Climate Change and Agriculture in Indiana[1]

July 2009

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Climate Change

Projecting possible consequences of global climate change at a regional scale is best done using climate projections also at a regional scale. Such climate projections typically are derived from one or more General Circulation Models (GCM) such as the HadCM2 or HadCM3 models developed by the Hadley Center. Typically several future climate scenarios are developed to examine for different forcing functions or possible future scenarios. These model results may be used at global scale or extracted to specific regions. Future climates projected using various scenarios for specified future dates are then compared with historical climate records to estimate both the magnitude and rate of climate change and create future climate scenarios. Projections of future temperatures, both globally and regionally, using a multitude of current GCMs, are quite consistent. Projections of future precipitation patterns are more variable, particularly at a regional scale because of the influences of mountain ranges, proximity to oceans, and related physiographic features that influence climate. The climate change projections used for this analysis are extracted for Indiana from the HadCM2 model and compared with the VEMAP historical climate records resulting in an average increase in maximum temperatures of 6.9° C, an average increase in minimum temperatures of 7.9° C, and a 32 mm increase in total monthly precipitation, all on an annual basis for 2050 (Southworth, 2002a).

More recent work downscaling climate scenarios for the Midwestern United States using the HadCM3 model produces results similar to the previous scenario but with slightly lower increases in precipitation and some increases in extreme weather. These climate projections indicate warmer, wetter winters, and warmer, drier summers (Diffenbaugh et al. 2005).

Agricultural Productivity

Field corn, soybeans, and winter wheat are the principal commodity crops in Indiana. USDA National Agriculture Statistics Service data for 2008 indicate: (1) an average yield of 160 bu/ac and a total production of 873,600 thousand bu (7.2% of US production) for corn, (2) an average yield of 45 bu/ac and a total production of 244,350 thousand bu (8.3% of US production) for soybeans, and (3) an average yield of 69 bu/ac and a total production of 38,640 thousand bu (2.1% of US production) for winter wheat. To assess the direct effects of climate change on the yields of these three crops, several Midwestern climate scenarios were used as input variables in the Decision Support System for Agrotechnology Transfer (DSSAT ver. 3) crop models (CERES-maize and CERES-wheat), and the SOYGRO soybean model. These crop models run on a daily time step and are driven by daily weather variables.

[1]This policy brief was written at the request of the Indiana Chapter of The Nature Conservancy and has been reviewed by that organization.

They simulate plant growth and development based on physical and physiological processes. In addition to weather variables, these models incorporate hydrological and soil processes. And these models also permit the use of detailed information on specific genotypes of the cultivars, and crop management practices such as planting date, types of cultivation, fertilizer, pesticide, and herbicide use. The models are validated by using representative values for input variables and comparing yield results with historical, site-specific yield data.

Climate Change Impacts on Yields

Using current cultivars and crop management practices but using three different climate change scenarios, the crop models projected the following changes in yields (bu/ac) for three types of corn cultivars, three types of soybean cultivars, and winter wheat in north-central Indiana for 2050 (Southworth et al., 2002b) Although these results are from a single study (Doering et al., 2002), similar results have been reported by several other studies investigating climate change impacts on agriculture in the midwestern U.S.

Crop Yield / Climate Scenario	**Greater CC**	**Intermediate CC**	**Lesser CC**
Long-season Corn	20-30% reduction	20-30% reduction	10-20% reduction
Medium-season Corn	20-30% reduction	20-30% reduction	10-20% reduction
Short-season Corn	40-50% reduction	30-40% reduction	20-30% reduction
Soybeans, late maturing	10-20% reduction	0-10% reduction	10-20% increase
Soybeans, mid maturing	20-30% reduction	0-10% reduction	20-30% increase
Soybeans, early maturing	10-20% increase	20-30% increase	20-30% increase
Winter Wheat	20-30% increase	30-40% increase	40-50% increase

In all climate scenarios, daily maximum summer temperatures result in large reductions in corn yields due to direct effects of heat stress at critical phenological stages in the crop's growth. These reductions are more severe in short-season corn than for the predominant long-season corn cultivar currently grown.

For soybeans, later maturing and mid-maturing cultivars experienced fairly large reductions in yield under the more extreme climate scenario, less reduction under a more intermediate climate scenario, and some increase in yield under the less extreme climate scenario. Crop model results indicated that early maturing soybean cultivars would experience increased yields in each of these scenarios due to a shift to earlier planting dates. For winter wheat yields increase as a result of warmer minimum temperatures that encourage early vegetative growth. The DSSAT models have the ability to vary atmospheric CO_2 concentrations in climate scenarios. CO_2 fertilization increases yields in soybeans and winter wheat, which are C_3 photosynthetic pathway plants and thus more sensitive to atmospheric CO_2 concentration, when compared to corn, a C_4 photosynthetic pathway plant.

Increased variability of weather events, including frequency and intensity of extreme conditions increases the variability of year-to-year crop yields for all cultivars. As mentioned above, the distribution of precipitation is expected to shift towards warmer winters with less snow and more rain, and warmer, drier summers. Wet soils in early spring could delay planting even though temperatures are suitable. Drier, warmer soils could increase the frequency and severity of drought conditions.

Pests and Pathogens

A complex interaction exists among crop plants, weeds, insects, diseases, and other crop pests, and all are influenced by weather events and overall climatic conditions. Both crops and weeds are hosts for insects and diseases, some insects devour parts of crop plants while others are vectors for diseases, and weeds compete with crop plants for nutrients, water, and sunlight. Various crop management practices, such as tillage, fertilization, use of herbicides and pesticides, are used for seasonal control of specific pests, but effectiveness of these practices also are greatly influenced by weather events. For example, warmer winter temperatures may allow overwintering of eggs or pupae of insect species previously prevented by colder temperatures. An altered climate in Indiana likely will encourage dispersal and abundance of invasive species of weeds, insects, and pathogens currently present in more southern locales.

Farm Management Practices

Climate change will affect farm management practices at the farm-level, particularly under conditions of increased climate variability. While two crops may produce equal returns on average over a period of years, one may be preferable in the future if there is lower susceptibility to extreme weather events. Not only will choices of the most suitable cultivars of crops become increasingly important, but also decisions about planting dates, tillage versus no-till practices, fertilization practices, herbicide and pesticide applications to better control possible new invasive pests, and harvest practices will become increasingly important. Irrigation of these commodity crops in Indiana occurs occasionally, but is not a common practice. With warmer, drier summer weather in the future, there could be increased demands for water for irrigation. The timing, severity, and duration of drought periods will require changes, and possible improvements, in many of these farm management practices.

Agricultural Industry

Although this discussion has focused on the three major commodity crops, agricultural products in Indiana are much broader, including a variety of important specialty crops, as well as significant livestock production, notably pork and poultry. Climate change will affect these other types of agriculture as well but with the occurrence of extreme weather events possibly being even more significant than for the primary commodity crops.

The agriculture industry encompasses more than farm-level production, and ranges from areas such as finance and insurance to agricultural chemicals and machinery to plant genetics. This industry is flexible and adaptive. Technological improvements, such as genetic manipulations to achieve more heat-tolerant corn cultivars and improvements in agricultural machinery including precision farming technologies, will be essential under an altered climate to sustain agricultural productivity.

Indirect effects of climate change also will affect Indiana agriculture. Relative demands and price changes in commodities may bring about significant changes in cropping systems and possibly land-use conversion to agriculture. The current emphasis on increased use of biofuels, principally ethanol production from a variety of feedstocks such as corn grain, corn stover, switchgrass, *Miscanthus*, or native prairie grasses, almost certainly will influence crop choice, cropping systems, and land use in Indiana (Tyner et al. 2008).

The Upper Midwest, notably Indiana and Illinois, is a relatively stable region in terms of agricultural systems and has been a major producer of corn and soybeans for many decades. Some adaptations, such as adjustments in planting dates, crop mix and choices of cultivars, and cropping systems, will be required to maintain this productivity, particularly with increased climate variability. These adaptations to future climate change will influence the structure and function of the overall agricultural industry in Indiana, although dramatic changes appear unlikely by 2050 (Doering et al. 2002).

Literature Cited

Diffenbaugh, N.S., J.S. Pal, R.J. Trapp, and F. Giorgi. 2005. Fine-scale processes regulate the response of extreme events to global climate change. Proceedings of the National Academy of Sciences of the United States **102:**15774-15778.

Doering, O.C., J.C. Randolph, J. Southworth, and R.A. Pfeifer (eds.) 2002. Effects of Climate Change and Variability on Agricultural Production Systems. Kluwer Academic Publishers. Boston. 267 pp.

Southworth, J. 2002a. Climate Scenario Construction for Midwest Analysis. Ch. 5 *in* Doering, O.C., J.C. Randolph, J. Southworth, and R.A. Pfeifer (eds.) *Effects of Climate Change and Variability on Agricultural Production Systems.* Kluwer Academic Publishers. Boston, MA. 267 pp.

Southworth, J., R. Pfeifer and M. Habeck. 2002b. Crop Modeling Results under Climate Change for the Midwest USA. Ch. 7 *in* Doering, O.C., J.C. Randolph, J. Southworth, and R.A. Pfeifer (eds.) *Effects of Climate Change and Variability on Agricultural Production Systems.* Kluwer Academic Publishers. Boston, MA. 267 pp.

Tyner, W.E. (2008). The US Ethanol and Biofuels Boom: Its Origins, Current Status, and Future Prospects. *BioScience* **58** (7): 646-653.