countries (Attavanich et al. 2013). In 2013, 65 percent of corn exports went through the Mississippi Gulf Port (Denicoff et al. 2014). In the Upper Mississippi River Valley, grain for export to markets via Atlantic shipping routes is trucked to barges that travel down the Mississippi River. Grain destined for Asian markets and ethanol heading for West Coast refineries travels west via rail. In 2013, about 45 percent of U.S. grain destined for export was moved by barge, 35 percent by rail and 20 percent by truck to outgoing ports (Sparger and Marathon 2015). In the U.S., from farm fields to terminal markets agricultural freight moves primarily by truck (Blanton 2015) on roads that are increasingly in poor repair. One interviewee noted that as farms have grown larger and livestock more concentrated, agricultural machinery and vehicles have become too heavy for rural roads as originally engineered. Another interviewee observed that rural road washouts are increasingly common as heavy rainfall pummels under-maintained roads. Moreover, all roads are compromised by climate extremes such as heat, moisture, and freezing and thawing, and require more maintenance than budgets allow (U.S. DOT 2015).

Quantitative models linking climate change, agriculture and food markets are increasingly sophisticated, but remain limited in their ability to address issues of scale and complexity (Antle 2015, Attavanich et al. 2013, Fischer 2005, Rotter et al. 2013). Models predicting the impacts of climate change on agriculture show that grain production may relocate, likely continuing to shift northward as it has since the middle of the last century (McCarl 2015a&b). While earlier yield models assumed that increased CO_2 would stimulate plant growth, more recent research suggests that weather-related changes that negatively impact plant productivity and decrease system diversity result in declining yields within a decade or less (Zhuoting 2012). These, and other, factors will alter demands on the transportation infrastructure for grain.

Markets drive farmers' production decisions, but regional changes in precipitation, temperature, and extreme weather events may reduce yields, shift cropping patterns northward, and erode transportation and supply chain infrastructure (e.g., Attavanich et al. 2013, Blanc and Reilly 2015, Zhuoting 2012). A growing world population, urbanization and a burgeoning middle class demand more grain (World Economic Forum 2015). This growing demand, coupled with the potential for extreme weather to disrupt supply from key grain producing regions (Attavanich et al. 2013), may result in regional food shortages and, in turn, political instability (World Economic Forum 2015, Bjerga 2012). The global market for commodity crops and national markets for animal feed and biofuels are changing, sometimes rapidly. These changes will influence the volume of commodity crops produced, where they are produced, and preferred freight transportation options (Blanc and Reilly, 2015; McCarl 2015a&b; Paloviita and Jarvela 2015). Crop and supply chain diversification at the regional level has the potential to add resilience to our food system in the face of unpredictable weather and markets (Aguilar et al. 2015, Blanc and Reilly 2015, Lengnick 2015, Lewandrowski and Zook 2015, Rotter et al. 2013).

Autonomous adaptation

Severe droughts in North America, Africa and Russia have and will likely continue to impact global grain supply chains. Globally, population growth and an expanding middle class are increasing food demand. In 2009, about 72 percent of U.S. corn exports went to five Organization for Economic Cooperation and Development (OECD) nations: Japan, Mexico, South Korea, Taiwan and Egypt. About nine percent of U.S. corn exports went to 70 nations designated by the United Nations Food and Agriculture Organization (FAO) as Low-Income Food Deficient. In 2009, 39 percent of the corn produced was used for ethanol (Olmstead 2011).

The interviews revealed concerns that increasingly volatile weather will intensify farming challenges across the Upper Mississippi River Valley, for all crops. Farmers are able to manage some of the risk, both to their crops and their soil, resulting from uncertain weather, through standard conservation practices such as cover cropping and contour planting. In addition to traditional soil conservation measures, diversifying annual crop production with perennial crops protects soil from erosion and increases carbon storage to reduce greenhouse gas (GHG) emissions (Lewandrowski and Zook 2015). Perennials can provide year-round ground cover and roots to hold soil in place. A five-year study of 12 agricultural watersheds in central Iowa found that strategically planting 10 percent of row crop fields to perennial prairie grass strips reduced runoff water nitrogen by 84 percent and phosphorus by 89 percent, respectively (Helmers et al. 2012, Zhou et al. 2014). However, farmers face increased economic risk with perennial crops. Incorporating perennial crops into a grain or livestock operation involves management risks associated with adopting new production practices and more complex farming systems. Establishing high-value perennial crops such as tree fruit and nuts requires a substantial capital investment, and may involve the need to create processing infrastructure. Perennial crops are at risk from extreme weather, especially temperature extremes in winter and spring and summer drought.

Supply chain disruptions could exacerbate grain shortages resulting from extreme weather events, affecting the spatial distribution of grain crop production and crop diversification. In the domestic livestock market, the regular flow of feed from grain farms to livestock operations is critical. One of the interviewees stated that livestock farmers are especially vulnerable to feed supply disruptions and cost increases due to extreme weather. This interviewee also said that domestic supply chain disruption is already occurring in coastal states where farmers may not raise feed for their own animals, due to high land prices. This person thought that population migration from coastal areas affected by climate change leads to an increase in inland land prices. Grain processors seek to geographically diversify their suppliers so that if extreme weather impacts crop production in one region, they will be able to source ingredients elsewhere (Bjerga 2012). This, in turn, increases transportation infrastructure demands.

To meet GHG reduction goals, and to reduce transportation costs, agricultural freight could move in more fuel-efficient ways that also reduce GHG emissions (Ala-Harja and Helo 2015).Ways to reduce emissions include expanding opportunities to move more grain via rail and barge, as well as rethinking truck transportation in urban and peri-urban areas. Another is to take advantage of engineering innovations such as aerodynamic trailers and alternative fuels for long- and short-haul freight movements. Bringing food production and markets closer together while increasing the distribution efficiencies of local markets is another approach to reducing emissions. Regionalizing food supply chains through integrated agricultural systems may reduce GHG emissions by decreasing the number of vehicles and amount of fuel required for food distribution (Bosona and Gebresenbet 2011, Jokinen et al. 2015). Reducing the need to ship food long distances will reduce emissions and improve food system resilience.

Planned adaptation

Government at all levels is being called upon to identify and develop solutions to volatility in natural and human systems, including crop production and agricultural market dynamics, resulting from a changing climate. Supply chain disruptions due to extreme weather events, and pest and disease outbreaks, may become more common. Processors and end users are sourcing food and feed grains differently, and from multiple sources, to adapt to these disruptions. Government responses that reduce immediate risks to people and economies, while supporting long-term private sector adaptation, are key.

Federal farm policy reduces the risk of growing some crops. The 2014 Farm Bill re-linked conservation program participation to insurance premium subsidies for highly erodible lands and wetlands, while reducing overall funding for conservation programs (NSAC 2014a). Conservation compliance is assessed based on USDA's erodibility index. This index averages rainfall and other criteria over the past 30 years. Useful as it is, past weather data masks current trends toward more erratic and heavy rainfall events. The 2014 Farm Bill includes provisions supporting on-farm diversification, such as Whole Farm Revenue Insurance and planting flexibility up to 35 percent of base acres (NSAC 2014b). Supporting regional agricultural diversity both in the U.S. and abroad is critical to maintaining flexibility in food provisioning. Globally, small- to mid-scale farmers are increasingly vulnerable to risks associated with climate change and become targets of financial speculation that work against diversification (Isakson 2015).

Federal and state transportation policies guide public investment in surface transportation infrastructure. U.S., state and local transportation infrastructure is in dire need of repair and rejuvenation to meet present agricultural transportation needs. The current federal gas tax is not enough to keep public infrastructure in good repair. This tax has not increased for over 20 years and the federal Department of Transportation is predicting an annual shortfall of $12 billion in the Transportation Trust Fund (U.S. DOT 2015). Because federal and state funds for transportation are insufficient, understanding agricultural needs now and anticipating future needs may help prioritize public investment. Interviewees often mentioned rail as a cost effective and fuel efficient alternative to truck and barge transportation (Tolliver et al. 2013), but privately owned and operated rail introduces more complexity into negotiations across the supply chain and requires private sector, rather than public sector, investment. Agricultural products are weak competitors with other products, such as petroleum, for rail access. Furthermore, there are historic conflicts between rail and other transportation modes. There are a few state-owned shortline rail lines, but these are not sufficient to serve as anything more than models for possible government investment in rail.

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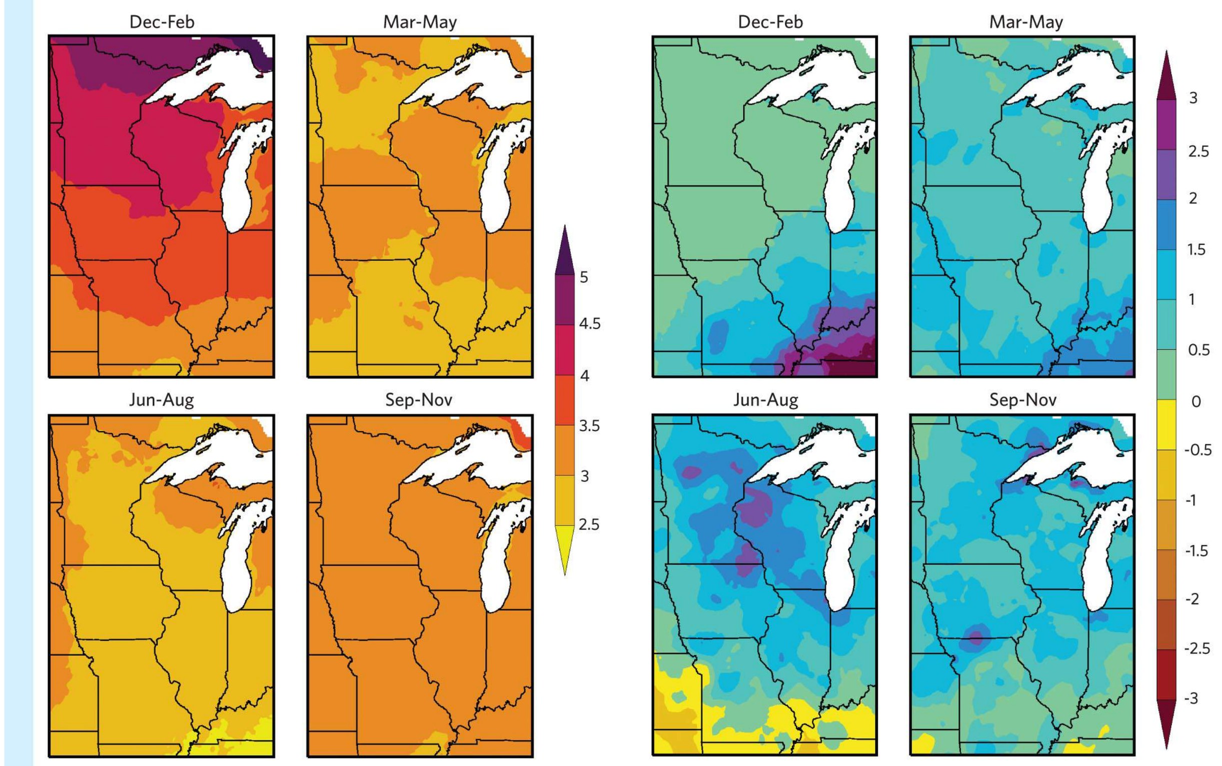
Figure 1. Modeled change in temperature (°C) by season, 2045-2065

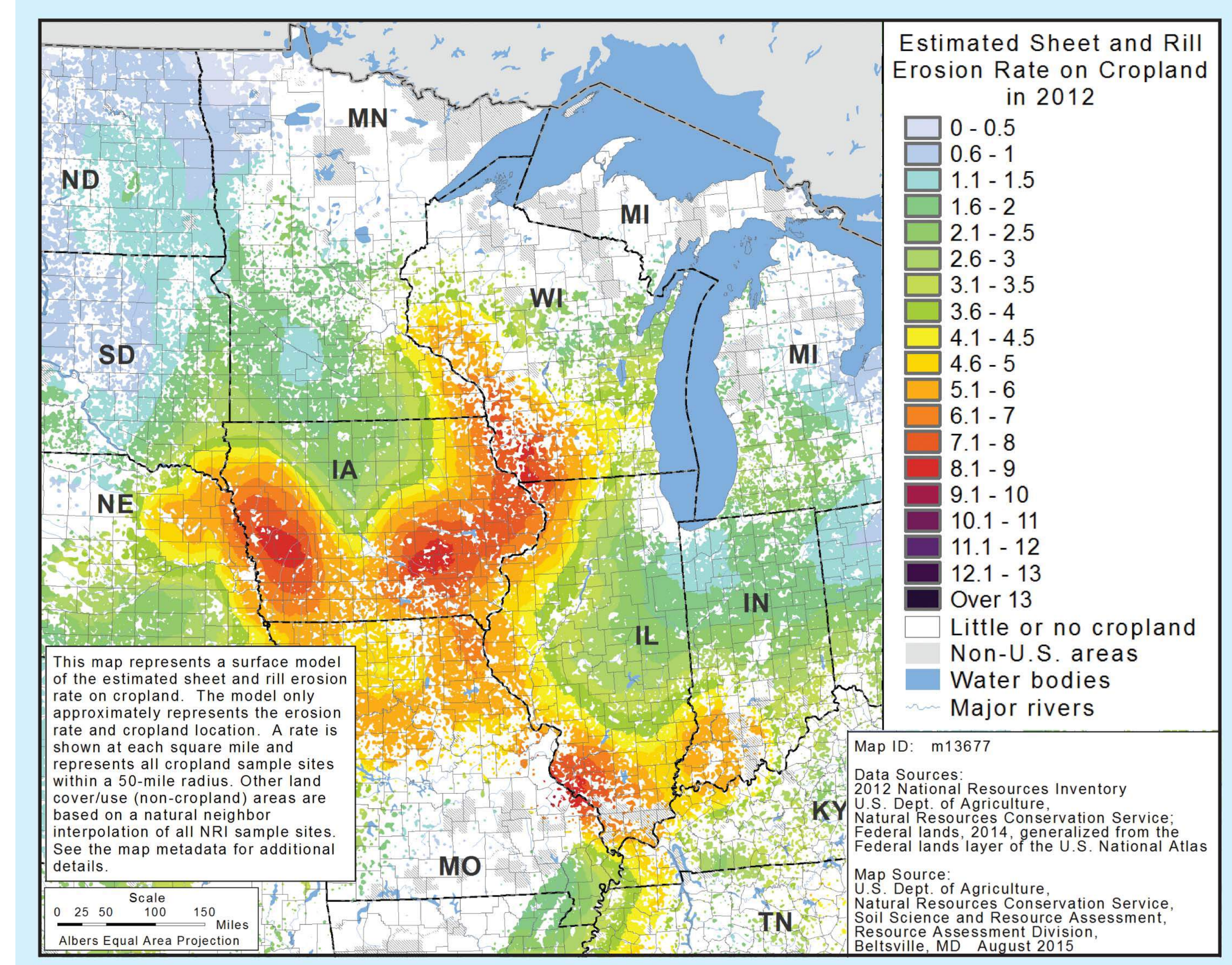
Figure 2. Modeled change in number of days per decade with more than 50 mm (2 inches) of precipitation by season, 2045-2065



Source: These regional precipitation and temperature maps are based on daily statistically downscaled climate projections (WICCI 2011, Notaro et al. 2014). Researchers took observed weather data from 1950-2009, and then projected future conditions using climate models developed by the World Climate Research Programme for the Intergovernmental Panel on Climate Change. The projections illustrated by the maps are compiled from thirteen climate models including three from the U.S., two from Canada, and others from Japan, Germany, South Korea France and Australia.

Barge traffic may be disrupted by extreme weather events, especially when early ice ends a barge season. While rising temperatures are projected to reduce ice cover duration overall (Attavanich et al. 2013 and Fig. 1 above), spring and fall variations are problematic. Increasing temperatures often extend the navigation season, but interviewees noted that navigation, like the growing season, closes at the first freeze, even if it thaws soon afterward. Heavy rainfall events leading to flooding are expected to continue to increase in frequency (Fig. 2 at right) Floods can interrupt river traffic and damage navigation infrastructure, and they can likewise close and damage roads. Because water levels and spring and fall ice patterns may profoundly impact barge traffic, agricultural truck freight will become more important in the Upper Mississippi River Valley (Attavanich et al. 2013). When it comes to freight transportation for agriculture and other industries, medium and heavy-duty trucks produce the most greenhouse gas emissions (U.S. EPA 2013) which then contributes to a vicious warming cycle unless counterbalanced.

Figure 3. Estimated sheet and rill erosion rates on cropland, 2012
Tons per acre per year



Source: USDA-NRCS. 2015. Summary Report: 2012 National Resources Inventory, Natural Resources Conservation Service, Washington, D.C. and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa, p. 2-7. August 2015. (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd396218.pdf)

Extreme weather events due to climate change may result in a dramatic increase in soil erosion, especially from highly erodible land and fields without vegetative cover. In the Upper Mississippi River Valley, the sloping terrain of the four-state Driftless Region is particularly vulnerable to soil erosion from extreme rainfall events (Fig. 3 above). Note that predicted warming in the region will alter precipitation patterns (Fig 1&2) and further advance erosion in the region. For instance, if snow turns to rain in winter months, snow cover may melt leaving soil exposed, and the frozen ground will not be able to absorb rain, resulting in an erosion event. Perennial winterkill will likely increase in these conditionsalso. Increased erosion reduces agricultural potential, negatively impacts river navigation, reduces water quality and contributes to the Dead Zone in the Gulf of Mexico. Crop diversification is proposed as a strategy to both adapt to a changing climate and mitigate GHG emissions (Aguilar et.al. 2015, Blanc and Reilly 2015, Lewandrowski and Zook 2015, Lengnick 2015, Rotter 2013), as well as market shocks (Aguilar et al. 2015, Blanc and Reilly 2015). Converting row crop acres to perennial pasture for livestock protects soil from heavy rainfall. In annual cropping systems, cover cropping protects soil, and incorporating perennial crops into these systems can also prevent erosion.