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Testimony of Heather S. Cooley and Dr. Juliet Christian-Smith[1] to the United States Congress

Select Committee on Energy Independence and Global Warming

For the Hearing on Global Warming Effects on Agriculture and Forestry

June 18, 2009

Thank you for the opportunity to testify today on the effects of climate change on agricultural production in the United States. Our testimony will focus on those impacts related to water resources – a critical connection especially in the western United States. These detailed comments are intended to supplement our oral testimony**.**

Key Messages:

- Agriculture is a water-intensive industry, using about 70% of the nation's freshwater resource. As a result, impacts of climate change on water resources will have major consequences for agriculture.
- Rainfed agriculture is especially vulnerable to altered precipitation patterns.
- Surface water supplies will be increasingly out-of-phase with agricultural water demand. Surface runoff is expected to decline during summer months, when agricultural water demand peaks. The impacts of climate change on groundwater resources remain largely unknown; however, recent research suggests they may decline.
- Changes in extreme weather events will have a greater effect on crop production than changes in average conditions.
- Adaptation can substantially reduce the risk of climate change for the agricultural sector. To support adaptation efforts:
    - The federal government must support adaptation efforts, including better management of surface and groundwater resources and improvements in water conservation and efficiency.

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- The federal government should support outreach to the agricultural community about the impacts of climate change and potential adaptation strategies.
- The federal government should support additional research and development. Specifically, more regional assessments and better weather forecasting are needed.

The Agricultural Sector Is Particularly Vulnerable to Climate Change

The global food crisis made headlines in 2008. This crisis was the result of a variety of factors, including low grain reserves, drought in multiple grain-producing regions, rising energy prices, and a massive increase in biofuel production, among other things. But it points to a larger problem: the growing vulnerability of global food systems. Pressures and demands on our agricultural systems are rising as populations continue to grow and as countries traditionally dependent on grain-based diets are shifting towards greater meat consumption. At the same time, urbanization, deforestation, and poor agricultural practices is contributing to the loss of prime farmland. Over the coming years, many of these factors will be made even more acute due to climate change.

The agricultural sector is particularly vulnerable to climate change because it is directly tied to land and water resources. Even modest changes in temperature and precipitation patterns, the length of growing seasons, or the frequency of extreme events will have large consequences for many farmers. In our testimony, we begin with an overview of the effects of climate change on agriculture, focusing on those impacts related to water resources. We discuss strategies that the agricultural sector can take to adapt to these impacts. We conclude with ways that Congress and the federal government can help farmers implement these strategies.

Climate Change: What Can We Expect for Agriculture?

Climate change will have a direct effect on agricultural crops. Plants require sunlight, water, heat, carbon dioxide, and nutrients. Changes in any of these factors affect plant

growth and development in complex and non-linear ways. Warmer temperatures, for example, may shift the geographic range of crops, permitting them to expand into areas that were previously too cold for production and preventing them from growing in areas that are now suitable for production. Warmer temperatures also increase crop water requirements.

The effects of climate change on crop production will reverberate throughout the agricultural community and the national economy. Reduced yields, and in severe cases, complete crop failure will affect the profitability of farms. In turn, farmers will purchase less fertilizer, seeds, equipment, and other products from farm suppliers. Revenue and employment may decline for local businesses, as well as processors and distributors. In addition, lower yields will increase food prices for consumers.

Climate change will also adversely affect the health of farm workers. Farm laborers typically spend long hours in the field, where they are exposed to the elements and often lack access to water, shade, and shelter. Extreme heat events increase the risk of heat-related illnesses, including heat exhaustion, stroke, heart attack, and death. Under future climate conditions, the frequency and intensity of these extreme heat events are projected to increase, increasing risks to farm workers.

Impacts on Water Resources Will Be Problematic for Agriculture

The U.S. Geological Survey regularly reports that the agricultural sector uses about 70% of the nation's water resources. Numerous national and regional studies indicate that climate change is already affecting U.S. freshwater resources and that these impacts will intensify in the future (Figure 1). Indeed, all of the Intergovernmental Panel on Climate Change (IPCC) reports concludes that freshwater systems are especially vulnerable. Because agriculture is water-intensive, impacts on water resources will have major consequences for agriculture. Here, we describe impacts on freshwater resources, including supply, demand, quality, and floods and droughts, and their effects on the agricultural sector.

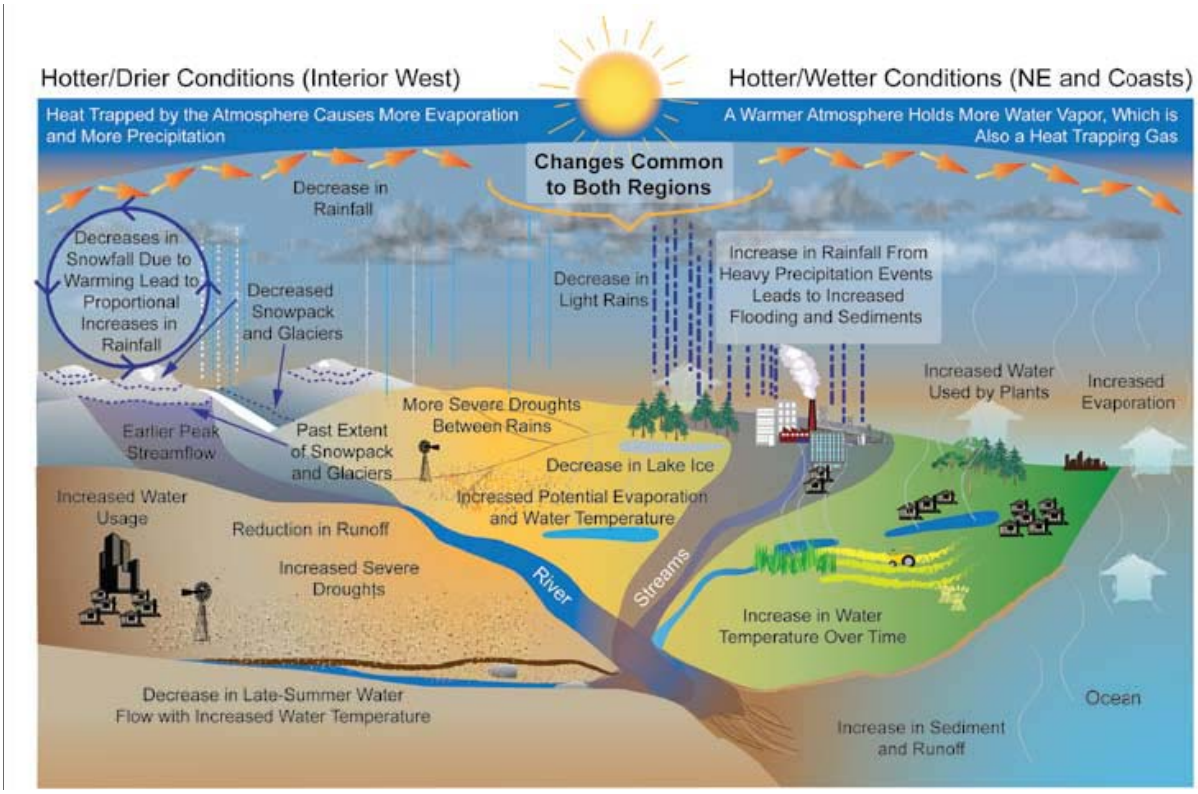

Figure 1. Graphical representation of the ways climate change will affect freshwater resources.
Source: United States Global Change Research Program. 2009. Global Climate Change Impacts in the United States.

Water Availability and Timing Are Changing

Precipitation Patterns Are Changing

Plant water requirements vary throughout its various life stages. Generally crop water requirements are low during the early vegetative period, but increase over the course of the growing season as the plant matures and temperatures increase. Consequently, the timing of precipitation is important for plant production. Too much or too little water during the plant's development could reduce yields.

Rainfed agriculture, which accounts for 94% of the nation's farmland, is particularly vulnerable to changes in precipitation patterns. Current climate models project that global precipitation will increase over the next century. Changes in precipitation patterns,

however, are subject to significant regional variation and are not yet well understood. As a result, impacts on crops are not well known. In general, warmer temperatures combined with *reductions* in precipitation will increase plant stress and may reduce yield and quality, whereas warmer temperatures combined with *increases* in precipitation may improve plant yield and quality.

In response to changing precipitation patterns, farmers may shift to supplemental irrigation, if water is available and if it is economically feasible. This shift will increase tensions over surface and groundwater resources that are, in many parts of the country, already over-allocated. In fact, this tension is already occurring. In Georgia's Flint River Basin, farmers are rapidly shifting from rainfed to irrigated agriculture; the fraction of harvested cropland that is irrigated has nearly doubled in the last 20 years, from an estimated 40% in 1985 to 70% by 2002. This is one of the factors fueling the ongoing tensions between Georgia, Alabama, and Florida, and these types of conflicts may become increasingly likely in the future.

Surface Water Availability May Decline During Summer Months

Models are in general agreement that climate change will affect the timing and volume of runoff. In rain-dominated basins, found throughout much of the eastern United States, studies suggest that changes in runoff will mirror changes in precipitation patterns. In snow-dominated basins, which are found throughout the western United States, warmer temperatures will create major problems. Hydrologic models suggest that with warmer temperatures, more precipitation will fall as rain, increasing winter flows and reducing the total snowpack. In California, for example, scientists forecast that warming will reduce total snowpack by as much as 70% by the end of this century (Figure 2). Similar kinds of changes are likely for the Rocky Mountain States and the Pacific Northwest. The winter snowpack acts as a natural reservoir, storing water during the winter and releasing it throughout the summer. A reduced snowpack, then, will reduce summer stream flows.

Changes in the volume and timing of surface water will have important consequences for irrigated agriculture. Agricultural water demand is highest

during the hot summer months. Yet, most climate models agree that in both snow- and rain-dominated basins, water supply will be lower during the summer months. Thus, surface water supplies will be increasingly out-of-phase with agricultural water demand. An inadequate water supply weakens the plant, making it more susceptible to disease and infestation, and in severe cases, can lead to total crop failure.

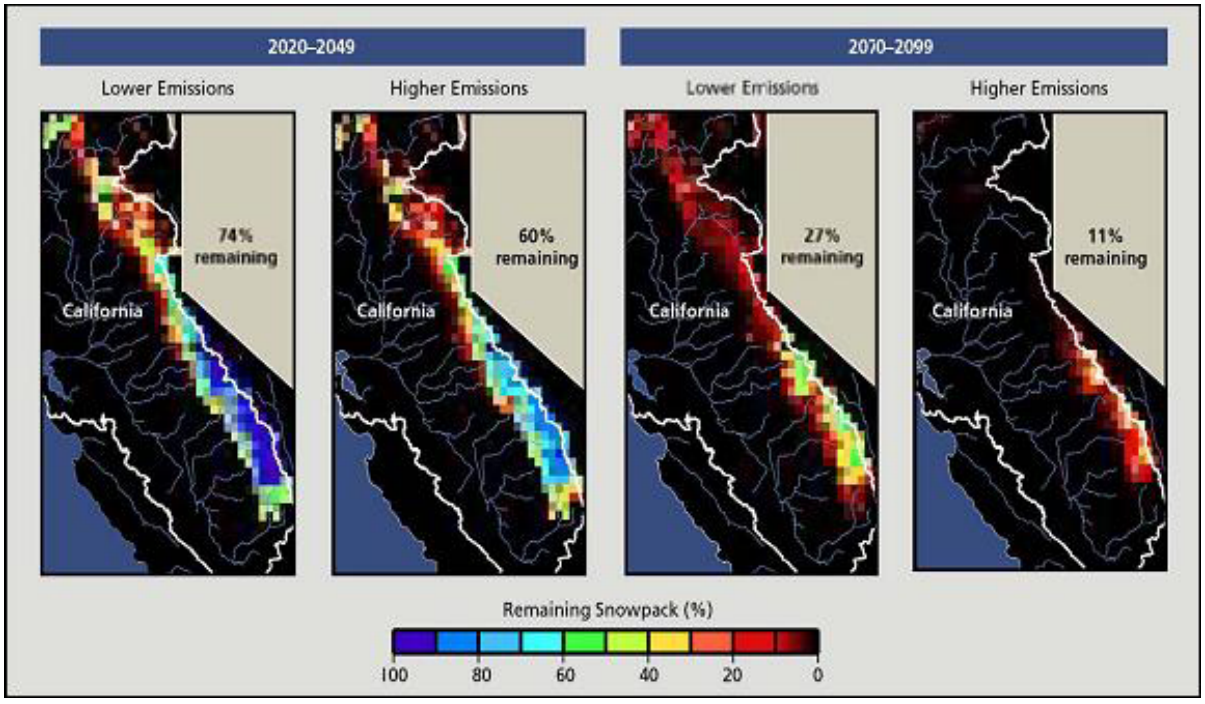

Figure 2. The loss of California snowpack under two climate scenarios by mid- and late-century.
Source: Proceedings of the National Academy of Sciences. 2004.

Groundwater Resources May Decline

The potential impacts of climate change on groundwater resources are not well understood. Recent studies, however, suggest that climate change will affect the availability and quality of groundwater resources. Groundwater recharge rates will change, increasing in some areas and decreasing in others. Groundwater will

likely become more saline as a result of higher evaporation rates and, in coastal aquifers, rising sea levels.[2]

Groundwater is an important source of water for agriculture in many parts of the United States, accounting for about 40% of all irrigation withdrawals. The Ogallala aquifer, for example, provides water to nearly 30% of the nation's irrigated land, yet it is already being pumped ten times faster than it can be naturally recharged. During drought years, when surface supplies are limited, groundwater becomes an increasingly important stop-gap measure for farmers. Thus, as the frequency and intensity of droughts increases, agriculture's dependence on limited groundwater resources may also increase.

Agricultural Water Demand is Expected to Increase

Agricultural water demand is sensitive to climate. Warmer temperatures tend to increase plant transpiration rates, thereby increasing crop water requirements. Higher atmospheric carbon dioxide concentrations, however, can reduce water requirements under some conditions as plants close their stomata. While few studies have explicitly evaluated the relative importance of these processes, most suggest that the temperature effect will be more important and overall crop water requirements will increase, particularly with greater levels of warming. As described above, the supply of water will become more variable. Greater reliance on what could very well be a diminishing resource will spark conflict among users.

Floods and Droughts Threaten Agricultural Productivity

New research suggests that changes in extreme weather events will have a greater effect on crop production than changes in average conditions, particularly if the extreme events

[2] Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, 2007: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

occur during sensitive plant developmental stages.[3] According to Reddy et al., "unexpected late spring and early frosts and periodic episodes of heat and drought stress are predicted to occur more frequently in the changed weather environment, and these could exacerbate climate change effects on many aspects of crop growth and development, reducing crop yield and affecting quality."[4]

Droughts have serious implications for agriculture. The Federal Emergency Management Agency estimates that the average cost of drought in the United States is $6-8 billion annually. Much of this cost is due to crop loss and other direct and indirect losses.[5] Drought conditions are often favorable for many insects, including grasshoppers and locusts, which damage crops further. Drought-stricken crops are also more susceptible to infestations and disease. Wind erosion associated with excessively dry soils can permanently destroy productive agricultural land, as the U.S. experienced during the Dust Bowl. In severe cases, agricultural losses, combined with a lack of food reserves or limited access to aid, can lead to widespread famine.

Floods, on the other hand, can either benefit or harm agricultural production. Floodwaters deposit nutrient-rich sediment on the floodplains, thereby creating fertile soil. These benefits are sometimes offset by the vulnerability of agricultural production to floods that destroy farms and crops. Floods may also cause significant damage to water infrastructure, further affecting the availability and reliability of water resources. A massive levee failure in the Sacramento-San Joaquin Delta, for example, could produce what is often referred to as the Big Gulp, where salt water rushes into the Delta. The massive water export pumps would be shut down, as levees are repaired, which could

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[3] Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber, and F.N. Tubiello, 2007: Food, fibre and forest products. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 273-313.

[4] Reddy, K.R., G.H. Davidonis, A.S. Johnson, and B.T. Vinyard. 1999. Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. Agron. J. 91(851-858).

[5] Federal Emergency Management Agency. 1995. National Mitigation Strategy; Partnerships for Building Safer Communities. Mitigation Directorate, p. 2. Federal Emergency Management Agency, Washington, D.C.

take months to complete. Shutting down these pumps would cut off a major source of water to the region and in particular to agriculture.

Water Quality May Be Compromised

The connections between climate change and water quality are not understood as well as climate change's impact on quantity, although the literature on these connections is growing. Climate change is expected to increase water temperatures in lakes, reservoirs, and rivers, leading to more algal and bacterial blooms and lower dissolved oxygen concentrations. More intense precipitation events could increase erosion rates and wash more pollutants and toxins into waterways. Along the coast, rising sea levels could push salt water further into rivers, deltas, and coastal aquifers, threatening the quality and reliability of these systems. Groundwater quality is also expected to decline as it become saltier, as described above.

Water quality concerns may have both direct and indirect impacts on agriculture. The increasing salinity of groundwater will pose a problem for farmers in some areas. In California's San Joaquin Valley, for example, shallow saline groundwater already threatens the productivity of an estimated 2.5 million acres of farmland. According to California Department of Water Resources, "this marginal to poor quality groundwater has mounded up to reach crop root zones in this area and is threatening the viability of agriculture there."[6] In addition, agricultural runoff may exacerbate water quality concerns in rivers and streams that are already impaired as a result of climate change. To protect human health and ecosystems, water quality regulations affecting the agricultural sector may need to be strengthened.

[6] California Department of Water Resources. (2005). The California Water Plan Update. Bulletin 160-05. Sacramento, California.

What Can We Do to Reduce the Risks to Agriculture from Climate Change? Adapting to a Changing World

Many of the impacts of climate change are now unavoidable. Adaptation "is essential to complement climate-change mitigation, and both have to be central to an integrated strategy to reduce risks and impacts of climate change."[7] The good news is that adaptation can substantially reduce the risk of climate change for the agricultural sector. Scientists estimate that agricultural losses could be reduced by up to 50% as a result of farmer adaptation to climate change.[8] We already know that anticipatory or preventive adaptation measures that predict and respond to vulnerabilities before damages occur are often far less costly than reactive measures.[9]

There is no single adaptation strategy for the agricultural sector. As noted in the 2000 U.S. National Assessment:

> "The wide uncertainties in climate scenarios, regional variation in climate effects, and interactions of environment, economics, and farm policy suggest that there are no simple and widely applicable adaptation prescriptions. Farmers will need to adapt broadly to changing conditions in agriculture, of which changing climate is only one factor."[10]

Farmers implement a variety of technologies and practices to adapt to current climate and weather-related risks. For example, farmers already shift the timing and types of crops grown according to seasonal weather forecasts. In addition, farmers install irrigation systems in response to periodic droughts. These response measures should serve as a starting point for developing comprehensive adaptation strategies. It is important to build upon existing risk mitigation measures, but we cannot assume that existing approaches are sufficient to adapt to future climate conditions.

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[7] Fischer, G., M. Shah, and H. van Velthuizen. 2002. Climate Change and Agricultural Vulnerability. International Institute for Applied Systems Analysis. Vienna, Austria. Prepared for the United Nations for the World Summit on Sustainable Development, Johannesburg, 2002.
[8] Mendelsohn, R. and J.E. Neumann. 1999. *The Impact of Climate Change on the U.S. Economy.* Cambridge University Press. Cambridge, UK.
[9] Repetto, R. 2008. *The Climate Crisis and the Adaptation Myth*. Yale School of Forestry and Environmental Studies. Working Paper Number 13.
[10] Reilly, J., F. Tubiello, B. McCarl, and J. Melillo. 2000. Climate Change and Agriculture in the United States. In U.S. National Assessment of the Potential Consequences of Climate Variability and Change. U.S. Global Change Research Program. Washington, D.C.

Action is needed now. As noted by Dr. Repetto, "saying that the U.S. *can* adapt does not imply that it *will* adapt, at least not in the efficient and timely way needed if major damages are to be avoided."[11] The United States must become a global leader in smart preparation and adaptation to climate change. Below, we offer a set of recommendations, focusing on those that reduce agriculture's vulnerability to changes in water resources. We also provide some specific thoughts about possible legislative action.

Recommendations

(1) Adaptation Efforts Must be Encouraged and Expanded

- **Improve management of surface and groundwater resources**

Water managers and policymakers must start considering climate change as a factor in the operation of existing facilities and systems. Existing state, federal, and local water systems should be tested under a range of potential future climate conditions to see how they respond and the extent to which they are vulnerable to expected changes. Water managers must re-evaluate engineering designs, reservoir operating rules, contingency plans, and water-allocation policies. Specifically, the federal government should

- Require the Bureau of Reclamation and Army Corps of Engineers, which operate many of the nation's reservoirs and water-related infrastructure, to revaluate their operation of these systems and develop new operational rules in light of climate change.
- Based on the experiences of the Bureau of Reclamation and the Army Corps of Engineers, provide guidance and oversight to local and state agencies to do similar assessments.

[11] Repetto, R. 2008. *The Climate Crisis and the Adaptation Myth*. Yale School of Forestry and Environmental Studies. Working Paper Number 13.

An estimated 40% of irrigated agriculture relies on groundwater. Because groundwater use increases during a drought, an increase in the frequency and intensity of droughts will likely increase our dependence on groundwater resources. Throughout much of the United States however, groundwater basins have been mismanaged and overdrafted. While overdraft certainly creates challenges, it may also provide an opportunity. In particular, we may be able to store excess surface flows, including storm water, during wet years for use during dry years. This option can improve supply reliability and flexibility, reduce land subsidence, and minimize the impacts of excess runoff on local steams and the marine environment. In particular, the federal government should

- Require all states to design and implement comprehensive local groundwater monitoring and management programs.
- Encourage use of groundwater basins to store excess surface water.

- **Capture water conservation and efficiency potential**

There is significant potential to reduce agricultural water use, thereby reducing vulnerability to drought and other water supply constraints. In California, for example, the Pacific Institutes estimates that widely available technologies and management practices can reduce agricultural water use by 10% and probably by substantially more. Aggressive efficiency improvements implemented in Australia as a result of their ongoing severe drought has increased agricultural water efficiency by as much as 25%. By improving agricultural water use efficiency, farmers reduce their vulnerability to water supply constraints. In addition, adopting many of these practices, including drip irrigation and improved irrigation scheduling, can increase crop productivity through higher yields and better quality. Many conservation practices, however, require substantial investment. EQIP, as described above, provides one means to defray these initial investment costs. Additional mechanisms are needed to support water conservation and efficiency improvements. Specifically, the federal government should:

- Provide greater emphasis on water conservation and efficiency improvements within the federal Environmental Quality Incentives Program and expand funding for these initiatives.

- Provide tax exemptions or rebates on efficient irrigation equipment to help offset capital investments for these systems.

- **Eliminate Federal Policies that Inadvertently Increase Vulnerability to Climate Change**

The U.S. Farm Bill contains vitally important federal agricultural policies. The 2002 Farm Bill authorized $619 billion in crop subsidies, of which $53 billion was provided in direct payments to support field crops. In some cases, direct payments make the production of certain field crops economically viable. These incentives, however, may encourage farmers to grow crops that are not appropriate under future temperature and precipitation regimes in some locations. Thus, direct payments may hamper the ability of farmers to adapt to changing conditions and thereby increase their vulnerability to climate change.

New policies that promote climate change adaptation should be introduced into the Farm Bill. The Environmental Quality Incentives Program (EQIP), for example, provides up to a 75% cost share for structural and vegetative practices that promote agricultural production and environmental quality. The 2008 Farm Bill includes a new stipulation that prioritizes water conservation and irrigation efficiency measures that reduce total water use for those producers that agree not to use the conserved water to bring new land under production. The 2008 Farm Bill authorizes EQIP funding at $1.2 billion in 2008, accounting for less than 0.2% of the overall Farm Bill budget. In 2009, Congress has threatened to reduce funding for this program. In order to capture potential efficiency improvements and to reduce our vulnerability to climate changes, the federal government should

- Reduce or realign subsidies from low-value, water-intensive crops to less water-intensive crops.

- Provide greater emphasis on water conservation and efficiency improvements within the federal Environmental Quality Incentives Program and expand funding for these initiatives.

(2) Information Must be Communicated to the Agricultural Community

- **Expand outreach efforts**

It is critical to communicate information on climate risks and adaptation strategies to the agricultural community. Farmers and local communities will ultimately be responsible for implementing adaptation strategies. While impact studies have been conducted at universities and research centers across the country, in most cases, this information has not been adequately conveyed to farmers. There is a significant gap between top-down analysis and bottom-up implementation. Additional outreach is needed to convey what information is available to farmers so that they can begin developing adaptation strategies.

Outreach efforts would be best accomplished by building on existing institutions. In particular, cooperative extension services and the Natural Resource Conservation Service (NRCS) have long-standing relationships with farmers and agricultural organizations throughout the nation. A University of Vermont Extension professor notes 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."[12] Because cooperative extension agents and the NRCS have already established these important relationships, these organizations would serve as ideal conduits for outreach efforts. To encourage these efforts,

- The United States Department of Agriculture, in association with the NRCS, should develop trainings and provide guidance to extension agents about climate change impacts and adaptation strategies for the agricultural sector.

[12] Grubinger, V. Climate Change and Agriculture: Challenges and Opportunities for Outreach. Climate and Farming.org. http://www.climateandfarming.org/

(3) Additional Research and Development is Needed

- **Expand impact assessments to include all regions of the United States**

Although climate change is a global problem, its impacts are local. Accordingly, detailed assessments of climate change risks require thorough analysis at the regional level. While climate change impact studies have been done in some areas, such as California, good assessments are lacking in others. Additional analysis is needed at the regional level to better understand climate change impacts. Without significant investment to generate the information needed to understand projected impacts, climate change will remain a vague and unwieldy threat.

- **Improve Weather Forecasting**

Short- and intermediate-term weather forecasts provide important information to farmers, allowing them to alter their planting regimes and implement other management practices in response to changing weather conditions. Improved forecasting would provide farmers with better information to make more informed decisions. Additional research is needed to improve weather forecasting. Funding for research programs to support this research, however, is declining. Congress should restore and expand this funding to support improved weather forecasting.