

7. AGRICULTURE

study conducted by

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Agriculture in the Great Lakes region follows a south to north gradient. Intensive rowcrop monoculture exists in southern sections and gradually gives way to forests and other natural vegetation across the north (Figure 7.1). Southern sections of the region form the northern boundary of the US Corn Belt region, with corn, soybeans, hogs, and cattle as major commodities. Dairy and associated alfalfa production are common in the driftless area of southeastern Minnesota and southwestern Wisconsin and scattered across central and northern sections of the region. Vegetable production is centered in the Central Sands area of central Wisconsin, across lower Michigan, and in the Red River Valley of Minnesota, which also forms the eastern boundary of the Great Plains small grain production area. Fruit and ornamental crops are grown intensively along the eastern shore of Lake Michigan.

Agriculture ranks among the most important economic activities of the Great Lakes region, accounting for more than \$15 billion in annual cash receipts [7-1]. Livestock, including dairy, is the number one agricultural commodity group, comprising over half of the total. Dairy production alone produces almost \$5 billion in receipts. Other major commodity groups

include: grains/oilseeds, vegetables, ornamentals, and fruit. Crop diversity is an important characteristic of agriculture in the region due at least partially to the moderating influence of the Great Lakes on regional climate [7-2]. Over 120 commodities are grown or raised commercially in the region [7-1].

Current Stresses

The major stresses on agriculture in the Upper Great Lakes region can generally be categorized as economic, social, environmental, and regulatory (Figure 7.2). The amount of water and the frequency of its availability are primary climatological constraints for the production of most annual crops [7-3]. Growing season precipitation provides the bulk of the moisture used by crops during the season, with the remainder provided by soil moisture storage accumulated during the off-season. Several factors will affect water management and water withdrawal for agricultural use in the future: the availability of groundwater and surface water; supplemental irrigation requirements; the real cost of energy for pumping; uncertainty regarding water application and crop yield; technical developments for management of irrigation delivery systems; and adverse environmental impacts from irrigation. The issue of adverse environ-

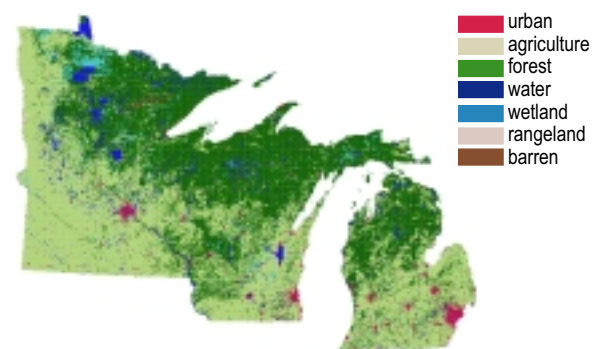


Figure 7.1: US Geological Land Use Data (LUDA), ca. 1980.

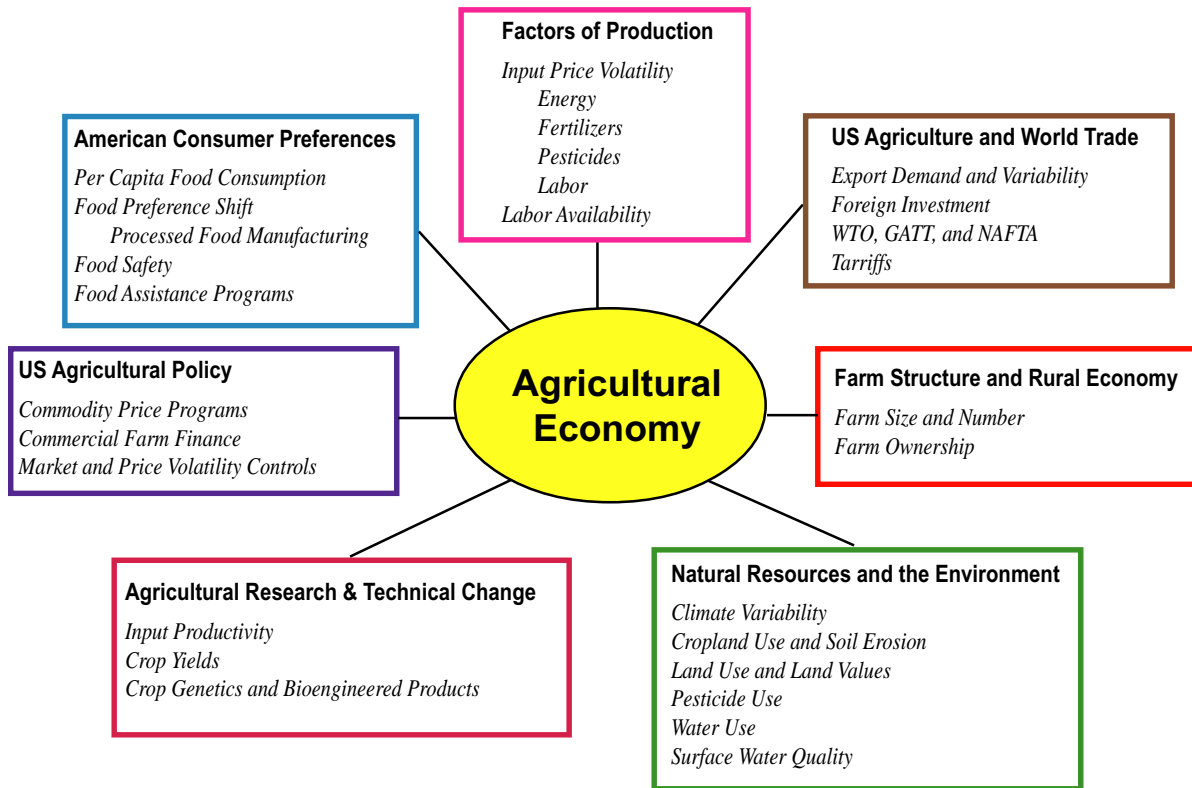


Figure 7.2: Factors that influence agricultural production.

mental impacts, in the form of non-point source pollution, may become more widespread with more intensive irrigated crop production on light soils and the predicted changes in water levels in the Great Lakes.

Another major stress in the Great Lakes region is the current low commodity price for most major field crops and the difficulty of gaining access to export markets. One-third of US commodities are marketed through foreign trade, but farmers' access to international markets is blocked through foreign market barriers, regulations and sanctions. These barriers have continually hurt US farmers, who typically produce about a third more than Americans can consume. Given that 95% of the world's consumers are outside of the United States, "the answer is not in cutting United States production, but rather in finding a home for these commodities," said Bob Boehm, Michigan Farm Bureau commodity and marketing department manager. "We can compete in the global marketplace, but we need access to those markets."

Deterioration in overall financial performance has also occurred in the Upper Great Lakes region. The region exhibited a significant decline in the percentage of farm businesses classified in a favorable financial position and an increase in the share considered vulnerable. The Great Lakes region was one of the few areas of the country where the average farm business debt/asset ratio increased in 1997. Its average of 0.24 was the highest among the different production regions. At the end of 1997, the Great Lakes region had the highest concentration of highly leveraged farms where at least one out of five farm businesses had a debt/asset ratio above 0.40 and lower income and increased debt pushed debt repayment capacity utilization to dangerously high levels [7-4].

Given significant land use changes occurring across the region, farmers are facing increasing pressure from urban encroachment and the loss of prime or productive agricultural land to urbanization [7-5]. The future rate of change of this loss is dependent on growth of population, especially around urban areas, and the vitality of regional economies. In the last 15 years, Michigan and

Wisconsin have both lost over 1.4 million acres of cropland and Minnesota has lost over 0.7 million acres, according to the 1997 Census of Agriculture [7-6].

Environmental factors like climate and its inherent variability; long-term degradation of soil resources; geographical concentration of livestock production and the associated management of large amounts of livestock waste, and the contamination of surface waters and groundwater by agricultural chemicals may also create direct stress on regional agriculture [7-7].

Finally, one category of stresses that integrates many of the above factors is governmental regulation, which may drastically change standards or alter the economics of the production system. One current example is the gradual implementation of the 1996 Food Quality Protection Act, which may ultimately result in the loss of many pesticides used commercially in agriculture (especially in fruit and vegetable production) and for which few, if any, substitutes now exist [7-8].

The potential impacts of climate change on regional agriculture will depend greatly on the magnitude, timing, and the variability associated with the change. Variability is generally considered to be the most difficult aspect with which to cope and adapt [7-9]. Most of the recent research on climate change in the Great Lakes region has suggested a warmer and wetter climate in the future [7-10], with relatively more warming occurring in the winter and spring than in other seasons [7-11]. Agriculturally, this would most likely lead to a longer growing season and greater potential productivity, but also to greater potential rates of evapotranspiration. An additional critical factor in determining potential productivity is CO₂ enrichment, which has been associated with increases in total plant dry matter accumulation and improved crop water use efficiency through decreases in transpiration rates. While some research studies have shown that yield-increases from higher atmospheric CO₂ levels may actually decrease when other resources are limiting and that the enrichment effect may decrease over time for some plant species, most scientific literature suggests

that there will be significant long term benefits to agriculture as atmospheric CO₂ levels increase in the future [7-12].

There may be potential changes in the productivity of arable land for specific crops in sub regions, especially where specialty crops will be sensitive to increases in CO₂ enrichment, temperature or rainfall during critical growth periods. This analysis indicated that these changes might be especially true for crop simulations at southern and western study locations with the relatively warmer and drier CGCM1 model. Potential productivity may also be affected by changes in the rate of vegetative development in a season prior to the last spring frost and in the frequency of subfreezing temperatures after critical growth stages for specialty crops such as cherries. (Focus – *Climate Change and Fruit Production: An Exercise in Downscaling*)

Other economic changes may occur in the commodity prices for field crops driven by worldwide changes in production and demand. This may affect the profitability of farm operations. There is likely to be an increasing dependence upon agriculture's use of rail and truck for moving agricultural commodities to market due to decreased capacity of shipping on the Great Lakes (Focus – *Climate Change and Shipping/Boating*). Finally, the impact of regulations may dictate changes in farming practices, including the types and amounts of fuel and fertilizers used to produce crops that can affect the cost structure of farm operations.

Current Assessment

There have been few past studies concerning climate change and agriculture in the Great Lakes region. The major objective of this study was to determine the impact of weather and climate on three crops commonly grown in the region: alfalfa, a forage used extensively for dairy production; maize, a coarse grain; and soybean, an oilseed. Daily weather data were obtained from the daily VEMAP series based on the two GCMs (HadCM2 and CGCM1). Additionally, simulation models based on the physiological processes that govern growth and devel-

opment of the crops were used: DAFOSYM, CERES-Maize, and SOYGRO, for alfalfa, maize, and soybean crops, respectively [7-13, 7-14, and 7-15]. The simulation models have been successfully used in a wide number of past studies and applications [7-16, 7-17, and 7-18].

Model Historical Trends

Several trends were identified using the historical climatological data and the model simulations. Increases in growing season precipitation were found at 10 or more of the 13 locations (Figure 7.3) for all three crops. Increases in simulated soil moisture available to the plant at mid-season, a key variable in determining ultimate yield potential, were also found for maize (11 of 13 locations with increases) and soybean (12 of 13 locations with increases). In contrast, simulated potential evapotranspiration, the potential loss of water due to soil evaporation and plant transpiration, was found to decrease at 11, 10, and 9 of the 13 locations for alfalfa, maize, and soybean crops, respectively. As a result of the trends towards wetter, less stressful conditions, increases in both maize (positive trends at 11 out of 13 locations) and soybean (positive trends at all 13 locations) yields occurred across much of the region. Alfalfa yield trends were mixed, with decreases at 8 locations and increases at 5 locations. Overall, greatest increases in simulated yields for all crops over time were found at western and northern study locations.

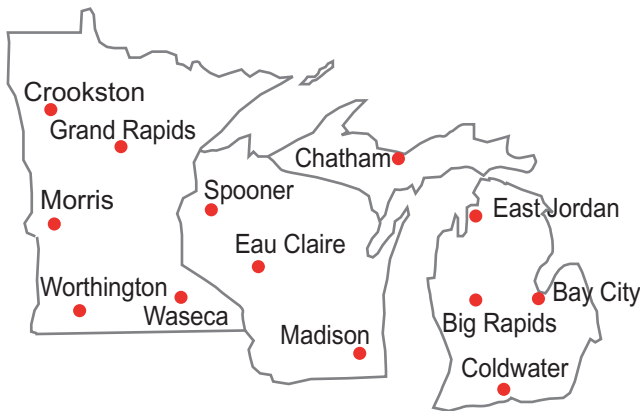


Figure 7.3: The 13 study locations.

Model Projected Future Trends

Both model simulations suggest an overall warmer and wetter climate by the year 2099 across the region. The CGCM1 model is the warmer of the two models, with a 7.2°F (4°C) or greater increase in mean annual temperatures at the study locations by 2099 versus a 4.5°F (2.5°C) increase for the HadCM2 model. Average annual precipitation totals across the region generally increase from approximately 31.5 inches (80 cm) at 2000 to 39.4 inches (100 cm) at 2099 for both GCMs. However, the rate of precipitation increase for the HadCM2 GCM is much more consistent over the 100 year period than for the CGCM1 Model, in which much of the overall 100-year increase occurs during the last 20 years of the period.

A comparison of historical and potential future simulated yields for the three crops averaged from 2000-2099 and across all 13 study locations for both GCM and CO₂ enrichment scenarios is shown in Figure 7.4. In general, the warmer and wetter climate suggested by both GCMs leads to increases in average simulated non-CO₂ enriched crop yields relative to historical yields, ranging from 6% for alfalfa in both GCMs to 26% for maize in

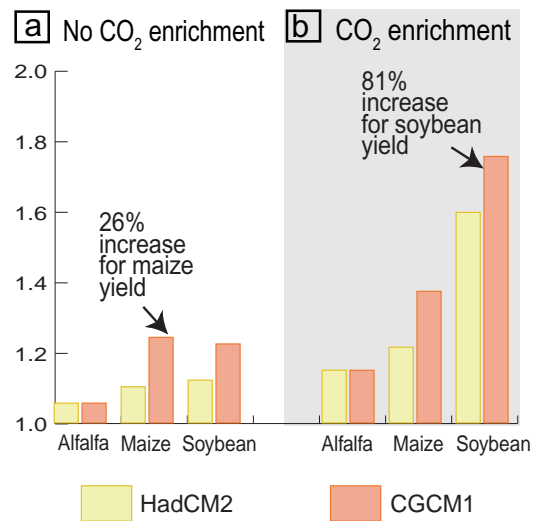


Figure 7.4: Ratios of GCM-projected future (e.g. 2000-2099) crop yields to historical observed crop yields averaged over 13 stations. Note: CO₂ refers to the inclusion of plant impacts resulting from enhanced CO₂ concentrations in the simulations in addition to climate change impacts.

the CGCM1 model. When the impacts of CO₂ enrichment are also considered, the yield differential relative to the historical period increases to a range of 16% for alfalfa to 81% for soybean in the CGCM1 model. Largest percentage increases in yield across the 2000-2099 study period were at northern locations. The ratios of the future scenarios with and without CO₂ enrichment suggest that the majority of yield increases during this period are due to CO₂ enrichment.

The ratios given in Figure 7.4 represent averages over the entire 100-year future period. Most of the simulated yield series actually exhibited consistent increases through the period, especially with the HadCM2 model output. Other yield series tended to decrease across the period, or increase during the initial decades of the period, followed by decreases later in the period. The latter pattern was especially true for crop simulations at southern and western study locations with the CGCM1 model. Simulated historical crop yields across the region also tended to increase with time during the past 50-60 years, due at least partially to concurrent increases in growing season precipitation and decreases in potential evapotranspiration.

The model simulation results suggest that the warmer and wetter climate for the Great Lakes region may lead to a northward shift of some current crop production areas [7-19]. Even with less suitable soils agronomically, the model simulations suggest that yield potential may improve at three of the northernmost study locations currently outside major agricultural production areas: Chatham, Michigan; East Jordan, Michigan; and Grand Rapids, Minnesota (Figure 7.5). The average yields for maize and soybean increase dramatically by the 2090-2099 decade relative to historical yields, ranging from 276% (263%) for soybean to 343% (373%) for maize in the Hadley (Canadian) model. The increases for alfalfa were smaller at 29% (26%) in the Hadley (Canadian) model.

The model simulation results from the two GCMs differ somewhat, but suggest that crop yields in the future may be substantially greater than those observed during the past century due

to the effects of CO₂ enrichment and because of more favorable growing season weather, especially in northern sections of the region. Some crop yields simulated with the relatively warmer CGCM1 scenario were greater than historical yields through 2050, but tended to decrease with time from 2051-2100, especially at western and southern study locations. The simulations also suggest that the fraction of total water used by crops during the growing season that is supplied by long term soil moisture storage (and not by recent precipitation) will decrease, making water shortages and moisture stress less likely than in the past. Finally, a number of projected future yield series exhibit decreasing interannual variability with time, which was associated with decreases of growing season temperature and precipitation variability.

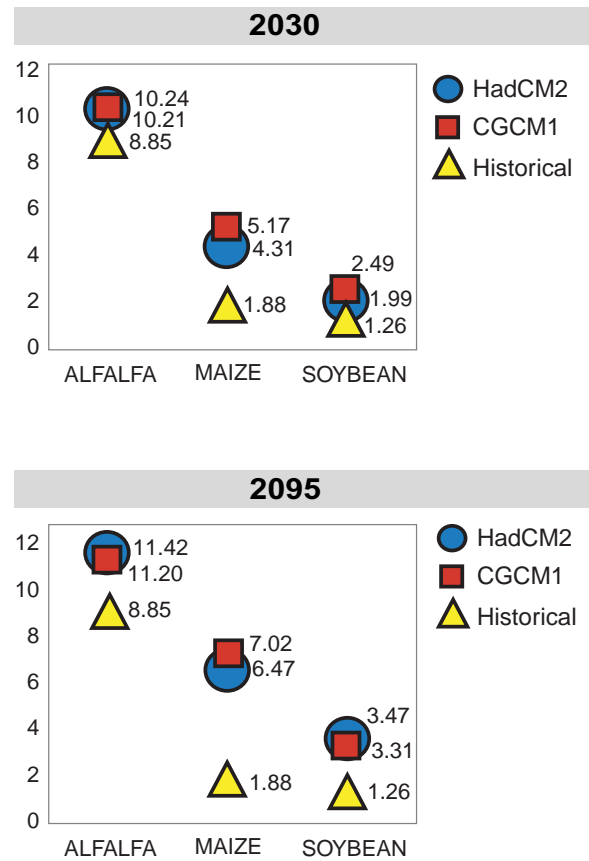


Figure 7.5: Average model simulated crop yields (ton/acre for alfalfa, bu/acre for maize and soybean) with CO₂ enrichment at three northern-most locations for 2025-2034 and 2090-2099 time periods. Historical (1896-1996) yields shown for comparison.

Economic Considerations

Water is used for agricultural irrigation on a small percentage of the harvested cropland in the study region. (Table 7.1). Irrigation water is applied as a supplemental production input to natural rainfall, especially during short periods of drought. Irrigation is applied because the rainfall is not adequate or reliable during the critical growth stage, the soil may offer a low soil moisture holding capacity that may increase the need to irrigate during critical stages, or the crops are water intensive and are subject to soil moisture stress [7-20].

Table 7.1: Land under irrigated agriculture in the upper Great Lakes (US Census of Agriculture, 1997).

State	Total Cropland (acres)	Harvested Cropland (acres)	Irrigated Cropland (acres)
Michigan	7,891,802	6,724,480	393,485
Minnesota	21,491,743	18,968,607	380,394
Wisconsin	10,353,300	8,625,011	341,813
TOTAL	39,736,845	34,318,098	1,115,692

The estimation of the quantities of water required for irrigation, however, is an integral component of the framework to determine the total water withdrawal or the consumptive use within the study region, especially within basins that may experience water shortages due to climate changes and have more intensive agricultural development. There is the potential for changes in irrigation demand in certain localized, but limited areas, that already have a higher percentage of farms utilizing irrigation due to the increase in temperature. A small percentage decrease in the amount of water used in agriculture could greatly reduce the possibilities for water conflicts and enhance the possibilities for economic growth within the region. The comparative stability of surface water use for irrigated agriculture in the face of increasing water scarcity reflects the insulation of water costs to surface irrigators from market considerations and energy costs [7-21].

Agriculture use generally exhibits a relatively low marginal value for water use. The incentives for farmers to utilize water

more efficiently without incurring financial losses and their ability to substitute other production inputs (labor, energy, fertilizer, and pesticides) are the keys to the future viability of irrigated agriculture, especially in basins or sub-basins that exhibit water scarcity. The efficient and productive use of factors of production on the farm, the policies that affect the technology or preferences underlying the demand for supplemental water, the associated costs, and the resulting profit in relation to climate change variables are major issues to be investigated in the Great Lakes.

Coping Strategies

If the magnitude of regional climatic changes in the future reaches values suggested by GCMs, farmers will be forced to adapt to the changes or become uncompetitive and unprofitable. Improvements in technology, the CO₂ fertilization effect, and the use of adaptive farm management strategies should help farmers mitigate any negative effects of climate change for the majority of farm operations in the Great Lakes region. Adaptive farm management strategies include: changes in crop selection or variety (using crop varieties that are currently used in more southern regions) changes in the timing of planting and harvesting; the development of new varieties of crops that are more adaptable to interannual variations of weather; double cropping; irrigation; and other unforeseen technical improvements.

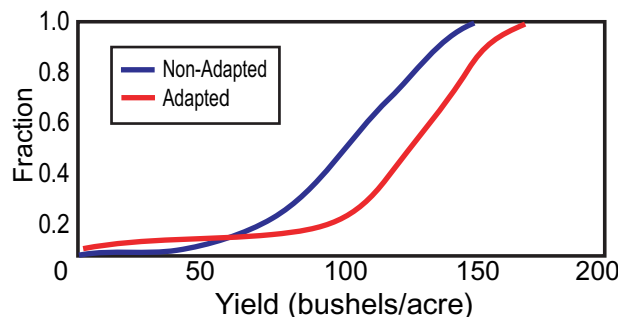


Figure 7.6: Cumulative simulated frequency distribution of adapted vs. non-adapted crop varieties, for Coldwater, Michigan using output from the HadCM2 model for the period 2000-2099. The adapted variety required 18% more growing degree days between planting and maturity than the non-adapted variety and was planted 15 days earlier.

As one simple example of the benefit of adaptive strategy, agronomic data in the CERES-Maize crop model was modified to better suit the warmer future climate suggested by the GCMs at Coldwater, Michigan, a location typical of the northern Corn Belt region (Figure 7.6). In particular, the crop was planted 15 days earlier each season (on or after 1 May, depending on weather and soil conditions) and the total number of growing degree day units required for the crop to advance from planting to maturity, was increased 18%. There were total crop failures in 4 of the 100 years of simulation (due to early freezes in the beginning decades of the future scenarios). The adapted crop exhibited a probability of zero yields for a small portion of the distribution. At a probability of 0.11 or greater, however, the adapted yields exceed non-adapted yields and continue as such for the remainder of the distribution, with magnitude of the differences generally ranging from 14.9-26.1 bu/ac (1.0-1.75 t/ha).

There is evidence based on past performance that agriculture will at least be able to partially adapt to a changing climate and that the costs of such adaptations will be small compared to costs associated with an expansion of or changes to major production areas [7-22, 7-23, 7-24]. Ultimately, however, the ability to adapt will likely depend upon the nature of the climatic change, as increases in variability could make future adaptations difficult [7-25].

Based on projections of a warmer and wetter climate, the future scenarios suggest greater agronomic potential for northern sections of the region, even with less suitable soils. Simple adaptations to a changing climate such as a switch to a longer season variety or earlier planting date will likely result in significant increases in potential crop yield.

Information & Research Needs

The current assessment did not consider the impacts of major limiting factors in agriculture such as inadequate fertility or pressure from weeds, diseases, and insect pests. In addition, the projected future weather scenarios are simplistic synthetically-derived series from the coarse-scale, monthly grid output val-

COPING STRATEGY: DOUBLECROPPING



The unusually mild spring of 1998 in Michigan allowed the winter wheat crop (that was planted in the fall of 1997) to reach maturity and be harvest-

ed at a record early pace in the beginning of July. Faced with low commodity prices, extra soybean seed, and an (albeit risky) opportunity for an increase in seasonal receipts, a grower in southeastern Lower Michigan decided to try and plant a second crop of soybeans following the harvest of the wheat. Due to limited growing season length and water available to the secondary crop (soybean), this type of double-crop system has been commercially successful only in warmer, wetter growing areas hundred of miles to the south of Michigan. Abnormally mild fall temperatures, a delayed first killing freeze of the fall season, and timely late summer rainfall favored the secondary soybean crop and allowed yields to reach 40 bu./acre, which translated into cash receipts of \$200/acre, total production costs less than \$70/acre, and an opportunity for profit that has traditionally never existed in Michigan.

ues of the GCMs and represent the output of only two GCM simulations. Future studies based on more representative regional- or local-scale climate simulations, which include these and other limiting factors as well as resulting economic impacts are needed for future risk assessment and for the development of new technologies necessary for commercial adaptive strategies as climate change occurs.

