PROCEEDINGS

Climate Change

and Northeast Agriculture:

DEVELOPING AN EDUCATION OUTREACH AGENDA

CORNELL

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Climate Change and Northeast Agriculture:

Developing an Education Outreach Agenda

November 17, 2004, Ramada Inn, Ithaca, NY

Program

Moderator: David Wolfe

1:00 Greenhouse gases and climate change: what we know now
Art Degaetano, Assoc. Professor, Dept. of Earth & Atm. Sciences, Cornell University

1:30 Evidence of climate change in the Northeast
Cameron Wake, Assoc. Professor, Climate Change Research Center, Univ. of New Hampshire

2:00 Weed ecology and global climate: preparing for the future
Lewis Ziska, Plant Physiologist, USDA-ARS, Beltseville, Maryland

2:30 Impact assessment for Northeast agriculture, and farmer adaptation
David Wolfe, Professor, Dept. of Horticulture, Cornell University

3:00 Break

3:15 Energy use and greenhouse gas emissions: A NY dairy case study
Jenifer Wightman, Research Associate, Crop and Soil Science Dept., Cornell University

3:45 Biomass fuels and other opportunities for farmers in the energy marketplace
Timothy Volk, Senior Research Scientist, SUNY-Environmental Science and Forestry

4:15 Climate change and agriculture: challenges and opportunities for Extension
Vern Grubinger, Director, Center for Sustainable Agriculture, Univ. of Vermont

4:30 Group Discussion: Where do we go from here?

5:00 Adjourn

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INTRODUCTION

The most recent report of the UN Intergovernmental Panel on Climate Change concluded that climate change is already upon us, and the impacts of this change will not be uniform across regions or species. This past summer was unusually wet in the Northeast, while drought conditions continued in much of the West. The Northeast's average annual temperature has increased 1.8 F since 1900, and winters (December to February) show the greatest rate of warming (2.9 F over the last century). A recent study has documented that spring bloom dates of lilacs, apples and grapes in the Northeast are coming 4 to 8 days earlier today than they were in the 1960s. Crops and weeds are highly sensitive to the direct effects of rising atmospheric carbon dioxide (CO_2) concentrations, as well as temperature and precipitation. Climate change and CO_2 could favor some invasive species, and will alter important interactions between plants and pollinators, insect pests, diseases, and weeds.

In this General Session leading experts will review: the current state of knowledge regarding climate change; the potential impacts (positive as well as negative) for farmers, landscape managers, and home gardeners; and implications for pest, soil, and energy management in relation to farm profitability. The Discussion at the end of the day will focus on if and how information on climate change might be integrated into Extension programs.

Greenhouse Gases and Climate Change: What We Know Now

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The term global warming conjures a wide range of images in the minds of different people. On one end are those who believe that the earth's climate will face dire consequences unless immediate action is taken to reduce the emission of greenhouse gases. On the opposite extreme are those who believe the idea of human induced climate change is unsubstantiated and that our current use of fossil fuels can continue unabated with little if any effect on the climate. Like many things, the correct image lies somewhere in between.

It is hard to argue that the concentration of carbon dioxide and other greenhouse gases in the earth's atmosphere has not risen dramatically over the last half century.

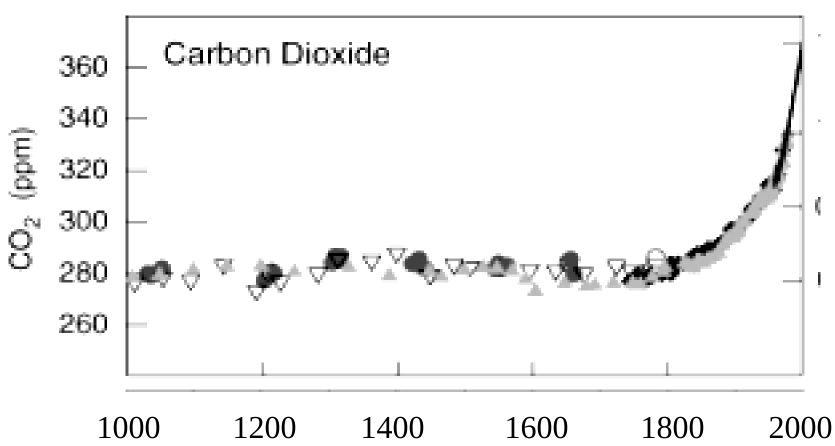

Figure 1 Concentration of carbon dioxide in the Earth's atmosphere from 1000 – 2000 AD.

From 1000 to 1800 atmospheric carbon dioxide concentrations remained relatively constant at 280 parts per million (ppm). In the last 200 years, however, these concentrations have risen, first slowly, reaching about 300 ppm in 1900. Since 1900, concentrations have risen very rapidly to the present day value of 370 ppm. The last time this much carbon dioxide was present in the atmosphere, was during the time of the dinosaurs.

So what does carbon dioxide have to do with the temperature of the earth? Carbon dioxide is a natural part of our atmosphere, without it the average global temperature would be well below freezing as opposed to a value near 60°F. In the atmosphere, carbon dioxide allows the sun's energy to pass unimpeded to the earth's surface. This energy heats the earth's surface. If the story stopped here, the earth would continue to warm, without stop, as more and more energy was added by the sun. To maintain its fairly constant temperature, the Earth must emit to space an amount of energy equal to that which it receives from the sun. This is where the carbon dioxide plays a role. Carbon dioxide and other greenhouse gases are not transparent to this energy. Rather, these gases absorb some of the energy and redirect it back to earth making it warmer (59°F) than if the carbon dioxide was absent (-4°F). The carbon dioxide warms the earth just like a blanket warms you in bed! If more carbon dioxide is added the earth warms more, just like adding another blanket to bed. If carbon dioxide is the only part of the climate system that changes, physics dictates that the Earth must warm.

Unfortunately changes in the Earth's carbon dioxide concentration do not occur in isolation, rather these changes are responsible for other changes in the earth's climate system. The warmer temperatures melt polar ice, meaning less sunlight is reflected from the earth, so the earth warms further. Warmer temperatures result in increased evaporation, adding more water vapor, another greenhouse gas, to the atmosphere warming temperatures further. More evaporation eventually leads to more clouds which block sunlight, hence cooling the earth. Accounting for these and a vast array of other feedbacks make it difficult to predict just how much the earth will warm for a specific increase in carbon dioxide concentration. However, Figure 2 gives a clear indication that changes in carbon dioxide levels and temperature go hand in hand.

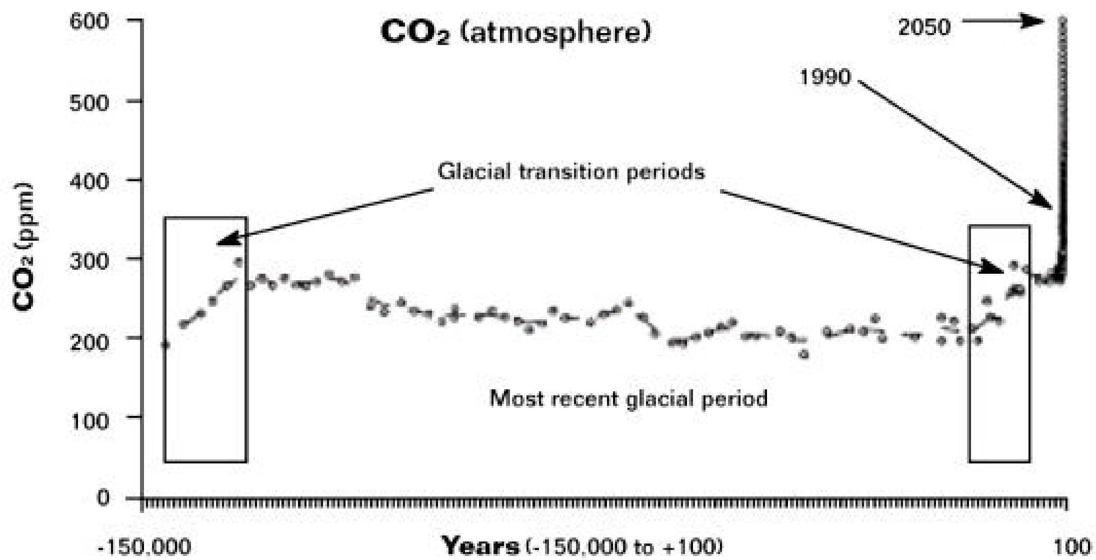

Figure 2. Long-term changes in atmospheric carbon dioxide showing high values during glacial transition periods (boxes) and low concentration during ice ages.

Recent temperature observations also support this notion. Figure 3 shows that global temperatures have risen by almost 1°C over the last century. This change has come in two steps, a 0.5°C rise from 1920 to 1940 and a similar increase from the mid 1970s to present. Regardless of the cause of this change, it is clear that climate conditions over the last 20 years are not reflective of those during the 1950s and 1960s. This is problematic since many agricultural and water resource practices are based on climate data from these earlier years. Global and regional changes in precipitation have also been observed. Although average precipitation shows only small changes, there has been a significant increase in heavy precipitation events. Stated differently although overall precipitation remains unchanged the amount of rain that comes in heavy (greater than 5 cm) events has increased.

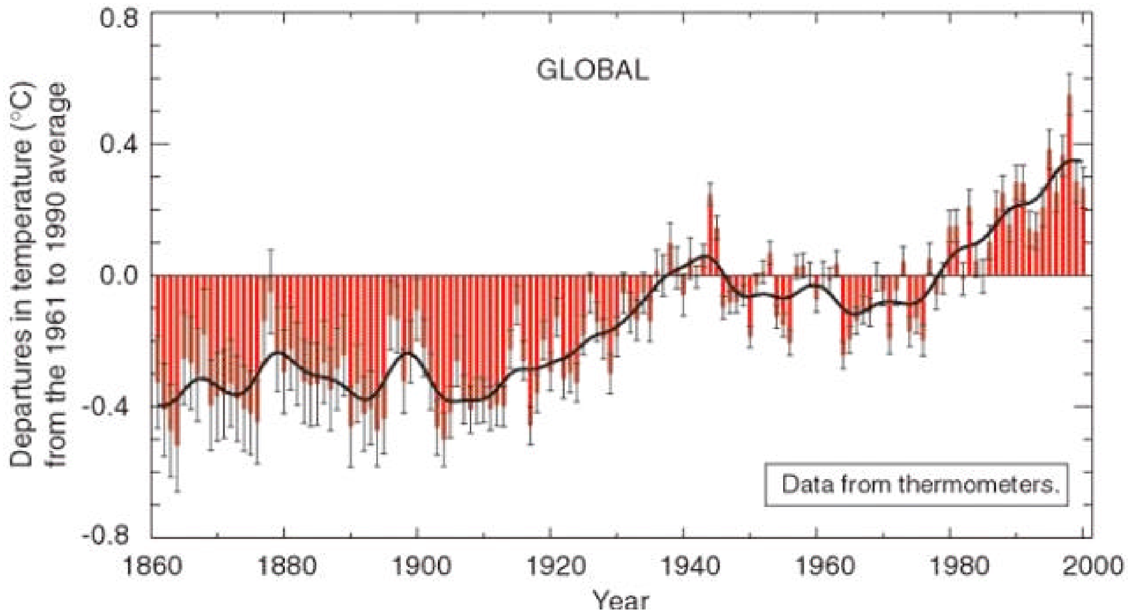

Figure 3. Global average temperature anomalies since 1860.

Climate models provide the best means of extending these trends beyond the present. These models are able to replicate the physics associated with increasing carbon dioxide concentrations. However, they are able to represent some feedbacks better than others. While changes in ice area and atmospheric water vapor are well modeled, the effects of clouds are difficult to incorporate. Thus, a number of different climate models exist, each handling these and other feedbacks differently. In addition, accurately modeling the climate 50 years from now requires a knowledge of how carbon dioxide emissions are likely to change over this time period, a difficult projection indeed.

Figure 4 gives an indication of the range of these model projections for global temperature. All models show a continued increase in global temperature. By 2100, global temperature are projected to range from 1 to 4°C warmer than current values.

It is difficult to cast these global projections onto regional or state scales. This complicates assessments of the impact of these changes on agriculture, water resources and human health. Nonetheless, based on current observed temperature trends there are few regions on the globe that have escaped warming over the last century. Moreover there is increasing evidence of environmental changes such as earlier bloom dates, species migration changes, etc. that support the anticipated regional impacts of climate change. Such observations, regardless of whether the cause is natural or human-induced, highlight the need for agricultural interests to be cognizant of and able to respond to changes in the background climate conditions. It is certain that climate conditions are all but unchanging.

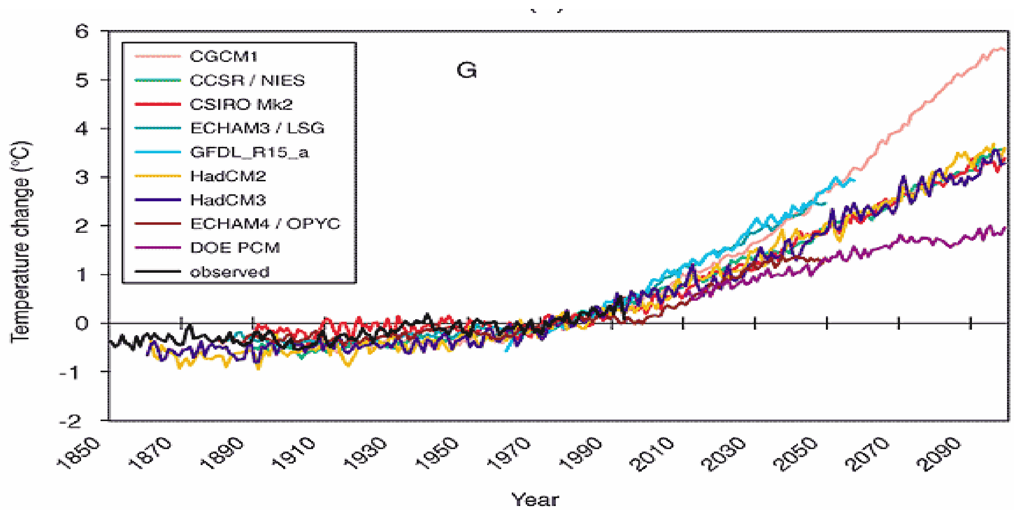

Figure 4. Climate model projections of global average temperatures through 2100

Evidence of Climate Change in the Northeast over the Past Century

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As part of the Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMAP) project, we have developed a series of indicators of climate change in New England from instrumental and observational records. This includes changes in atmospheric and sea surface temperature, annual precipitation, precipitation from intense events, ice out dates, length of growing season, and days with snow on ground. While there is some spatial variability, these indicators overall show that New England's climate over the past century has become warmer and wetter. The largest seasonal warming has occurred during the winter, and the increase in precipitation is due mainly to an increase in extreme precipitation events (more than two inches of rain over a 48 hour period). The indicators data will be published as a report for the general public and is also available in easy to view formats on the AIRMAP web page (airmap.unh.edu), along with real-time air quality data, so that the New Englander's can investigate climate change in their own backyard.

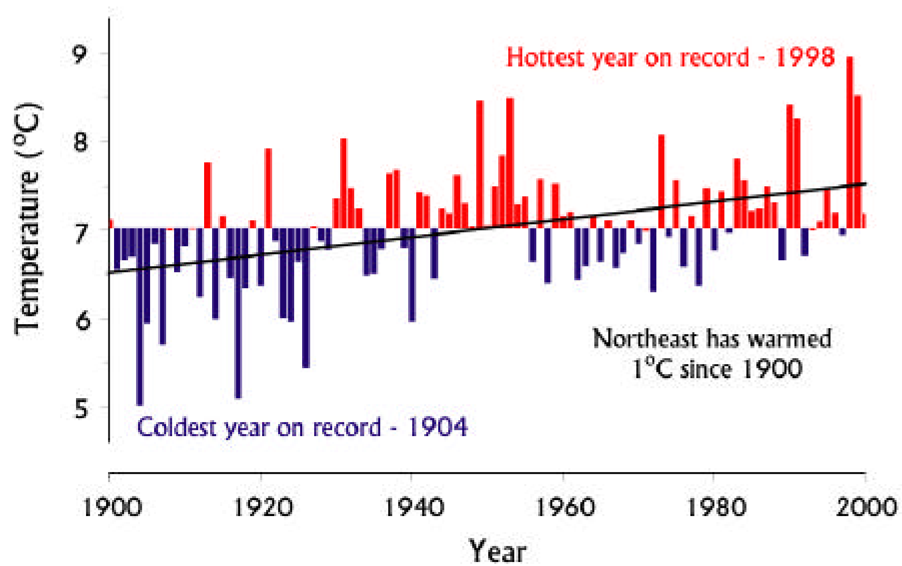

Figure 1: Average annual temperature for the Northeast from 1899 through 2000. This time-series is an areally weighted average of temperature records from 56 stations in the region

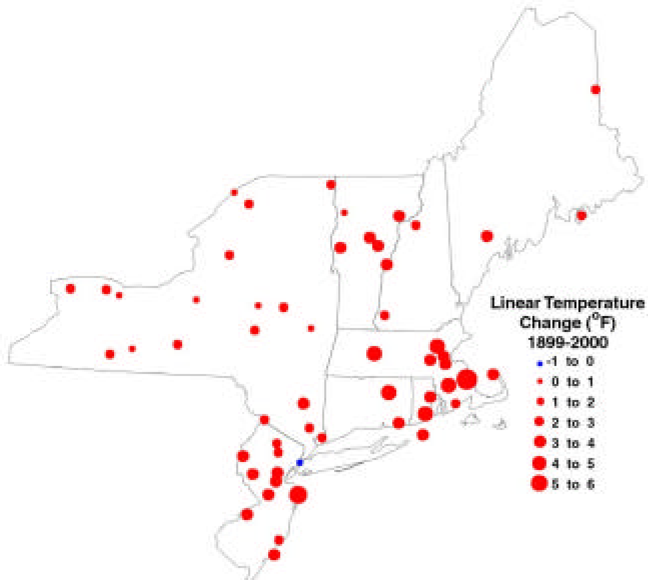

Figure 2: Map illustrating the linear trend in annual temperature (°F) from 1899-2000 for Northeast meteorological data. Cooling trends are shown with blue dots, while warming trends are shown with red dots. The change was estimated from a linear regression of annual average temperature for each station.

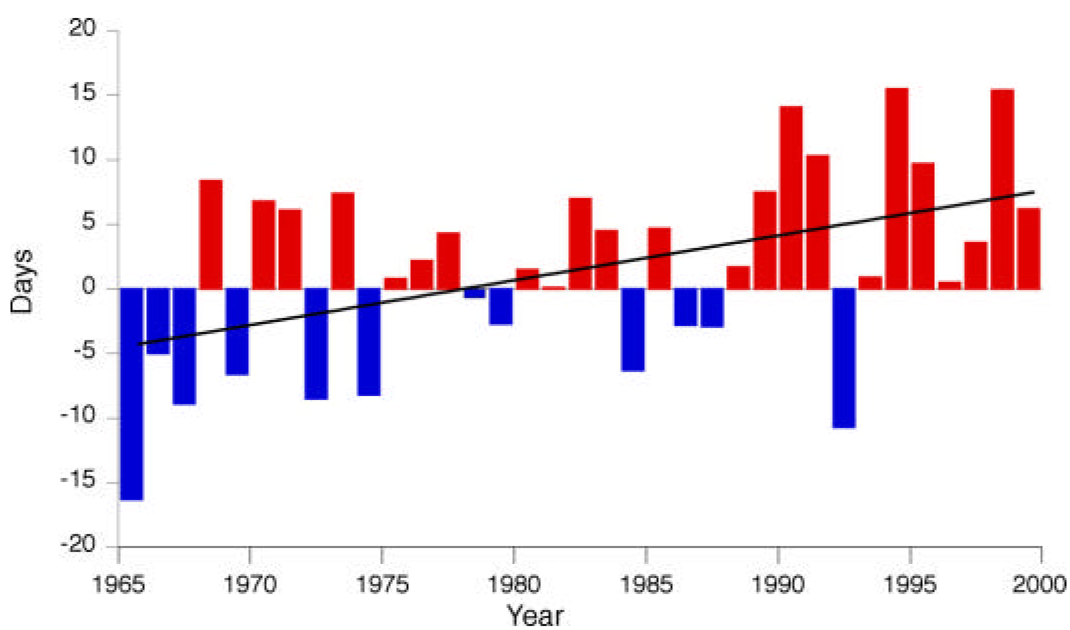

Figure 3. Change in the length (days) of the growing season in New England from 1965 – 2000. Data from 26 meteorological stations from NOAA-NCDC.

Weed Ecology and Global Climate: Preparing for the Future

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Increases in the concentration of atmospheric carbon dioxide, [CO_2] will almost certainly alter the growth and physiology of weedy species *per se*, with subsequent effects on their ecology and impact on human systems. Here we will provide a brief overview of these impacts focusing on three general areas.

1. *Crop/weed interactions.* One of the most recognized undesirable characteristics of weedy species is interference in crop production. Human selection of desirable crop species has led to inadvertent selection of other species that simulate or mimic a particular crop (e.g. commercial and wild oat). Therefore, while crops are likely to benefit from the ongoing increase in atmospheric [CO_2], growth of weedy competitors is also likely to be stimulated. In spite of this, the current paradigm is that rising CO_2 will result in less weedy competition because many of the worst weed species have C4 metabolism, a photosynthetic pathway that shows a minimal response to rising atmospheric CO_2 concentration. However, the idea that crops are fundamentally C_3 and weeds C_4, and that weed competition will consequently decrease with rising atmospheric CO_2 is overly simplistic. Clearly there are C_4 crops of economic and nutritional importance (e.g., corn [*Zea mays*], grain sorghum [*Sorghum bicolor*], pearl millet [*Pennisetum americanum*], sugarcane [*Saccharum officinarum*]), and many important C_3 weeds (e.g. lambsquarters [*Chenopodium album*], wild oat [*Avena fatua*]). Crop-weed interactions vary significantly by region; consequently depending on temperature, precipitation, soil, etc. C_3 and C_4 crops may interact with C_3 and C_4 weeds. For all studies that have examined crop/weed interactions for species of the same photosynthetic pathway, crop losses increased with increasing CO_2. Overall, the greater range of responses observed for weeds to elevated CO_2 is consistent with the hypothesis that

weeds have a greater physiological plasticity and genetic diversity relative to crop species.

2. *Invasive weeds.* Invasive plants are generally recognized as those species, usually non-native for a given system, whose introduction, commonly by human transport, results in economic or environmental harm. The severity of damage induced by these species and their panoptic scale have produced a new class of unwanted plants: invasive, noxious weeds. To determine whether rising carbon dioxide has been a factor in the establishment and success of such plants, we have compared the potential response to recent and projected changes in carbon dioxide between invasive, noxious species and other plant groups, and assessed whether CO_2 preferentially selects for such species within ecosystems. A synthesis of literature results indicates that invasive, noxious weeds on the whole have a larger than expected growth increase to both recent and projected increases in atmospheric CO_2 relative to other plant species. There is also evidence from a limited number of experiments that rising CO_2 can, in fact, preferentially select for invasive, noxious species within plant communities. In addition, there is initial data suggesting that chemical control of such weeds may be more difficult in the future. However, the small number of available studies make such conclusions problematic, and emphasize the urgent need for additional investigations to address the biological and economic uncertainties associated with CO_2-induced changes in the ecology of invasive, noxious weeds.

3. *Weeds and Public Health.* Weeds and plants in general have a significant direct and indirect effects on public health, although these are not always recognized. Weeds impact public health directly, through allergies, contact dermatitis, physical injury and toxicology. Indirect effects may include botanically derived pharmaceuticals, pesticide use, changes in nutritional value and changes in the food supply for disease vectors such as mosquitos or rats. Overall, the impact of rising CO_2 on the interaction of weeds and public health has not been examined in great detail. There is increasing evidence that rising CO_2 and/or temperature could impact the pollen production and allergenicity of common ragweed; the degree of contact dermatitis inflicted by poison ivy; the degree of

mechanical damage induced by spines in Canada thistle, and the amount of atropine in jimsonweed. There is also evidence that rising CO_2 could increase the pharmaceutical content of some plants, while decreasing others, and that reductions in herbicide efficacy could result in increased spraying for Canada thistle. However, these results are based on a small number of experiments and additional data are crucial to reduce the biological and economic uncertainties associated with CO_2-induced changes in plant biology and human health.

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Climate Change Impacts on Northeast Agriculture, and Farmer Adaptation

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Introduction

The value of agriculture to the Northeast (NE) economy is often underestimated. In upstate New York alone the total farm cash receipts approach $3 billion on an annual basis. Even many residents of the region are surprised to learn that New York 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. Collectively, the NE provides a significant proportion of the total U.S. supply of dairy and maple syrup products. In addition, 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.

Key questions regarding NE agriculture and climate change are:

- How will current NE crops and livestock respond?
- Is there any evidence of crop, weed, or pest responses already?
- Can the "carbon dioxide (CO_2) fertilization effect" compensate for negative climate change effects?
- How can farmers adapt, and what will it cost them?
- Who are likely winners and losers in our region?

Potential Crop, Weed, and Pest Responses to Climate Change

For anyone who has been frustrated trying to grow a warm-season crop like watermelon in our region, the immediate reaction to the thought of "global warming" might be "Great, I can't wait!" The analysis for the majority of farm families who make their living off the land is not nearly so simple, however, and in a significant number of cases the forecast may not be so optimistic.

The fact is that the financial well-being of most farm families is *currently* structured around crops and particular varieties adapted to our *current* relatively cool climate. For example, many temperate tree crops grown in the region have winter chilling or “vernalization” requirements, and winter warming in our region could reduce productivity. Crops that could be negatively affected by warming include sugar maple, apples, concord grapes, and cool season-adapted vegetable crops such as potatoes and cabbage. Although corn is generally considered a warm-adapted crop, our current relatively cool summers are ideal for ripening of sweet corn kernels, leading to an outstanding eating quality that is well known among consumers and wholesale buyers. If warming trends continue, we will probably still be able to produce all of these crops, but our competitive edge in the marketplace associated with superior quality may be lost unless new varieties adapted to the new climate are developed.

Weeds, insect pests, and plant pathogens will also be responding to a changing climate. 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 invasive species will almost certainly increase (Logan et al. 2003; Weltzin et al. 2003), and approval of chemical control measures may not keep pace with these invasions. Warmer winters will increase the populations of marginally over-wintering insect species, such as flea beetles. It remains difficult to predict future rainfall patterns, but wetter summers would tend to favor many foliar pathogens (Coakley et al. 1999).

On the positive side, a warmer, longer summer will create new opportunities for farmers with enough capital to take risks on new crops (see section on Farmer Adaptation, below). A “benign” warming trend (moderate warming, and no increase in extreme weather events) will tend to benefit those attempting to grow crops such as watermelon, tomatoes, peppers, peaches, and some red wine grape (*V. vinifera*) varieties. However, even warm season-adapted crops such as these are negatively affected by heat stress at critical growth stages (e.g., Sato et al. 2001), and rainfall patterns as well as temperature will affect productivity.

Potential Effects of Warmer Summers on Livestock

Summer high temperature stress could negatively affect the health and productivity of dairy cattle and other livestock (e.g., poultry) important to the NE economy. Dairy cows are particularly sensitive to heat stress, with the temperature optimum for maximum milk production at cool temperatures between 40 and 75 F (Bray and Bucklin 1996). 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. This heat stress can have a carryover effect on milk production and reproduction for up to 150 days.

Climate change will also affect dairy, poultry, and other livestock industries indirectly by its impact on the availability and price of animal feed such as corn silage and corn grain.

Evidence of Crop and Insect 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. Some of these other studies have documented that spring arrivals and migration of many insect and animal species are also occurring earlier (Montaigne 2004; Goho 2004, Walther et al. 2002). Aphid trap records in Great Britain documented an advance in spring flight phenology of 3 to 6 days from 1970 to 1995, a period when average annual temperatures increased 0.7 F (Harrington et al. 1995) It is possible that

IPM or other records could be useful for evaluating spring arrival or migration patterns of important crop pests in the NE, but to date, no such study has been conducted.

It is very difficult to determine whether crop yield trends can be attributed to climate change because there are so many other factors, such as cultural practices and market prices, 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 warmer than average winters (accumulated degree days > 41 F from Jan 1 to budbreak) led to below average yields, possibly related to variations in fruit set (A. Lakso, personal communication).

The CO_2 Fertilization Effect on Crops and Weeds

Carbon dioxide, in addition to being a greenhouse gas, is also the gas that plants take up in the process of photosynthesis to produce sugars and grow. Therefore, the exponential rate of increase in CO_2 could have a direct beneficial effect on Earth's plant life. The magnitude of the "CO_2 fertilization effect" varies tremendously among plant species and from variety to variety (review: 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_2 levels (expected to occur within this century) and at optimum environmental conditions. In general, plants that are able to easily expand their growth capacity, such as plants with an indeterminate growth habit, respond most positively to a CO_2 doubling. Ziska (2003) has found that some of the most invasive and noxious weeds are particularly responsive to increases in CO_2 and can become more difficult to control with herbicides.

It is important to note that CO_2 effects can become negligible at low or high temperatures, on shallow soils restricting root growth, or when water, nutrients or other factors limit growth. In general, high CO_2 cannot compensate for negative effects from other environmental stresses (Luo and Mooney 1999). For example, multi-year field and greenhouse studies conducted at Ithaca, NY showed significant yield increases for both potatoes and beans at twice current CO_2 levels when daytime maximum temperatures did not exceed 80 F, but when maximum temperatures were allowed to reach 95 F during tuber or pod formation, there was no yield benefit from higher CO_2 (Peet and Wolfe 2000; Jifon and Wolfe 2005).

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. 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_2 fertilization" benefit often requires increases in these inputs, and some studies have shown increased feeding by insect herbivores on plants grown at high CO2 (Lincoln et al. 1986). Climate change is likely to increase weed and pest pressure in most cases, but for some lucky farmers, it is possible these pressures would decrease.

- *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.

Win-Win Opportunities for Farmers

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_2 in the atmosphere (via plant photosynthesis), so it reduces the amount of this greenhouse gas in the atmosphere);
- Enter the expanding market for renewable energy (e.g, wind energy, biomass fuels) using marginal land.

Concluding Remarks

Potential beneficiaries of climate change are:

- Growers currently producing or shifting to crops that show significant benefit from climate change and high CO_2;
- 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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European phenology network: www.dow.wau.nl/msa/epn/index.asp

UK phenology network: www.phenology.org.uk

UN Intergovernmental Panel on Climate Change: www.ipcc.ch

US Lilac and related phenology sites: www.edu/~mds/markph.html

USDA/NRCS climate change site: www.nrcs.usda.gov/technical/ECS/air/change.html

Washington State Univ website: http://cff.wsu.edu/index.html

Energy and Greenhouse Gas Emissions: A New York Dairy Case Study

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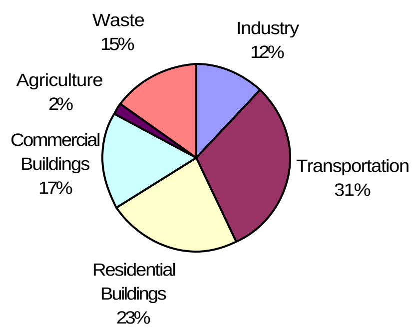
In April 2003, a greenhouse gas (GHG) report commissioned by Governor Pataki was released: "Recommendations to Governor Pataki for Reducing New York State Greenhouse Gas Emissions." With only 0.3% of the world population, NY state contributes nearly 1% of the global total greenhouse gas emissions (http://www.ccap.org/pdf/2003-Apr-NYGHG-Chapt1-Intro.pdf). We estimate that NY agriculture contributes roughly 2% of NY total greenhouse gas emissions (below, slightly modified pie chart from the Pataki report).

NY greenhouse gas emissions by sector



MITIGATING GREENHOUSE GASES WITHIN AGRICULTURE

In an effort to identify how agriculture could mitigate its own emissions, an analysis of climate change gas emissions from the NY dairy herd was completed. In the chart below, we calculated the energy required for production of inputs in British Thermal Units (BTU) and we calculated the GHG emissions in CO_2 equivalents (CO_2e). Different gases have different Global Warming Potential (GWP):

Carbon Dioxide (CO_2) = 1 CO_2e

Methane (CH_4) = 21 CO_2e

Nitrous Oxide (N_2O) = 310 CO_2e

NY DAIRY INDUSTRY	ENERGY		GREENHOUSE GASES	
700,000 milking cows	10^9 BTU	%BTU	tonnes CO_2e	$\%CO_2e$
FEED				
Nitrogen	5,174	31%	1,281,679	20%
Phosphorus	298	2%	58,571	1%
Potassium	288	2%	31,456	0%
Lime	905	5%	252,127	4%
Herbicides	663	4%	43,477	1%
Insecticides	47	0%	2,277	0%
Tractors	3,933	24%	429,226	7%
Seed	1,369	8%	85,644	1%
FEED Total	12,678	76%	2,184,457	34%
Feed transport[1]	1,010	6%	73,874	1%
Milk transport[2]	1,617	7%	117,121	1%
Dairy farm electricity	2,202	10%	230,172	3%
Enteric CH_4			2,446,107	38%
Manure management				
CH_4			938,277	15%
N_2O direct			297,846	5%
N_2O indirect			223,384	3%
TOTAL for dairy system	17,507	100%	6,511,238	100%

[1] transport of imported feeds from out of state [2] transport of milk to processing plant only

Greenhouse Gas Emissions from NY Dairy Farms:

Energy use was analyzed for the 700,000 milking dairy herd plus young replacement stock in NY State using predominantly 1997 data. The production and transport of imported feed (soybeans, corn grain) was "charged" to NY.

ENERGY USE:
Dairy total
Nitrogen Production
31%
Tractor Use
24%
Transport (feed and milk)
13%
Farm Electricity
10%

GHG EMISSIONS:	Dairy total
Animal related CH_4 emissions	53% (38% from rumen/stomach, 15% manure)
Feed Production	34% (20% from nitrogen production and use)
Farm Mechanical Operations	9% (transport of imports account for only 1%)

The relative contributions of CH_4, N_2O and CO_2 to global warming potential (GWP) were 53, 22 and 25% respectively. Farmers who are interested in mitigating greenhouse gas emissions within their own production can 1) reduce their nitrogen use in feed production (contact Harold Van Es), 2) closely regulate animal diet to reduce methane emissions (contact Larry Chase), 3) improve manure management and investigate energy capture via manure digesters for biogas generation (contact Norm Scott).

AGRICULTURE MITIGATING CLIMATE CHANGE BY MOVING INTO THE ENERGY SECTOR

Moving into the energy production sector represents a new economic opportunity for land-owners. Within the context of the Northeast USA, use of solid biomass fuels for direct combustion, primarily replacing fossil fuels for heat is a choice that is responsive to concerns over energy and greenhouse gas emissions. This choice is based on increasing the economic output from much of the land in the Northeast that is not competitive for conventional crops or is in poorly managed forests, coupled with the comparative advantages of adequate rainfall and low land rent for low-cost biomass production. These include grass and wood pellets and wood chips. Direct use of these products for heat is the most efficient use of the captured solar energy and provides the maximum potential for additional economic benefit through carbon trading markets as biomass fuels substitute for fossil fuels.

Currently, neither the production of value added biomass fuel products nor the market for their use is developed, although production of wood pellets from sawdust wood waste is somewhat of an exception.

Wood pellet use in the Northeast USA has increased at the rate of 25% over the last 4 years and 20% over the last 10 years (http://www.pelletheat.org/industry/industry.html?SalesSurvey.shtml~main). To date, wood pellet producers have had a large economic advantage as they use no-cost or low cost waste sawdust as feedstock that is easy to pellet. However, the waste wood stream is finite and is rapidly being used up; a major producer in NY (Dry Creek Pellets) has widened the radius for collection of sawdust to 150 miles and has purchased a grinder for use with wood chips. Nearly 20% of NY farmland is in woodlands (http://www.nass.usda.gov/ny/Bulletin/2004/Annp006-04.pdf) which could be managed for fuel and for lumber (contact Peter Smallidge). 22% of NY farmland is in hay production (http://www.nass.usda.gov/ny/Bulletin/2004/Annp080-081-04.pdf). An outstanding, though yet unrealized opportunity for farmers is through production of grass pellets because grass production is an activity that most farmers are already equipped to do, is very suitable for low quality lands and requires less time when feed quality is not a factor (contact Jerry Cherney).

Agriculture suffers economically because its production of raw materials places it at the bottom of the food-system economic ladder. Rising energy costs present an opportunity for farmers to move into various kinds of energy production. Using abandoned or under-utilized farmland for energy production diversifies the farm economy. As energy prices rise, the value of the energy product also rises. We estimate that approximately 1 acre will heat 1 home for a 1 year. This not only adds money to the local economy, but it defers part of the $-139.5 billion energy trade balance from fossil fuel imports (personal communication, Duane Chapman) and reduces our greenhouse gas emissions by burning carbon neutral fuels (recycling surface carbon that is captured from the atmosphere by plants in photosynthesis thus having a net zero affect on the atmosphere when combusted). In NY state, with roughly 25% of our land in agriculture, and 60% in woods, we have a unique opportunity to develop low-input, clean energy products, support local economies, and encourage land-management activities.

Cornell's Agricultural Ecosystems Program (AEP) is aimed at sustainable use of natural resources for agriculture, while maintaining the quality of environmental resources and non-agricultural ecosystems. Underlying the program are the concepts that soil health and efficient use of agricultural inputs are central to desirable agricultural and environmental outcomes. We also seek to identify new opportunities for agriculture to assist in mitigation of global climate change through reduction of agricultural emissions of greenhouse gases and provision of bio-fuel feedstocks (contact John Duxbury).

Developing Willow Biomass Crops for Bioenergy and Bioproducts in the Northeastern United States

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Short-rotation woody crops (SRWC), like willow biomass crops, are an alternative farm crop that can be used to replace fossil fuels for the production of bioproducts and bioenergy while providing numerous positive environmental and rural development benefits. Over 40 million hectares of idle or surplus agricultural land are available for the deployment of short-rotation woody crops (SRWC) (Graham et al. 1994) in the U.S. Projections indicate that biomass will provide 7.5 exajoules (7.1 quads) of energy in 2025. Woody biomass will make up 67% of that total. Dedicated energy crops (SRWC and herbaceous energy crops) are projected to develop rapidly in the next two decades, and will make up 32% (1.6 exajoules) of the woody biomass resource in 2025 (EIA 2003).

Interest in SRWC has developed over the past few decades because of the multiple environmental and rural development benefits associated with their production and use. SRWC development in the northeastern U.S. has concentrated on willow shrubs (*Salix spp*.) and hybrid poplar (*Populus spp*.). Willow shrubs have several characteristics that make them ideal for SRWC systems that are focusing on bioenergy and bioproduct markets including high yields that can be obtained in three to four years, ease of propagation from dormant hardwood cuttings, a broad genetic base, ease of breeding, ability to resprout after multiple harvests, and feedstock uniformity.

Willow biomass crops are being developed as sustainable systems that simultaneously produce a suite of environmental and rural development benefits and a renewable feedstock for bioenergy and bioproducts. The perennial nature and extensive fine-root system of SRWC reduces soil erosion and non-point source pollution, promotes stable nutrient cycling and enhances soil carbon storage in roots and soil organic matter (Volk et al. 2004). Bird diversity in SRWC is comparable to diversity in shrub land, successional habitat, and intact eastern forests (Dhondt and Wrege 2003). These characteristics have made willow attractive for other applications across the region including phytoremediation, riparian buffers, and living snowfences.

The near term large-scale market for willow biomass is co-firing at pulverized coal power plants. Two power plants, AES Greenidge and NRG Energy's Dunkirk steam station, in New York are currently retrofit for cofiring woody biomass with coal with the combined potential for about 20 MW of cofiring potential. Up to 294 MW of biomass cofiring could be developed in NY alone. The production of 1 MW of power would require about 300 hectares of willow biomass crops, if willow were the sole source of woody biomass for co-firing. Test firing of willow biomass at Greenidge provided valuable lessons about harvesting and processing so willow would flow through the system. Intensive test burns and air quality monitoring using an input of 10% woody biomass were completed at Dunkirk in November 2002 on a 100 MW boiler. Over 15 tons of willow biomass was included in the tests. Testing confirmed that SO_2, NO_x, and particulate matter emissions were reduced when woody biomass was co-fired with coal.

In addition to cofiring facilities, willow biomass can be used as part of the fuel mix in power plants that use woody biomass for heat and/or power. Longer-term conversion technologies include gasification and pyrolysis. The future for willow and other woody biomass is complex "biorefineries" where an array woody biomass resources are used as input to create an extensive portfolio of new "value-added" products including fuels, chemicals and advanced materials. The development of these value-added bioproducts will provide several new markets for SRWC producers.

Despite the numerous environmental and rural development benefits associated with SRWC, and projections of their deployment in the future, their use as a feedstock for bioproducts and bioenergy has not yet been widely adopted in the U.S. The primary reason is their high cost. Current costs to produce and deliver SRWC to an end user are $43–50 odt^{-1} (Walsh et al. 1996, Tharakan et al. 2004). On an energy unit basis, these prices are greater than commonly used fossil fuels like coal. A commercial SRWC enterprise will not be viable unless the biomass price, including incentives and subsidies, is comparable to that of fossil fuels, and parties involved in growing, aggregating and converting the fuel, are able to realize a reasonable rate of return on their investment.

There are two pathways to make SRWC cost competitive with fossil fuels. One is to lower the cost of production by reducing operating costs and increasing yields. The other is to value to the environmental and rural development benefits associated with the crop. Ongoing research projects are focused on reducing operating costs and increasing yields. Recent policy developments in the federal Conservation Reserve Program (CRP) and state Renewable Portfolio Standards (RPS) are mechanisms that begin to value some of the benefits associated with willow biomass crops. Their implementation will have a significant impact on the delivered price of willow biomass and the potential to deploy SRWC in the Northeast.

Conservation Reserve Program

Under the CRP program, landowners that meet a certain level on an environmental benefits index can opt to voluntarily enter into an agreement with the United States Department of Agriculture wherein they will retire the land from agricultural production and maintain a permanent vegetative cover of grasses or trees that will create wildlife habitat and improve soil and water quality. In return, the landowners are eligible for annual rent payments for the life of the contract as well as cost sharing funds to offset the establishment costs (not more than 50%) of a vegetation cover (FSA 2004). The duration of the contracts are between 10 and 15 years.

Until 2002, haying or grazing of land under CRP contract was not allowed, except under emergency conditions such as droughts or similar weather related emergencies. The 2002 Farm Bill modified these restrictions by including a managed haying and grazing option.

Managed haying and grazing can occur no more frequently than one out of three years after the cover is fully established on the site (FSA 2004). These activities can only take place with approval from the local FSA office and in accordance with the conservation plans for those areas. Collaborative efforts over the past five years in NY have resulted in the development of state level draft guidelines that will make the establishment and harvest of willow biomass crops an acceptable conservation practice that can be deployed across the state.

Renewable Portfolio Standards

New York State has joined 13 other states, seven of which are in the northeast, in developing a RPS to increase the proportion of non-fossil fuel electricity purchases in the state. New York's RPS, when fully implemented in 2013, will require that 25% of the electricity retailed in the state be from renewable resources, up from the current baseline of 19%. Biomass cofiring will supply nearly 7% of the RPS target. The RPS Biomass Eligibility Working Group has recommended that through 2008, 10% of the biomass used in cofiring should be from sustainably managed energy crops, such as willow. Starting in 2009, the proportion of biomass from dedicated energy crops used for cofiring should be increased to 25%.

Impact of Incentives

Modeling indicates that without any incentives or supports the farm gate price and delivered price for willow under future and current yields was \$2.50 GJ^{-1} and \$3.00 GJ^{-1}. The delivered price of willow feedstock was up to twice the current delivered price of coal (\$1.50- 2.00 GJ^{-1}) (Tharakan et al. 2005). At this price, the power plant cannot afford to utilize the feedstock and a commercial willow enterprise cannot exist.

Growing willow on CRP land with the landowners receiving CRP payments significantly reduced the cost of producing willow feedstock. Farm gate and delivered price was \$1.42 and \$1.90 GJ^{-1} (Tharakan et al. 2005). This represents a 33% reduction in the delivered price of the feedstock, relative to the base case scenario. These delivered prices, however are still higher than coal so the CRP program alone will not result in the large-scale deployment of willow unless other incentives or policies are put in place.

> *In the near term, co-firing can be an economically viable market for willow biomass if federal and state incentives are applied that value environmental and rural development benefits associated with production and use of biomass feedstock. The development of knowledge, experience and an infrastructure for growing and using willow in the near term will allow it to be deployed for other end uses in the future.*

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Climate Change and Agriculture:

Challenges and Opportunities for Extension

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When I started with Extension as a County Agent, I was told during my orientation that extension work was about being an agent of change. The reality of course is that extension work is also about building trust and mutual respect with clients so they will be receptive to the information you have to offer. That information, however useful or necessary, is not always what clients want to hear, or think they need. For example, nutrient management, pesticide applicator training, and food safety come to mind as Extension programs that were developed for reasons other than farmer demand.

Farmers eventually warmed to the programs just mentioned, or at least came to tolerate them, in part because they perceived a risk to not doing so, and in part because they will accept a reasonable level of responsibility to the greater public good. But success in these program areas was only possible because the topics were addressed in a manner that did not threaten or blame farmers, and the recommended actions were practical and affordable, even profitable over the long term.

Extension programming on climate change and agriculture poses a similar situation. At present there is little call from farmers to address the issue. In fact, some farmers, just like some of the general public, are skeptical that climate change is even real. Others are doubtful it will affect agriculture, and some don't even want to bring it up for fear it might generate yet another concern about the environmental impact of farming.

Many extension agents and specialists also have concerns about engaging in climate change education, regardless of whether they believe that climate change poses risks to farmers. Below are some specific Extension concerns, based on responses to a pilot presentation addressing climate change and agriculture given to an agricultural in-service meeting in a New Hampshire in November 2003, and a survey completed by extension educators from across the Northeast in October 2004.

- Climate change isn't important to farmers so it will be difficult to interest or engage them in the issue
- Farmers are small contributors to climate change so they should not be singled out to make changes to address it
- Short-term business survival is more important and farmers don't have the luxury of spending a lot of time on a long-term global issue like climate change
- Climate change education would be nice but it is not a priority
- Educators need to develop their own knowledge about climate change issues before they will be comfortable offering or preparing programs for their clients
- There is fear of blaming agriculture disproportionately for its contribution to global warming; why is action needed if farming is a relatively small contributor?
- A lot more specific data needs to be gathered to answer questions that producers and leadership will have on the extent to which certain practices affect greenhouse gases and global warming

There is also some receptivity, if not enthusiasm, for climate change education among farmers and Extension. Comments reflecting that viewpoint include:

- Climate change is likely to have a significant impact on farming and whether people accept that or not at present, so we should move forward on the issue
- It is important to improve our understanding of the issue even if we are not completely sure of the agricultural implications or recommendations
- Some actions that address climate change are simply good management practices such as: efficient N fertilizer and manure use, farm energy efficiency, cover cropping, and development of local markets
- Innovative farming practices that may address climate change can also enhance profitability and/or air or soil quality (such as use of bio-diesel and alternative fuels, on-farm energy generation, and reduced tillage systems)

According to CAST (the Council on Agricultural Science and Technology), agriculture has a role to play in the broader effort to reduce greenhouse gas concentrations by:

- Taking CO_2 from the atmosphere and sequestering it in biomass and soils;
- Decreasing the rate of land clearing for agriculture and taking marginal lands out of production;
- Changing agricultural practices on productive, established agricultural lands;
- Increasing efficiency of farm inputs such as fuel, fertilizers, and pesticides;
- Increasing production of agricultural biofuels (renewable biological-based energy fuels) to replace fossil energy emissions;
- Improving N-use efficiency as the primary means of decreasing N_2O emissions;
- Decreasing methane emissions by capturing or preventing emissions from animal manure storage and by increasing livestock production efficiency.

The scientific evidence, summarized by the climate change experts here today, leaves little room for doubt that our climate is changing, and that agriculture will be affected. The sooner Extension becomes familiar with the issue and with range of possible responses, the sooner we will be able to integrate climate change into our programming, as one of the many factors that farmers should consider when making management decisions. For more information on climate change and agriculture, see:

http://www.cast-science.org/cast/src/cast_top.htm
CAST task force report 141, May 2004: Interpretative Summary: Climate Change and Greenhouse Gas Mitigation, Challenges and Opportunities for Agriculture.

http://www.c-ciarn.uoguelph.ca/documents/c-ciarn-ag-position-paper.pdf
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'Climate Friendly Farming' project, Washington State University