

## **Climate Change Impacts on Northeast Agriculture: Overview**

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### **Introduction**

The value of agriculture to the Northeast (NE) economy is often underestimated. Collectively, the NE provides a significant proportion of the total U.S. supply of dairy and maple syrup products. In upstate New York alone the total farm cash receipts approach \$3 billion on an annual basis, and the state usually ranks within the top three in the nation for production of apples, grapes, fresh market sweet corn, snap beans, cabbage, milk, cottage cheese, and several other commodities. Throughout the NE, small family farms are vital to the economy of rural areas, and they fill an important market niche for fresh, high quality, affordable local produce.

A recent comprehensive analysis of climate trends in the NE (Wake 2005; *and see also Fact Sheet by C. Wake in the Climate section*) found that average annual temperatures increased +1.8 F from about 1900 to 2000, slightly more than the +1.1 F warming observed globally during the same time period. The analysis by Wake (2005) also documented several other trends relevant to agriculture, such as: a greater rate of warming (+2.9 F) during the winter months (December to February) compared to the annual average; an average 8 day increase in length of the growing season; and an increase in the frequency of extreme precipitation events. Crops and weeds in the region will not only differ in their response to changing temperature and precipitation, but also in their growth response to increasing atmospheric carbon dioxide (CO<sub>2</sub>) concentrations (the so-called “CO<sub>2</sub> fertilization effect”). Some crops and weeds could benefit by changing conditions, at the expense of other species that do poorly and become less important in the region. Climate change and CO<sub>2</sub> could favor some invasive species, and will alter important interactions between plants and pollinators, insect pests, diseases, and weeds.

Key issues that will be addressed here include:

- Will warming be good or bad for NE crops, and is there evidence of plant response to the warming trend in our region already?
- What is the “carbon dioxide (CO<sub>2</sub>) fertilization effect”, and can it compensate for negative climate change effects?
- What are the implications for weed, insect and disease control? (*See also Fact Sheets in this section by L. Ziska (weeds) and C. Petzoldt and A. Seaman (insects and disease)*).
- What are the implications for the dairy industry? (*See also Fact Sheet on livestock in this section by L. Chase*).
- How can farmers adapt, and what will it cost them?
- Who are likely winners and losers in our region?

### **Temperature Change and NE Crops**

The facilities, marketing, and financial well-being of most farm families in the NE is currently structured around crops and varieties adapted to our current relatively cool climate. Examples

of these include winter wheat, sugar maple, apples, concord grapes, and cool season-adapted vegetable crops such as potatoes and cabbage. The NE is a major sweet corn production region, in part because our relatively cool summers are ideal for ripening of sweet corn kernels, leading to an outstanding eating quality that has led to a positive reputation among consumers and wholesale buyers. For crops such as these, while we may still be able to produce them in a warmer climate, our competitive edge in the marketplace could be lost due to lower yields or quality.

Many important grain crops, such as field corn, wheat, and oats tend to have lower yields when summer temperatures increase because the plant developmental cycle is speeded up and the duration of the grain-filling period is reduced (Mitchell et al. 1993). Farmers can adapt to this problem by switching to longer growing season varieties when available, but suitable new varieties may not always be available, or there may be problems marketing the new varieties.

Some important crops in the NE, such as winter wheat, and tree fruit crops such as apples and grapes, have winter chilling, or “vernalization”, requirements. These requirements usually involve a prolonged winter period where temperatures do not exceed a certain threshold temperature (e.g., 30 consecutive days with temperatures below 40 F). Warmer winters and/or an increase in winter “thaws” could have negative consequences for spring flowering and yield of these crops, whether or not spring and summer temperatures are optimum for their growth.

There is a potential positive side to climate change in the NE, of course. Some crops will do better, and a warmer, longer summer could create new opportunities for farmers with enough capital to take risks on new crops (assuming a market for new crops can be developed). A “benign” warming trend (moderate warming, and no increase in extreme weather events) will tend to benefit those attempting to grow crops that are currently a challenge to produce in the region because of our cool temperatures. Examples might include watermelon, tomatoes, peppers, peaches, and European red wine grape (*V. vinifera*) varieties. However, a warmer climate is likely to increase the frequency of high day or night temperature stress events that can negatively affect flowering, fruit set, and quality. Even a warm-season adapted crop such as tomato can have reduced yield and/or fruit quality if temperatures exceed 90 F during critical flowering and pollination periods (Sato et al. 2001).

### **Rainfall Change and NE Crops**

Increased temperatures will tend to increase crop water demand (evapotranspiration or ET). Many crops in the NE, particularly grain and silage crops, are not irrigated, so what climate change brings in terms of summer rainfall will be critical. There is still a great deal of uncertainty regarding climate model predictions of rainfall, but many of the models predict more, not less, rain for the region, which could lead to modest increases in yield of rain-fed crops (Reilly et al. 2002).

We are already observing an increase in the frequency of high-precipitation events (> 2.0 inches in 48 hrs.) in the region (Wake 2005). If this trend continues or is made worse by climate change, we would tend to see more field flooding, creating problems for field operations, more soil compaction, and possible crop losses due to lack of oxygen for roots and disease problems associated with wet conditions.

### **Evidence of Crop Responses to Date**

As the evidence of climate change has mounted, plant scientists and ecologists have begun examining historical records for signs of *biological* responses to the warming trend. For example, a recent analysis of records for apples, grapes, and lilacs in the NE documented that on average the date of first bloom advanced by 4 to 8 days for these woody perennials between 1965 to 2001 (Wolfe et al. 2005). In other words, spring is indeed coming earlier in the region, not only based on what the thermometers at weather stations tell us, but also based on plant response. The magnitude of the advance in spring phenology observed in the NE is similar to reports coming from other regions of the U.S. and Western Europe (Montaigne 2004; Goho 2004, Walther et al. 2002).

It is very difficult to determine whether historical crop yield trends can be attributed to climate change because there are so many other factors, such as cultural practices and market forces that affect yields. Data for woody perennials, where varieties are not replaced as frequently as annual crops, may be a little easier to interpret, but evidence of climate effects is still mostly circumstantial. For example, the rapid expansion and success of the *V. vinifera* wine grape industry in upstate New York during the past 20 years may in part be attributed to less severe winters (reduced frequency of temperatures below -12 F) and reduced risk of vine and root damage (A. Lakso, personal communication). On the other hand, an analysis of apple yields for Western New York (1971 – 1982) found that yields were lower in years when winters were warmer than average (based on accumulated degree days > 41 F from Jan 1 to budbreak), possibly related to variations in fruit set (A. Lakso, personal communication).

### **The CO<sub>2</sub> Fertilization Effect on Crops**

Carbon dioxide, in addition to being a greenhouse gas, can also directly affect Earth's plant life because plants take up CO<sub>2</sub> during photosynthesis to produce sugars for growth. The magnitude of the "CO<sub>2</sub> fertilization effect" varies tremendously among plant species and from variety to variety (Wolfe 1994). Plants with the so-called "C-3" photosynthetic pathway, which includes most NE crop species (with the notable exception of corn) and many weed species, can show productivity increases of 20 to 30% or more when grown at twice current CO<sub>2</sub> levels *and at optimal conditions*. Attaining maximum CO<sub>2</sub> benefits often requires more fertilizer (to support bigger plants), optimum temperatures, unrestricted root growth, and excellent control of weeds, insects, and disease.

High CO<sub>2</sub> can have another direct effect on plants- reducing transpiration (water loss) per unit leaf area by causing partial closure of leaf stomates (the small openings on the leaf surface). However, often this water conserving response is minimized or not observed at the whole-plant or field (ET) level because high CO<sub>2</sub>-grown plants have more total leaf (transpirational surface) area.

In general, the CO<sub>2</sub> fertilization effect cannot compensate for negative effects from other environmental stresses (Luo and Mooney 1999). For example, multi-year field and greenhouse studies with potato and dry bean conducted at Ithaca, NY showed significant yield increases for both potatoes and beans at twice current CO<sub>2</sub> levels when daytime maximum temperatures did not exceed 80 F, but when maximum temperatures were allowed to occasionally reach 95 F

during tuber or pod formation, there was no yield benefit from higher CO<sub>2</sub> (Peet and Wolfe 2000; Jifon and Wolfe 2005). Similarly, Mitchell et al. (1993) observed significant increases in winter wheat yields from a CO<sub>2</sub> doubling at optimum temperature, but high CO<sub>2</sub> did not make up for yield losses when plants were grown at high temperatures that cause stress and a shortening of the grain filling period.

**Weeds, Insect and Disease Pests** (*see also Fact Sheets in this section by Ziska, Petzoldt and Seaman*)

Crop plants in agroecosystems do not grow in isolation. Weeds, and beneficial and harmful insects, microbes, and other organisms in the environment will also be responding to changes in CO<sub>2</sub> and climate. For example, Ziska (2003) has found that, in general, many of the most invasive and noxious weeds respond more positively to increasing CO<sub>2</sub> than do most of our cash crops. To make matters worse, Ziska's research indicates that weeds are much more difficult to control with herbicides at CO<sub>2</sub> levels we anticipate will occur in the coming decades (Ziska et al. 1999).

It is mostly speculation at this time as to which crops and regions will benefit and which will be worse off in the future with regard to weed and pest control. The optimists can hope that some current crop pests will migrate out of the region, while pessimists will worry with the knowledge that the threat of invasive species will likely increase (Ziska and George 2004; Weltzin et al. 2003), and approval of chemical control measures may not keep pace with these invasions. Studies conducted in Western Europe and other regions have already documented changes in spring arrival and/or geographic range of insect and animal species due to climate change (Montaigne 2004; Goho 2004, Walther et al. 2002). Warmer winters will likely increase the populations of marginally over-wintering insect species, such as flea beetles in the NE region. Some leaf-feeding insects appear to do more crop damage to plants under high CO<sub>2</sub> conditions (Hamilton et al. 2005). It remains difficult to predict future rainfall patterns, but wetter summers would tend to favor many foliar pathogens (Coakley et al. 1999).

**Potential Effects of Warmer Summers on Livestock** (*See also Fact Sheet in this section by Chase*)

Climate change will affect dairy, poultry, and other livestock industries indirectly by its impact on the availability and price of crops used for animal feed, such as corn silage and corn grain. More directly, the health and productivity of livestock important to the NE economy would be negatively affected by summer temperatures that cause stress to the animals. Heat stress in dairy cattle can have a long-term effect (weeks to months) on both milk production and birthing rates (Klinedinst et al. 1993). Dairy cows like it cool, with the temperature optimum for maximum milk production at temperatures between 40 and 75 F. At high relative humidity (>80%) heat stress in dairy cows can begin at temperatures as low as 73 F, and stress becomes severe at 93 F. Dairy farmers could adapt to this by renovating barns with better cooling systems, but these costs would have to be weighed against potential risks and benefits.

**Can Farmers Adapt to Climate Change?**

It is generally assumed that farmers will adapt to climate change, with production areas for specific crops shifting as needed. Hopefully, farmers in the Northeast will be able to take advantage of new opportunities and minimize negative effects associated with climate change.

It is important to recognize, however, that adaptation in the midst of climate uncertainty will not be cost- or risk-free. Below is a brief description of some farmer adaptation strategies:

- *Change planting, harvest dates [cost- 0 to low]:* An effective, low-cost option. The major risk is that this will put farmers into a different market window with lower prices.
- *Change varieties grown [cost- 0 to moderate]:* Usually a no or low cost option, although in some cases seed for new varieties is more expensive, or new varieties require investments in new planting equipment, or require adjustment in a wide range of cultural practices. In some cases, there may not be a suitable new variety available, or the market may not accept certain quality features of a more heat-tolerant variety. This would be a very expensive option for tree crops of course.
- *Increase water, fertilizer, herbicide, pesticide use [cost-low to moderate]:* Obtaining the maximum “CO<sub>2</sub> fertilization” benefit often requires increases in water and fertilizer to support bigger plants. More aggressive weeds may increase herbicide costs. Pesticides for control of insects and disease may increase or decrease, depending on changes in the crop-insect-disease complex.
- *Change crop species or livestock produced [cost- low to high]:* Could bring new profits, but also a risky option because there are no guarantees that there will be the necessary infrastructure and a market for the new crops or livestock products.
- *New irrigation or drainage systems, other major investments [cost- moderate to high]:* It is likely that climate change will require new investments such as these, but could be a risky guessing game as to where and when to make these investments.

### **Win-Win Farmer Adaptation Strategies**

Climate change may be an incentive for farmers to take advantage of some “win-win” opportunities that benefit both the farmer and the environment. These include:

- *Conserve energy* and reduce greenhouse gas emissions (increase profit margin and minimize contribution to climate change)
- *Increase soil organic matter* (this not only improves soil health and productivity, but organic matter is mostly carbon derived from CO<sub>2</sub> in the atmosphere (via plant photosynthesis), so it reduces the amount of this greenhouse gas in the atmosphere)
- *Improve nitrogen (N) use efficiency* (synthetic N fertilizers are energy-intensive to produce, transport and apply; and soil emissions of nitrous oxide (a greenhouse gas) increase as more N fertilizer is applied to the soil)
- *Enter the expanding market for renewable energy* (e.g., wind energy, biomass fuels) using marginal land.

### **Summary**

Potential beneficiaries of climate change are:

- Growers currently producing or shifting to crops that show significant benefit from climate change and high CO<sub>2</sub>;
- Growers with sufficient capital for risk-taking adaptation measures;
- Growers who guess correctly about climate and market trends;
- Corporate farms with multi-regional production areas.

Those most vulnerable would include:

- Growers producing crops poorly adapted to the new climate, or trying new crops with little market potential;
- Growers with few resources to adapt;
- Growers producing crops where weeds, disease, or insects gain an advantage;
- Climate change could put additional stresses on the fragile dairy industry.

Assuming a “benign” warming scenario, agricultural productivity in the NE should be sustainable, with some sectors expanding while others decline or disappear.

However...

- this will require strategic decisions by farmers and policy-makers that will not be cost- or risk-free;
- the dominant crop-weed-pest complexes will be different than what we have today;
- there will be both winners and losers among farm families and communities;
- the transition will be economically and politically stressful for the region.

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### **Relevant Websites**

Northeast Information on Climate Change: <http://neisa.unh.edu/Climate/index.html>

UN Intergovernmental Panel on Climate Change: [www.ipcc.ch](http://www.ipcc.ch)

National Phenology Network USA: <http://www.uwm.edu/Dept/Geography/npn/>

Climate Friendly Farming: <http://cff.wsu.edu/index.html>