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Changing Agricultural Climate: Implications for Innovation Policies

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Summary of Findings:

- Average temperatures are rising, both globally and in the Midwest United States.
- Rainfall is increasing on average in the Midwest while also becoming more unpredictable on any given farm.
- Episodes of extreme air moisture content are increasing, affecting both animal and plant agriculture.
- Agriculture is especially sensitive to the ever-changing natural environments in which it operates.
- Agricultural producers can respond to variations in climate given the right know-how and technologies.
- Choices made now will have long-run implications for the productivity and competitiveness of U.S. agriculture.

Climate Change and Agriculture in the Midwest United States

Significant changes in important climate attributes are evident in the daily measurements made over the past few decades by thousands of dedicated weather observers in the Midwest. Some of these changing climate attributes have statistical significance in that their pattern, persistence, and amplitude are outside the range of historical measurements (some of which go back to the mid-19th Century). There are three agriculturally important features of the environment that are changing significantly and with consequence: temperature, water vapor, and precipitation.

The average temperature is increasing across the Midwest. The National Oceanic and Atmospheric Administration's recent release of new climate normals (averages of measured climate attributes) covering the period 1981-2010 show significant departures from earlier periods of record. Daily average temperatures in the Midwest have increased. The nighttime minimum temperature has risen more than the daytime maximum, with important implications for the amount of heat stress on plants like corn. Further, for Midwestern states (IA, IL, MI, MN, ND, SD, and WI) the winter months have seen larger changes than other months of the year. For example, six of the warmest ten years in Minnesota history (back to 1895) have come since 1998, and 2012 is on track to be the warmest year in history for every state in the Midwest.

The water vapor content of the atmosphere, measured as the dewpoint (the temperature where the air reaches saturation and water vapor condenses into liquid droplets), is increasing in some parts of the Northern Hemisphere. When the dewpoint of an air mass exceeds 70 degrees, it is said to be "tropical-like" the Midwest is experiencing a higher frequency of tropical-like air masses during the growing season (May-September). Because water vapor is a greenhouse gas, higher dewpoints translate into higher overnight minimum temperatures, as well as higher Heat Index values (which take account of the combined effect of high dew points and temperatures on human, and by implication livestock, physiology). As a result, the National Weather Service has issued more heat advisories and excessive heat warnings in recent years due to higher dewpoints.

Annual precipitation over the region is increasing, and thunderstorms represent an increasing fraction of the total annual rainfall amount. Because spatial variability in the pattern of rainfall is magnified by thunderstorms, a given location experiences much more variable rainfall than is reflected in average values for the whole region. As a result, recent decades have produced more frequent flash flooding and events that erode agricultural soils, and more farmers are less able to anticipate the amount of rainfall they will receive.

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The Impact of Changing Climate

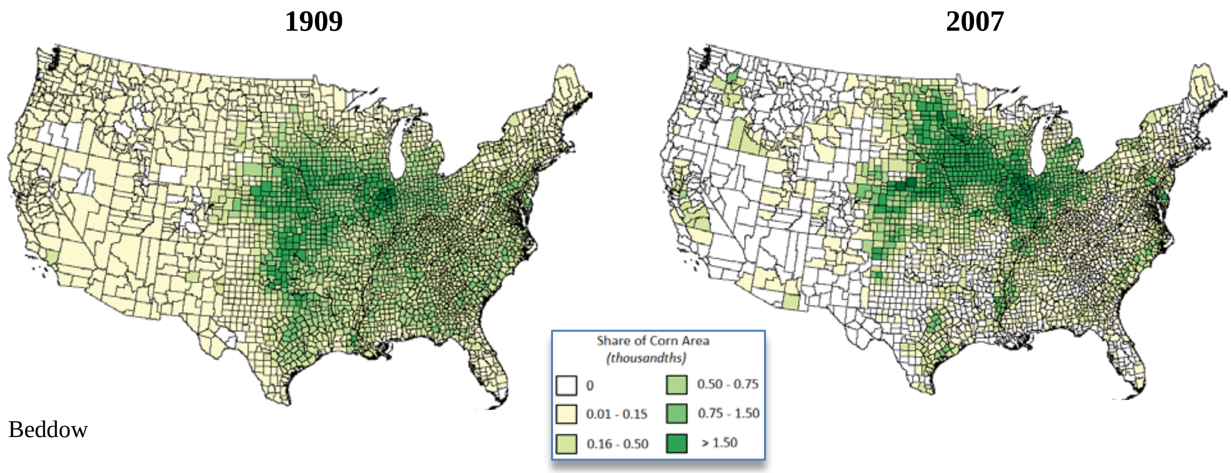
The consequences of changing climate are very important for Midwest agriculture. Some of the changes are beneficial to the region's farmers; some are not. Growing seasons are generally longer with more Growing Degree Days for crop growth. However, with milder winters, insect and plant pathogen mortality is reduced, most crop residues degrade faster, and soils freeze less. Higher dewpoints have resulted in the northward migration of certain insects and plant diseases which thrive in tropical-like air masses. Livestock are exposed to heat stress more frequently during summer episodes of high dewpoints and high Heat Index values, with negative effects on reproduction, mortality and feeding.

Implications for Innovation Policies

Unlike some natural systems, agriculture is intensively managed—farmers can and do respond to changing environmental and economic conditions. New crop varieties have allowed farmers to expand corn and soybean acreage to the west and to the north. More attention is now given to soil and residue management to deal with higher moisture variability. New drainage systems have been installed to mitigate excessively wet periods. More crop resides are left on harvested fields to conserve stored soil moisture.

Climate ultimately affects agricultural production at the scale of a farm or a field. Thus some hints about how much farmers might adjust can be gleaned from data on where farmers produce particular crops. In 1909, corn—the largest U.S. crop in terms of area—was grown almost everywhere in the conterminous United States, although the Corn Belt states (IL, IN, IO, MO and OH) accounted for the largest share of corn area. By 2007, corn production had become more highly concentrated in the Northern Plains, Corn Belt and Lake States, which together increased from about 59 percent of the nation's corn area in 1909 to about 85 percent in 2007. Figure 1 shows the distribution of U.S. corn area in 1909 and 2007. The figure is constructed such that counties are colored darker as they account for a larger share of the nation's production.

Figure 1: Share of U.S. Corn Area by County, 1909 and 2007



Source: Beddow

Irrespective of how climate has changed, the changing location of production affects the *agricultural* climate. For example, the average corn plant is grown further north and west than the average plant of a century ago and, since the U.S. climate generally becomes cooler as one moves north, the average May corn growing temperature decreased by about 6 degrees over the past century. Other crops have seen different changes, with some increasing their average growing temperatures; rainfall patterns, soil types and other characteristics of the growing environment also change as crops move.

A host of new technologies, made possible by prior investments in research and development (R&D), both spurred and supported this dramatic change in the U.S. agricultural landscape. Farmers' ability to adapt has been enabled by technologies developed by the various state agricultural experiment stations, other public research agencies (including USDA), and private firms Anticipating, innovating for, and adapting to environmental and economic change are critical to the economic vitality of U.S. agriculture. But just as changes in agricultural climate take decades to reveal themselves, agricultural innovations stemming from public and private investments in R&D take decades to develop and deploy in farmers' fields. Decisions about agricultural R&D funding made now will influence the U.S. agricultural landscape for decades to come and the ability of the nation's primary producers to adapt to ever-changing environmental and economic circumstances.

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