Journal of Extension
www.joe.org

April 2009
Volume 47 Number 2
Article Number 2FEA9

Return to Current Issue

From Climate Variability to Climate Change: Challenges and Opportunities to Extension

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Abstract: Interest of farmers in climate change has recently increased in response to intense media coverage of climate change, recent weather extremes in Florida such as 2 years of intense hurricane activity and a drought in 2007, and additional revenue possibilities in the carbon market. This article discusses the challenges involved and potential opportunities for the development and implementation of a climate change extension program at the University of Florida, complementing a recently established climate Extension program aimed at helping farmers cope with seasonal climate variability.

Introduction

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) concluded that global average mean temperature and the frequency of hot extremes, heat waves, and heavy precipitation will very likely increase in response to increased concentrations of greenhouse gases in the atmosphere. The IPCC report also concluded that, due to improved understanding of anthropogenic warming and cooling influences on climate, the globally averaged net effect of human activities since 1750 has been one of warming. The combination of long-term change (warmer average temperatures) and greater extremes (heat waves, droughts, and floods) suggests that climate change could have negative impacts on U.S. agricultural production.

The University of Florida recently established a climate Extension program under the Agricultural and Biological Engineering Department and in cooperation with the Southeast Climate Consortium (SECC). The SECC is a consortium of seven universities: Florida State University, University of Florida, University of Miami, University of Georgia, Auburn University, University of Alabama at Huntsville, and North Carolina State University. The main goal of the climate Extension program is to develop an information system for the southeastern U.S.A. in which climate forecasts and information, together with decision support tools for agriculture, forestry, and water resource managers are made available to improve management decisions and reduce risks associated with seasonal climate variability.

Our main hypothesis is that many aspects related to vulnerability, defined as the degree of sensitivity and ability to cope with climate variability, and adaptation, defined as adjustments to environmental stresses caused by climate variability, can also be applied to climate change. The question this article addresses is whether and how research and Extension efforts to develop adaptation strategies aimed at helping farmers cope with seasonal climate variability can be extended to address longer-term climate change. We might also ask whether a climate Extension program should promote agricultural management practices that help the agricultural industry reduce the emission of greenhouse gases into the atmosphere. Are there enough opportunities in agriculture to make a difference and would farmers be interested in such a program?

This article discusses the challenges involved and potential opportunities for the development and implementation of a climate change Extension program. Such program would fit well as a component of a broader sustainable living education program recently discussed in the *Journal of Extension* by Elliott et al. (2008).

Climate Change Projections

Natural, long-term climate change occurs in responses to fluctuations in the amount of solar energy reaching the Earth, changing ocean currents, formation or loss of ice sheets, and many other causes. Global climate also varies naturally in response to shorter-term events, such as volcanoes, which send sun-blocking particles into the stratosphere to cool the Earth, or the Pacific Ocean event known as El Niño, which transfers thermal energy from one part of the planet to another.

In addition to these natural causes of climate variability, human activities have been shown to influence climate in many ways. Land use changes like the irrigation of historically semi-arid areas for farmland, the paving and development of sprawling urban areas, the draining of wetlands, and increased aerosols in our atmosphere are all anthropogenic forcings to our climate system. Perhaps the most significant human influence today is the increasing concentrations of greenhouse gases in the atmosphere, mainly carbon dioxide (CO_2) and methane (CH_4), which have modified the Earth-atmosphere energy balance, leading to a warming of the system (IPCC, 2007).

Projections of future climate are based on climate models, complicated computer programs that attempt to describe how the atmosphere will behave through time in response to the forces that act upon it. According to the 2007 IPCC report, the best estimates from these models indicate that the global average surface temperature would rise from 1.8°C (3.2°F) to 4°C (7°F) by the year 2099, depending on how much the concentrations of CO_2 and other greenhouse gases increase. An important question for agriculture is if a changing climate will also affect the occurrence of extreme events. Will droughts, floods, heat waves, freezes, or storms become more or less frequent? It has been theorized that a warmer planet would lead to more frequent and more severe extremes, but limitations in computer models keep us from answering that question conclusively.

Potential Impacts of Climate Change on Agriculture

Potential impacts of climate change on agriculture are broad and not completely understood. Despite the potential challenges such as increased disease pressure and more frequent occurrence of extreme climate events, climate change may also bring opportunities for the introduction of new crops and increased yields.

Crops

There is general belief that the beneficial effects of an increase of CO_2 on plants, the CO_2 fertilization effect, may compensate for some of the negative effects of climate change. However, recent studies demonstrate that the effects of elevated CO_2 on plant growth and yield will depend on photosynthetic pathway, species, growth stage, and water and nitrogen management practices (Jablonsky, Wang, & Curtis, 2002; Kinball, Kobayashi, & Bindi, 2002; Ainsworth & Long, 2005). On average across several species and under unstressed conditions, crop yields are expected to increase in the range of 10-20% for C_3 crops and 0-10% for C_4 crops (Ainsworth, Rogers, Nelson, & Long, 2004; Gifford, 2004). However, temperature and precipitation changes in future decades will also modify, and potentially limit, direct CO_2 effects on plants (IPCC 2007).

Temperature is important for plant growth and development. There is an optimum temperature range for maximum yield for any crop. Warmer temperatures speed annual crops through their developmental phases and also increase their water requirements. If a crop variety is being grown in a climate near its temperature optimum, a temperature increase of several degrees could reduce photosynthesis and shorten the growing period. High temperature during flowering may lower grain number, size, and quality (Thomas, Boote, Allen Jr., Gallo-Meagher, & Davis, 2003; Baker, 2004; Caldwell, Britz, & Mirecki, 2005). Most crops cultivated in the southeastern U.S. are at, or near, optimal temperatures for the CO_2 and water conditions that currently prevail. Substantial temperature increases could have significantly negative impacts, limiting potential benefits of increased CO_2 concentrations.

Weeds, Insects, and Diseases

Increases in the concentration of atmospheric CO_2 will likely stimulate the growth of weeds. Some weeds respond more positively to increasing CO_2 than most cash crops, particularly C3 "invasive" weeds that reproduce by vegetative means (Ziska & George, 2004; Ziska, 2003). Insect pests are responsible for major impacts on yield quantity. Insects are particularly sensitive to temperature because they are cold-blooded. In general, higher temperatures increase rate of development with less time between generations. Warmer winters will increase survival and possibly increased insect populations in the subsequent growing season (Gutierrez, 2000; Rosenzweig, Iglesias, Yang, Epstein, & Chivian, 2000). Recent warming trends are believed to have led to earlier spring activity of insects such as the mountain pine beetle (Crozier & Dwyer, 2006).

Climate factors that affect growth, spread, and survival of crop diseases include temperature, precipitation, humidity, dew, radiation, wind speed, circulation patterns, and the occurrence of extreme events. Higher temperature and humidity and greater precipitation result in the spread of plant diseases, as wet vegetation promotes the germination of spores and the proliferation of fungi and bacteria (Rosenzweig et al., 2000).

It is likely that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea-surface temperatures (IPCC, 2007). There is more controversy about a potential increase in the number of tropical cyclones. Since 1995 there has been an increase in the number of storms and in particular the number of major hurricanes (categories 3, 4, and 5) in the Atlantic. But the changes of the past decade in these metrics are not so large as to clearly indicate that anything is going on other than a multidecadal variability. Consequently, in the absence of large or unprecedented trends, any effect of greenhouse gases on the frequency of storms or major hurricanes is necessarily very difficult to detect in the context of this documented variability (Pielke Jr., Landsea, Mayfield, Laver, & Pasch, 2005).

Hurricanes have played an important role in recent spread of diseases in spite of the lack of a clear connection between the increase of greenhouse gases and an increase in the number or intensity of hurricanes. Hurricane Ivan, which landed in the U.S. in September 2004, is believed to have carried spores of Asian Soybean Rust from infected fields in Colombia <http://www.ceal.psu.edu/ivan04.htm>. The citrus industry in Florida has also suffered during recent hurricane seasons. The United States Department of Agriculture (USDA) announced in January of 2006 that it is no longer possible to eradicate citrus canker, a disease that is considered the greatest threat to the industry. Based on USDA analysis, the unprecedented 2004 and 2005 hurricane seasons spread the pathogen that causes citrus canker to the extent that a new management plan must be devised.

The mild temperatures and frequent rainfall predispose the southeastern U.S. to an array of agricultural pest problems causing the region to be a relatively high user of pesticides. If climate changes bring increased moisture and warmer temperatures to the region, it is likely to exacerbate epidemics and prevalence of leaf fungal pathogens and overwintering population of pests.

Livestock

Effects of climate change on livestock are likely to be variable, based on a number of factors such as the magnitude of temperature increase and animal feed prices. Dairy cows are particularly sensitive to heat stress, with temperature optimum for milk production between 4.5ºC (40ºF) and 24ºC (75ºF). In addition to ambient temperature, humidity and wind velocity also affect performance (Harris, 2003). Long-term adaptation may include crossbreeding with more heat tolerant-breeds and furthering research on heat tolerance in known milking breeds.

Climate change may also affect the beef cattle and poultry industries, both through direct effects on production and indirectly through changes in grain prices, pasture productivity, or costs for cooling. Cooling costs are particularly worrisome in light of a steep upward trend in the price of fossil fuels. In general, analyses indicate that intensively managed livestock systems have more potential for adaptation than crop systems. Some of these adaptations may be enabled by the use of alternative energy sources on farm.

Strategies for Adaptation and Mitigation

Interest of farmers in climate change impacts has recently increased in response increased media coverage of climate change, including the much-publicized record loss of sea ice in the Arctic during the summer of 2007. Intense hurricane seasons in 2004 and 2005 and recent press coverage of carbon-offset markets also sparked an interest in climate change and potential opportunities to generate additional income. Some Extension agents in Florida have expressed interest in engaging in climate change education, even if claims of linkage between global warming and hurricane activity are premature and if risks that climate change poses to farmers are still uncertain.

Adaptation

The development and dissemination of management practices that are best adapted to seasonal climate variability is the main focus of the existing climate Extension program. The approach used to mitigate risks associated with seasonal climate variability focuses primarily on techniques such as shifting planting dates, changing crop varieties, and cultural practices.

However, adapting to climate change might require farmers to use management practices and technologies that are beyond those existing today. Research must play proactive role to generate necessary responses and technologies that farmers will need to handle such future challenges. Nevertheless, the education process involved in establishing an Extension program aimed at mitigating risks associated with climate variability seems to be an efficient and effective way to introduce a climate change program. The following adaptation strategies could be part of a combined climate variability/change Extension program.

- Changing planting or harvest dates are effective, low-cost options. The major risk could be shifting to a different market window with lower prices;
- Changing varieties is another low-cost option, although some varieties can be more expensive or require investments in new planting equipment. Examples are the development of new peanut varieties resistant to Tomato Spot Wilt Virus (TSWV) disease, a major threat to peanut production in the southeast U.S., and the increased adoption of genetically modified cotton varieties resistant to certain types of herbicides and pests;
- Increased use of irrigation, fertilizer, herbicide, and pesticide may be necessary to achieve maximum benefits from increased atmospheric CO_2. Climate change is also likely to increase weed and pest pressure in most cases as discussed above;
- Changing crop species or livestock produced could bring new profits, but is a risky and more expensive option because the necessary infrastructure or marketing mechanisms may not exist locally;
- Investments in new irrigation or drainage systems or other capital items are likely to be essential if climate change increases climate variability.

Adaptation strategies could also include changes in tillage practices, selection of varieties with greater drought and heat tolerance, and development and implementation of improved Integrated Pest Management (IPM) programs. The extent of adaptation will depend mostly on the affordability of proposed strategies, the rate of climate change, and access to knowhow and technology.

Mitigation

Dissemination and promotion of emission reduction strategies to help mitigate climate change would be a new activity under the existing climate Extension program. Management of forestry and agricultural activities is regarded as an important option for greenhouse gases (GHG) mitigation. Activities in these sectors can reduce and avoid the release into the atmosphere of the three most important GHGs: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The main goal would be to shift agriculture from a net source to a net sink for greenhouse gases. Florida ranks sixth in among the states in total GHG emissions and is 30th among the world's top 75 emitters among states and nations (Mulkey, Alavalapati, Hodges, Wilkie, & Grunwald, 2008).

Although the GHG sources and sinks in the forestry and agriculture sectors of Florida are minor portions of the total emissions profile, they represent significant potential for offsetting and reducing the projected increases in emissions over future decades. Activities with potential for GHG mitigation include afforestation, improved forest management and protection, soil carbon sequestration, agricultural CH_4 and N_2O mitigation, and biofuels offsets.

Soil carbon sequestration has additional appeal because practices that enhance soil carbon also improve soil quality and fertility. Soils store carbon for long periods of time as stable organic matter, which reaches an equilibrium level in natural systems that is determined by tillage and other management practices, climate, soil texture, and vegetation. When native soils are disturbed by agricultural tillage, fallow, or residue burning, large amounts of CO_2 are released (Allmaras, Schomberg, Douglas Jr., & Dao, 2000). However, a significant portion of the carbon captured by plants through photosynthesis can be sequestered by soils managed with direct seeding and other techniques that minimize soil disturbance. Irrigation can enhance carbon sequestration over native soil levels by overcoming the moisture limitation to increased plant biomass production. Examples of management practices with the potential to increase soil organic carbon include:

- Adoption of conservation and no-tillage practices;
- Optimize crop rotations by using legumes, rotations crop-pasture, green manures;
- Improved fertilization to stimulate biomass production and root growth;
- Optimize manure management;
- Promotion of land use shifts that enhance soil organic matter (e.g., forest, wetlands), mixed cropping systems that combine annual and perennial crops (e.g., agroforestry).

Agriculture alters the terrestrial nitrogen cycle as well. Through nitrogen fertilization and improper water management, nitrogen is more prone to being lost to ground or surface water and to the atmosphere. N_2O, a common emission from agricultural soils, is a potent greenhouse gas (296 times more than CO_2). Atmospheric concentrations of N_2O have increased by 15% during the past two centuries (Mosier, 1998) but reductions can be achieved through improved nitrogen management.

Methane emissions from livestock include enteric emissions from ruminant activity in cows and manure management emissions (Mulkey et al., 2008). Methane traps heat about 21 times more effectively than does CO_2. Other than reducing the number of cows, there is little opportunity to reduce enteric emissions.

On the other hand, emissions from manure management are affected by management options. Most modern dairies utilize a lagoon system for animal waste treatment, a practice that leads to large emissions of methane and nitrous oxide. Closed-system anaerobic digestion of the manure has the potential to eliminate most methane emissions from lagoons while conserving more nutrients and also producing a renewable energy source.

Livestock production in Florida includes both confined animal operations and pastured animals. The increase in production and concentration of intensive livestock operations along with increased urbanization of rural regions have resulted in greater awareness and concern for the proper storage, treatment, and utilization of livestock manure. Pastured animals offer limited opportunity for managing livestock manure to lessen greenhouse gas emissions. The principal opportunities for altering manure management, therefore, occur in dairy and poultry operations with confined livestock. Table 1 gives the CH_4 emission estimates for confined dairy and poultry production in Florida with their CO_2 equivalent global warming potential. Greenhouse emissions from broilers account for more than twice that of dairy cows, while the layer population produces around one-sixth of the emissions of dairy operations.

Table 1.

Estimated CH_4 Emissions from Manure of Confined Animal populations in Florida (Mulkey et al., 2008)

Animal Type	No. of Animals	CH_4 Emission kg/animal/yr	CH_4 Emissions Gg/yr	CO_2 Equivalent Tg CO_2/yr
Dairy cows	135,000	54	7.29	0.153
Poultry layers	10,700,000	0.117	1.25	0.026
Poultry broilers	139,800,000	0.117	16.36	0.343
Total			24.90	0.523

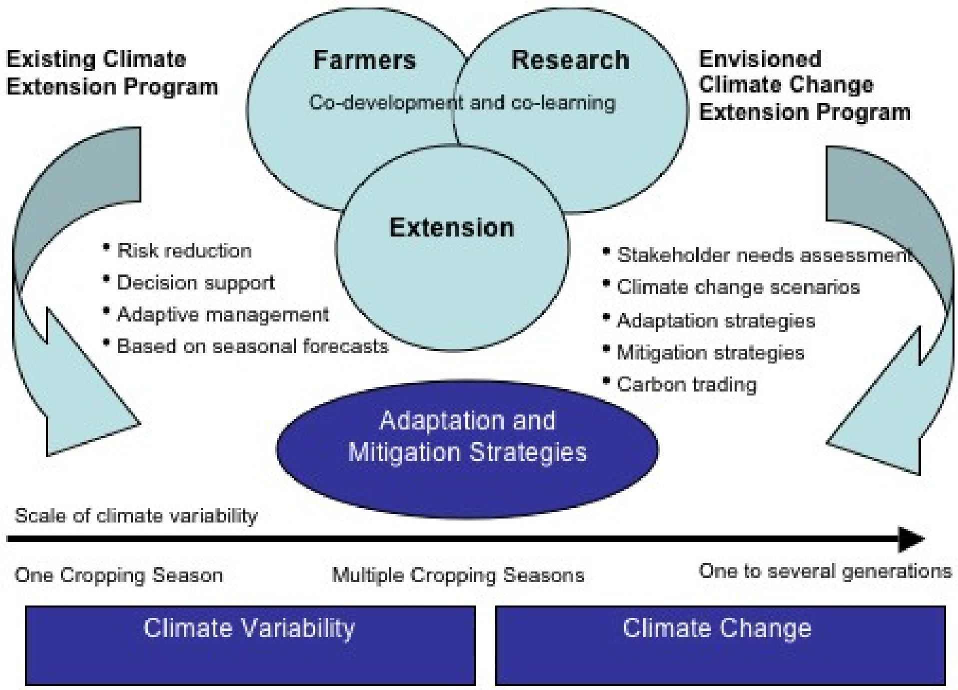
In Conclusion

The main goal of our climate Extension program at the University of Florida is to reduce risks associated with climate variability. Adding the perspective of climate change to the existing program is an attractive option given the existing focus on developing adaptation strategies and training of stakeholders to add seasonal climate variability as part of their decision making process. Dissemination and promotion of mitigation strategies should also be included, especially strategies that increase the efficiency of inputs, improve soil quality, and may allow the participation of producers in the carbon trading market.

The first step towards developing a climate change Extension program should be to undertake initial or ex ante assessment to understand farmers' perceptions, attitudes, long-term goals, and other cognitive and decision-making information through participatory methods. Once enough data has been elicited and analyzed, we may start to developing adaptation and mitigation strategies targeting and end-goal of economic and ecological sustainability.

Figure 1 shows a framework for the envisioned integrated climate Extension program. Many adaptation strategies such as changing planting dates and crop varieties are common to climate change and climate variability. The integrated program should also include mitigation strategies that are technically sound and affordable. Examples include conservation tillage, energy conservation, biofuels, conservation practices, and improved N management. Many of these are already being promoted due to increased competition and high energy costs. A program to help to educate farmers about potential opportunities in carbon trading markets and establishment of base line carbon levels for different ecosystems and agricultural activities should also be undertaken to promote farmers engagement.

Figure 1.
Framework of a Combined Climate Variability and Change Extension Program



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