Testimony of Dr. Jerry L. Hatfield

Director, National Soil Tilth Laboratory – Ames, Iowa

Before the

House Select Committee on Energy Independence and Global Warming

June 18, 2009

Introduction: Chairman Markey, Ranking Member Sensenbrenner, members of the committee, I am Dr. Jerry L. Hatfield. I am an employee of the USDA's Agricultural Research Service and the Director of the National Soil Tilth Laboratory in Ames, Iowa. It is a pleasure to be able to present the current information on climate impacts on agriculture to this committee. Agriculture is extremely sensitive to climate and weather and the resilience of our production systems to changes in climate is enhanced by understanding these impacts and their effects. It is also important to realize that US agriculture is diverse and that simple statements about the impacts of climate are not possible. For example, the effects of climate on corn production are different from those on tomatoes except in the broadest of generalities. Agriculture is extremely complex in its response to climate change. It should also be understood that agriculture does play a role on climate because of the effects of changing land cover and management on greenhouse gas concentrations, reflectivity of the land surface, and water exchanges. However, the focus of this discussion is on the impacts of climate on agriculture.

Climate change as evidenced by warming temperatures, increasing precipitation and intensity of storms, and rising carbon dioxide (CO_2) and ozone (O_3) levels that will impact agriculture. Warming temperatures of 1.5°F over the past 100 years with projections of continued increases over the next 50 years will alter the length of the growing season. The increase in the winter temperatures and especially nighttime temperatures over the next 50 years will affect agricultural systems. The projected increase in heat waves and extreme temperature events will impact agriculture as much as the human population. The projections of continued increases in precipitation over the northern areas and drier conditions over the southern regions of the US will further impact water supplies for agriculture and water management strategies. Increases in the intensity of rainfall events will increase the likelihood of soil erosion and water quality problems from agricultural lands. Extreme events, like heat waves and regional droughts, have become more frequent and intense in the past 50 years and affect agricultural operations and decision making. Rising CO_2 levels are a positive influence on plants and increase plant growth; however, the effects vary among different plants. All of the aspects of the changing climate have been detailed in a recently released report entitled "Global Climate Change Impacts in the United States" from the U.S. Global Change Research Program. Details on the impact of climate on agriculture are presented in Synthesis and Assessment Product 4.3 "Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States" from the U.S. Climate Change Science Program which was released in May 2008. The scenarios projected for climate change in the US have implications for agriculture which must be understood to protect the capability for food, feed, fiber, and fuel production. The information presented here represents a summary of the information contained in these reports which was developed by a team of agricultural experts studying the impacts of climate on agriculture.

Animal Response: One of the easier ways for us to understand the implications of climate change on agriculture is to first consider the impacts of climate on animals. Unless farmers are able to insulate animals from climate change, the increase in temperature and the potential for more heat waves and extreme heat events will affect animal production. Animals respond to a combination of temperature and humidity in a similar fashion to humans. When it is hot and humid, we decrease our activity, reduce our food intake, and generally are less energetic than at other times. In a similar way, high temperatures and humidity reduce the feed intake of animals which in turn reduces the rate of meat, milk, or egg production. At the opposite end of the range, cold temperature extremes can increase feed intake but the extra energy consumed is used to maintain warmth which also results in reduced growth or milk production. Extremes at either hot or cold have negative impacts on animals. Heat waves can have serious consequences on animals and can create conditions in which there is increased death of animals in feedlots or barns. There are recent examples of heat waves in California and the impact on milk production and heat waves in the High Plains resulting in increased deaths in feedlot beef cattle. An additional implication for beef and dairy animals is that as the temperature rises there is a decrease in the conception rate. Livestock producers will have to understand that climate changes will affect their management decisions. Changes in temperature will have impacts on animal production which must be considered in designing improved management strategies to cope with these stresses.

Changing precipitation patterns affect animals in a multitude of ways. Range animals that are dependent upon stored water in surface ponds may have to have supplemental water provided or even supplemental feed if drought reduces plant production or surface water recharge. Water supply to rangeland animals will be a critical concern in areas with the potential for increased drought. Excess precipitation can create muddy conditions in feedlots and increase stress on animals and the potential risk of runoff from feedlots into nearby water bodies.

In terms of environmental management needed to address global climate change, the impacts can be reduced by recognizing the adaptive ability of the animals and by proactive application of appropriate counter-measures (sunshades, evaporative cooling by direct wetting or in conjunction with mechanical ventilation, etc.). Specifically, the capabilities of livestock managers to cope with these effects are quite likely to keep up with the projected rates of change in global temperature and related climatic factors. However, coping will entail costs such as application of environmental modification techniques, use of more suitably adapted animals, or even shifting animal populations to other locations.

Climate change will affect the presence and range of parasites and pathogens. The increased presence of parasites and pathogens will increase the pressure on animals and lead to lost productivity or survival. Duration and intensity of potential stressors are of concern with respect to the coping and/or adaptive capabilities of an animal. Further, exposure to one type of stressor (heat or humidity) may lead to altered resistance to other types of stress (parasites or pathogens). Other interactions may exist such that animals stressed by heat or cold may be less able to cope with other stressors (restraint, social mixing, transport, etc). Improved stressor characterization is needed to provide a basis for refinement of sensors providing input to control systems. Animal producers will have to increase their awareness of these factors in order to maintain productivity under conditions of climate change.

Plant Response: Plants are more complex in their response to climate. Temperature, precipitation, and CO_2 and O_3 are all critical factors that affect plant growth and the harvestable products from plants. Unlike animals, plants do not maintain their temperatures and are more affected by the air temperatures. Extremes of temperatures can have devastating effects on plants. Plants are also dependent upon the water that is supplied to them by precipitation or irrigation and when these amounts are either in excess or in deficit there are negative impacts on plant growth. A basic building block for plants is CO_2 and up to a point increases in CO_2 concentrations generally have a positive impact on plant growth but these impacts do not necessarily improve harvestable yield or commodity quality. Yet, building resilient agronomic crop, vegetable, and fruit production systems which can cope with the changing climate can be accomplished as we understand the interactions among temperature, water supply, and CO_2 levels.

Agriculture has and can adapt to changing climate. The areas in which we grow certain plants demonstrate how we adapt plant production systems to the climate. This adaptation has been occurring in agriculture for centuries as farmers have selected the best crops for their regions, changed their cultural practices to cope with risks from environmental stresses, and modified their practices to reduce the impacts of biological stresses caused by weeds, insects, and diseases which also respond to the climate. Research has been able to help speed this process by providing information to help guide decisions about the impacts of climate on agricultural systems and the magnitude of the response from various stresses. There are three components to the current climate change scenarios that are critical to agriculture; the trends in temperature, precipitation, and CO_2 and O_3 over years compared to within growing season variation in these climatic components. Adaptation strategies will be different for each of these components and there is a different form of risk in each of these as well.

In addition to the general trends in climate, a major factor is the extremes in temperature and precipitation which occur within the growing season. Similar to animals, the occurrence of these extremes may be the most detrimental to plant growth and agricultural production.

Plants differ in their response to temperature. There are cool-season plants which are best suited to lower temperatures, e.g., many of the vegetables like peas or spinach. Warm-season plants like watermelon, cotton, or cucumber thrive when the temperatures are warm. Temperature responses for plants have three values that describe their response: the minimum temperature below which there is no growth, the maximum temperature at which growth ceases, and the optimum temperature at which there is the maximum rate of growth. Just as important, there is a difference between the vegetative periods of growth, when the plant is producing leaves or stems, compared with the reproductive period when the plants are producing seed or fruit. The optimum temperature ranges for the vegetative period are warmer than for the reproductive period.

Warmer temperatures cause plants to progress through their stage of development at a rate which does not allow for maximum expansion of leaves, stems, or fruits. Exposure to warmer temperatures also increases the rate of water evaporation from the plant. Since plants use the evaporation of water to cool their leaves, the warmer the air, the more water that will be used by the plant. In water limited areas this creates a situation in which plants may be under some amount of water stress, which in turn reduces growth. Based on a projected temperature increase of 1.8°F over the next 50 years, soybean yields in the southern US are predicted to decrease by

3.5% while in the Midwest they are projected to increase by 2.5%. Rising temperatures will exceed the optimum range for soybean in the south while bringing the soybean into the optimum range in the Midwest. Likewise, for many vegetables warming temperatures will cause a reduction in production even more quickly in these cool season crops, compared to warm season crops. Many of these vegetables are grown during the winter in temperate climates; with warmer winters the length of time that this period is optimum will decrease. Increasing winter temperatures does increase the length of the growing season, there is a potential negative impact on fruit trees, e.g., apples, which require a certain amount of chilling or exposure to cool temperatures. The warmer temperatures during winter may create a situation in which these chilling requirements are not fulfilled and reduce the production of fruit.

A sensitive portion of the growth cycle for plants is the pollination stage when plants are producing pollen for seed or fruit. The temperature ranges for pollen survival are lower than those for vegetative or reproductive development; and exposure of pollen to high temperatures can destroy the pollen and reduce the production of seed or fruit. Occurrences of heat waves at pollen time could have a significant negative impact on plant production. While we tend to focus on the extremes in temperature, there are more subtle effects that occur in rice because of the time of day in which they shed their pollen. If the temperatures are above the threshold temperature for pollen survival at this time then the grain set is reduced. Timing of pollen release in plants relative to temperature patterns may provide new insights into management methods to reduce the impacts of climate on yield.

Climate models and observations indicate that night-time temperatures are rising faster than day-time temperatures. This change has significant impacts on plants particularly during the reproductive stage of development. Warm temperatures at night increase the respiration rate which reduces the amount of sugars and starches that can be stored in grain or fruit. This causes the fruit or seed size to be smaller and also the length of the grain or fruit-growing period to be shorter. As a result these warmer nighttime temperatures reduce the grain or fruit yield of plants. Conversely, cooler nighttime temperatures decrease the respiration rate and lengthen the period of seed or fruit development leading to a larger yield.

Increases in the occurrence of heat waves may require a change in planting date so that the crop is not flowering at a time with the highest probability of high temperatures. Heat waves can also impact growth because of the impact on crop water use. If the amount of water available to the plant is decreased then the impact of even moderate heat waves will be large because the plant will not be able to have adequate water to cool the leaves. As an example, the drought in the Southeastern US had such a large impact because these soils do not have a large reservoir of water they can hold and without timely rainfall there is a severe impact of drought on plants. In contrast, areas of the US that have soils with larger soil water reservoirs can cope with less frequent rainfall if the rainfall from each event is stored within the soil.

Precipitation is the ultimate source of water for plant growth. This can be either directly from events that recharge the soil with water or indirectly from irrigation supplied from water captured in streams, lakes, or dams that originates as rainfall or snowfall. Excesses and deficiencies in water cause negative impacts on plant growth. Changes in the rainfall distribution across the US have implications for being able to provide adequate water supplies for crop growth. In the southern and southwestern US the projections are for reduced precipitation and these areas require large amounts of water for crop production because of the warmer temperatures. There are shifts in the form of precipitation that is occurring in many areas with a trend toward more rainfall compared to snowfall and also earlier melting of the snowfall because of the warmer temperatures. These changes in precipitation patterns will affect water availability in areas capturing precipitation for later use as irrigation water.

Increases in precipitation amounts in the Midwest and the intensity of storms has implications for agriculture. Wetter conditions in both the spring and fall can impact production by delaying planting in the spring and creating problems for harvest in the fall. When soils are saturated and have excess water, not only is there an increased potential for flooding, but also a negative impact on plant growth because excess water decreases plant growth from the deprivation of oxygen in the soil. Increases in precipitation intensity will increase erosion from agricultural lands unless adequate protection of the soil surface is provided by conservation tillage, crop residues, or cover crops. Soil erosion occurs when the soil can no longer efficiently absorb the rainfall and the continuing rain begins to move off of the land creating a condition in which the moving water loosens the soil and causes it to move with the water. Providing adequate soil cover to protect the soil surface will be necessary to reduce the potential for increased runoff or soil erosion from agricultural fields. Water management strategies for rain-fed and irrigated agriculture provide opportunities for more water use efficient cropping systems that increase the amount of biomass, grain or fruit yield per unit of water.

Carbon dioxide is one of the basic building blocks of plants. The photosynthetic process converts CO_2 into sugars which in turn are combined into other plant components, starches, proteins, carbohydrates, etc. Plants are efficient users of CO_2 and respond positively to increases by increasing their growth. An interesting observation is that as the CO_2 increases there is also a decrease in water use by the crops which increases their water use efficiency. Therefore, we produce more plant material per unit of water used by the plant. Not all plants respond the same to increases in CO_2 levels; plants like corn show less response than do wheat or soybean and vegetable crops. There are varying degrees of change in water use efficiency by plants subjected to the higher CO_2 levels.

Increasing CO_2 concentrations benefit weeds even more than crops and cause them to grow more quickly and produce more seed. There are observations which suggest that weed management may be more difficult under the conditions of increasing CO_2 because weeds may become more tolerant of herbicides. This effect alone would impact agricultural production because increased weed pressure leads to reduced crop yield and increased costs for weed control.

An interesting example of the impacts of changing CO_2 on plant growth has been observed in rangeland plants. Increases in CO_2 cause the plant to grow more quickly; however, in doing so the growth of the plant exceeds the capacity of the root system to absorb nitrogen from the soil. As a consequence there is a decline in the protein content of the grass. Since these rangeland systems provide food for grazing animals there is a less nutritious food source for these animals and a requirement for these animals to consume more grass in order to meet their dietary requirements. The changes in the climate also cause a shift in the species that grow in these rangelands toward less desirable plants for grazing animals to eat. Climate changes and their effect on plants have to be examined from many different perspectives in order to fully appreciate the significance of the potential impact on agriculture.

Although not considered as part of climate change scenarios, the changes in O_3 may be as important as greenhouse gases with a significant impact on plant growth. Ozone at the land surface has risen in rural areas of the US, particularly over the past 50 years, and is forecast to continue increasing over the next 50 years. Levels of ozone during the day in rural areas of the Midwest are six times higher than 100 years ago. Ozone is toxic to many plants and studies in greenhouses and small chambers have shown soybean, wheat, peanut, and cotton are the most sensitive. Exposure to O_3 results in decreased photosynthesis, dry matter, and yield. Ozone is a complicating factor affecting crop yield that should not be ignored in the evaluation of the impacts of climate change on crops.

Crop Quality: Most of the attention on climate impacts on agriculture focuses on the amount of commodity produced; however, there are impacts of climate and weather on product quality. Variations in wine quality among years are often related to subtle changes in the weather at sensitive periods of the growing season. Grain quality in wheat across the Great Plains is related to timing of rainfall events during the grain-filling period while excess rainfall during the harvest period can reduce quality by delaying harvest or causing the plant to fall over, exposing the grain to moisture on the soil. Excess rainfall during hay harvest can reduce the quality by continued exposure to unfavorable harvest conditions. One example of product quality that is affected by weather events is aflatoxin in grains, spices, and nuts that is induced by either high humidity levels or drought during the latter stages of reproductive development. This affects product quality and also produces a health hazard from the products. Quality impacts from changes in the climate should be considered as important as production impacts in helping producers understand appropriate management strategies to cope with climate change.

Direct and Indirect Effects of Climate Change on Agriculture: Temperature, precipitation, and CO_2 provide direct effects on plant growth and production of biomass, seed, fiber, or fruit.

These effects are detectable in altered growth and there are compensating effects of warming temperatures and rising CO_2. However, the impacts of changing climate on agriculture are significant and will greatly impact production. As one example, corn yields in the US show a steady increase with time; however, the majority of the deviations below the trend line are a result of abnormal weather conditions within the growing season that affect a region of the country. Late season frosts impact fruit production in many areas and early rainfall events cause reductions in the raisin grape harvest in California. All crops produced outside of greenhouses in the US are subject to variations in climate which impact their production.

There are also indirect effects from climate change. These are due to the impacts of climate on weeds, insects, and diseases. Warmer temperatures over the winter will allow some insects to survive and maintain viable populations that can infest the next crop with a greater intensity. Increasing temperatures can expand the range for insects which will increase the impacts due to insect damage. In a similar way warmer temperatures and wetter soil conditions can lead to more favorable environments for disease causing pathogens to populate and grow. Increased pressure from insects and diseases will require that producers be more vigilant in their control efforts. Changing where crops or livestock are produced may not alleviate the risks from pests and may expose these production systems to new pests. Weeds show a great adaptability to climate and have been responding to increases in CO_2, this coupled with the warmer temperatures have expanded the range of some weeds. For example, kudzu is limited in its northward migration because of temperatures below 68°F in the winter; however, as temperatures warm this invasive weed will expand its range. Invasive weeds will respond favorably to changing climate and efforts to evaluate how climate is affecting these species will be critical to ensure appropriate weed management strategies are in place.

To ensure future food security and viability of production systems there are some critical questions which need to be addressed.

- How much resilience is there in our crop germplasm, which can be used to develop varieties that can withstand temperature and precipitation extremes and take advantage of increased CO_2?
- How can linkages among crop growth and yield, pest biology, and epidemiology be quantified in response to climate change that would reduce the risk of production losses and enhance product quality?
- How can resource managers ensure the availability and delivery of adequate water quantity and quality under changing climate conditions?
- What are the best agricultural management practices for creating systems that are economically competitive and environmentally sustainable?

Summary Comments: Climate impacts on agriculture will be regionally specific because of the combinations of climate and agricultural commodities in that region. Increases in heat waves and extreme temperature events will impact both animals and plants. Heat stress on animals and plants will impact their ability to produce harvestable products. Increases in temperature will increase the rate of plant development but not the size of the plant which will reduce the amount of biomass, seed, fruit, or fiber produced. The projected increases in nighttime temperature will hasten the rate of development during the reproductive stage of growth which in turn causes reduced production because of a shorter growing period. Efficient agricultural production is dependent upon a consistent water supply and as precipitation amounts, and in some areas the form becomes more variable there will be an impact on plant growth because of this variability. More intense storms can lead to flooding but also more runoff from fields or delay planting or harvesting operations. Increased rainfall during harvest can lead to damaged crops and reduced quality of the produce. While increasing CO_2 levels are regarded as a positive for plants, this has to be considered in combination with the temperature and precipitation changes. The direct impacts of climate change on plants must not ignore the indirect impacts that result from climate impacts on weeds, insects, and diseases. These biological systems respond to climate changes and in many cases there will be increased populations of pests along with an expanded range of pests.

The impact on agriculture can be both positive and negative; however, avoiding the negative impacts will require management strategies and practices that consider the impact of climate and the development of alternative strategies that will mitigate the risk of climate impacts and increase the resilience of our agricultural systems. Agriculture has adapted to climate and weather risks throughout history. Producers and researchers have developed an understanding of the environmental and biological risks that are mediated by climate and weather and have adapted by changing plants or animal breeds, identifying more resistant production systems to stress, altering planting dates, and adjusting their culture methods. These have been effective in enhancing the efficiency of our current production systems; however, the anticipated change in climate that has been described will present a new challenge for more robust agricultural systems to cope with the magnitude of the change and the degree of variability within a growing season. Agriculture has responded to these challenges in the past and can do so again.