AGRICULTURE SECTOR

The US is a major supplier of food and fiber for the world,accounting for more than 25% of the total global trade in wheat,corn,soybeans,and cotton. Cropland currently occupies about 400 million acres,or 17% of the total US land area. In addition, grasslands,and permanent grazing and pasturelands,occupy almost 600 million acres,another 26% of US land area. The value of agricultural commodities (food and fiber) exceeds $165 billion at the farm level and over $500 billion,10% of GDP, after processing and marketing.

Economic viability and competitiveness are major concerns for producers trying to maintain profitability as real commodity prices have fallen by about two-thirds over the last 50 years. Agricultural productivity has improved at over 1% per year since 1950, resulting in a decline in both production costs and prices. This trend maintains intense pressure on individual producers to continue to increase the productivity of their farms and to reduce costs of production. In this competitive economic environment,producers see anything that might increase costs or limit their markets as a threat to their viability. Issues of concern include regulatory actions that might increase costs,such as efforts to control the off-site consequences of soil erosion, agricultural chemicals,and livestock wastes; growing resistance to and restrictions on the use of genetically modified crops; extreme weather or climate events such as droughts and floods;new pests;and the development of pest resistance to existing pest control strategies. Future changes in climate will interact with all of these factors.

The agriculture sector Assessment considered crop agriculture, grazing,livestock, and environmental effects of agriculture. The focus in this document is primarily on crop agriculture which was studied most intensively in this Assessment. Although extensive,the analysis of crop yields did not fully consider all of the consequences of possible changes in pests,diseases,insects,and extreme events resulting from climate change. This analysis assumes continued technological advances and no changes in federal policies or international trade.

KEY ISSUES

- **Crop Yield Changes and Associated Economic Consequences**
- **Changing Water Demands for Irrigation**
- **Surface Water Quality**
- **Increasing Pesticide Use**
- **Climate Variability**

Economically, consumers are likely to benefit from lower prices while producers are likely to see their profits decline.

Key Issue: Crop Yield Changes and Associated Economic Consequences

It is likely that climate change,as defined by the scenarios examined in this Assessment,will not imperil the ability of the US to feed its population and to export foodstuffs. Results of this Assessment suggest that,at the national level,productivity of many major crops will likely increase under the climate scenarios used in these crop models. Crops showing generally positive results include cotton,corn for grain and silage,soybeans,sorghum,barley, sugar beets,and citrus fruits. Pastures also show positive results.

CO_2 Effects on Crops

Greater concentrations of CO_2 generally result in higher photosynthesis rates and may also reduce water losses from plants. Photosynthesis is enhanced when additional carbon is available for assimilation and so crop yields generally rise.

The actual response to increased CO_2 differs among crops. Most commercial crops in the US, including wheat, rice, barley, oats, potatoes, and most vegetable crops, tend to respond favorably to increased CO_2, with a doubling of atmospheric CO_2 concentration leading to yield increases in the range of 15-20%. The crop models used in this Assessment assume a CO_2 fertilization effect in this range, and also assume that sufficient nutrients and water will be available to support these increases. Other crops including corn, sorghum, sugar cane, and many tropical grasses, are less responsive to increases in CO_2, with a doubling of its concentration leading to yield increases of about 5%.

In situations where crop yields are severely limited by factors such as nutrient availability, an enduring CO_2 fertilization effect is very likely to be of only minor importance.

For other crops, including wheat, rice, oats, hay, sugar cane, potatoes, and tomatoes, yields are projected to increase under some conditions and decrease under others. The crop models assume that the CO_2 fertilization effect will be considerable (see box).

In the crop yield models, a limited set of on-farm adaptation options are considered, including changes in planting dates and changes in varieties. These contribute small additional gains in yields of dryland crops and greater gains in yields of irrigated crops. The economic models consider a far wider range of adaptations in response to changing productivity, prices, and resource use, including changes in crops and the location of cropping, irrigation, use of fertilizer and pesticides, and a variety of other farm management options.

All agricultural regions of the US are not affected to the same degree by the climate scenarios studied in this Assessment. In general, this study finds that climate change favors northern areas. The Midwest, West, and Pacific Northwest exhibit large gains in yields with both climate scenarios in the 2030 and 2090 time frames. Crop yield changes in other regions vary more widely depending on the climate scenario and time period. For example, projected wheat yields in western Kansas decline under the Canadian scenario.

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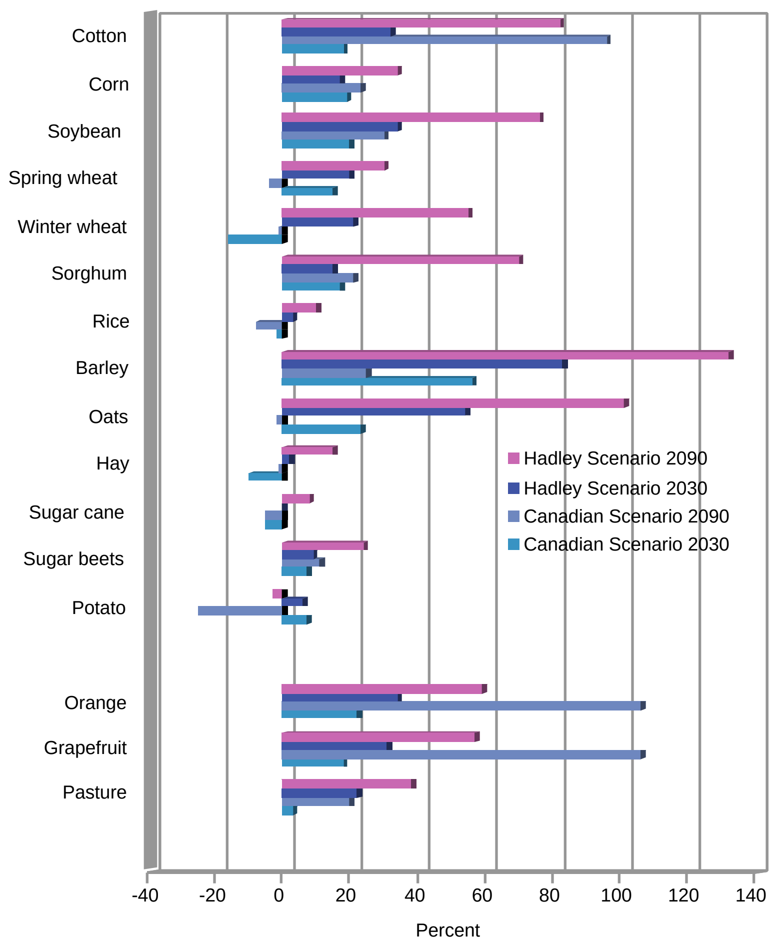
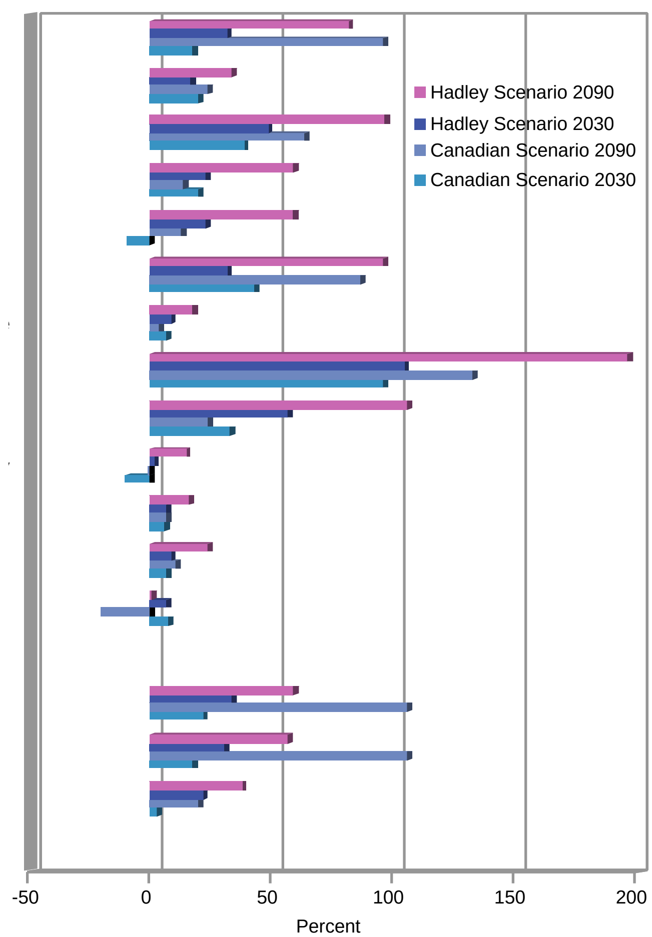
Dryland Yields in 2030 - 2090
Without Adaptation



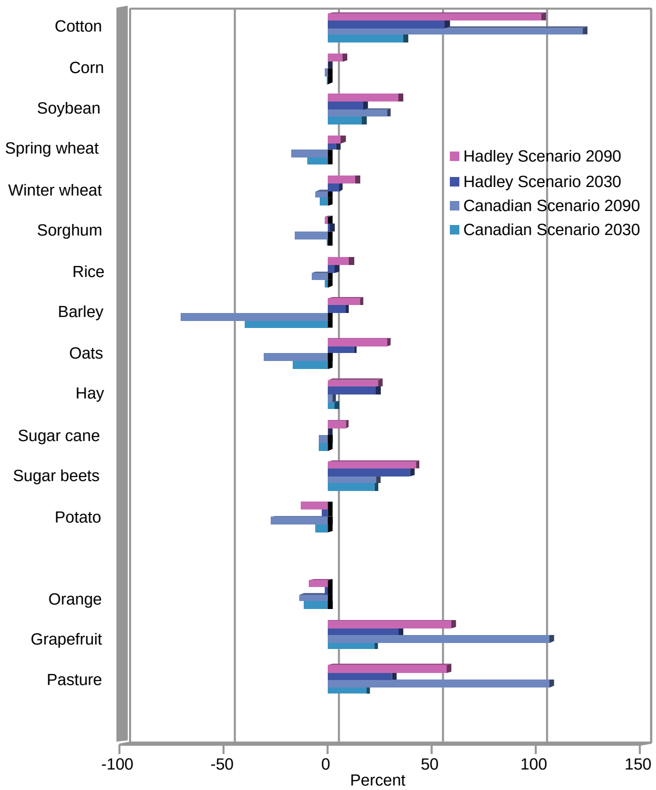
Dryland Yields in 2030 - 2090
With Adaptation



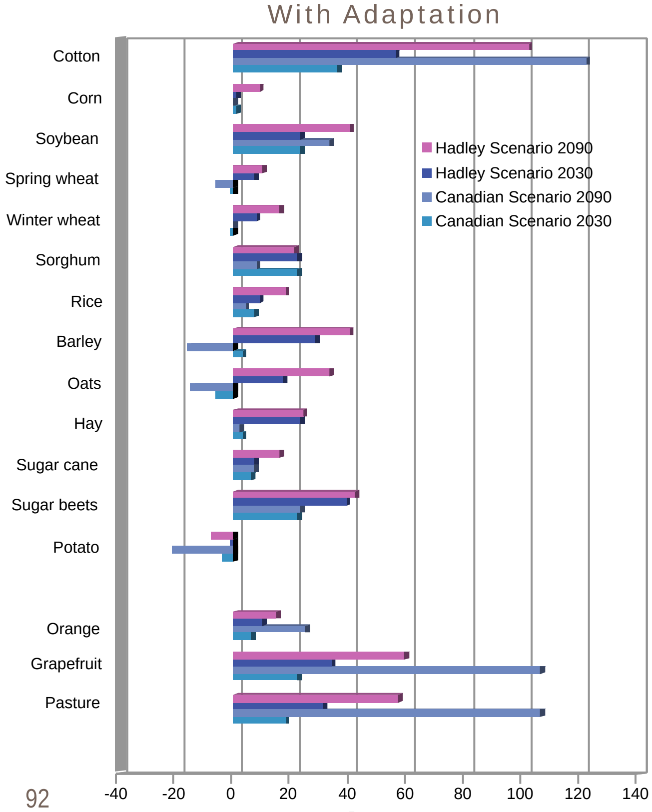
Model simulations of average changes in crop yields for 16 crops. The yield changes are given as percentages and represent the differences between current yields and those projected for two time periods, 2030 and 2090. Two scenarios of future climate, the Canadian and Hadley, were used. The results consider physiological responses of the crops to climate under either dryland or irrigated cultivation. They also consider either "no adaptation" or "adaptation" responses by producers to climate change. Adaptations included changes in planting dates and crop varieties. Only 11 of the 16 crops were actually modeled: cotton, wheat (winter and summer), corn, hay, potato, orange, soybean, sorghum, rice, pasture grass. Results for the other crops are based on extrapolations from the modeled crops.

AGRICULTURE KEY ISSUES

Irrigated Yields in 2030 - 2090
Without Adaptation



Irrigated Yields in 2030 - 2090
With Adaptation



Model simulations suggest that the net effects of the climate scenarios studied on the agricultural segment of the US economy over the 21st century are generally positive. The exceptions are simulations under the Canadian scenario in the 2030 time period,particularly in the absence of adaptation.

Economically, consumers benefit from lower prices while producers'profits decline. Under the Canadian scenario, these opposing economic effects are nearly balanced, resulting in a small net effect on the national economy. The estimated $4-5 billion reduction in producers' profits represents a 13-17% loss of income,while the savings of $3-6 billion to consumers represent less than a 1% reduction in the consumers' food and fiber expenditures. This large difference exists because much of the final cost of agricultural goods to consumers reflects processing,transportation,and retailing costs that the models used here assume are not affected by climate. Under the Hadley scenario,producers' profits decline by up to $3 billion (10%), while consumers save $9-12 billion (in the range of 1%). The major difference between the model outputs is that under the Hadley scenario,productivity increases are substantially greater than under the Canadian, resulting in lower food prices,to the consumers' greater benefit. The smaller producer losses in the Hadley scenario,despite greater productivity gains and price changes, reflect the fact that the US farmers' advantage over foreign competitors grows and they are thus able to significantly increase export volume. Analyses show that producer versus consumer effects depend on how climate change affects production elsewhere in the world. The sector Assessment was not able to extend its estimates on crop and livestock production to other regions of the world but used worldwide shifts in crop and livestock production projected in previous studies.

Regional production change,the total value of crop and livestock production,is positive for all regions in both the 2030 and 2090 time frames under the Hadley scenario. Adaptation measures have a small additional positive effect. In contrast,this economic index differs among regions under the Canadian scenario in both the 2030s and 2090s. It is positive for most northern regions,mixed for the northern Plains,and negative for Appalachia,the Southeast,the Delta states,and the southern Plains. Adaptation measures help somewhat for the southern regions,but the value of production is lower in these regions under both the 2030 and 2090 climates considered.

Changing Water Demands for Irrigation

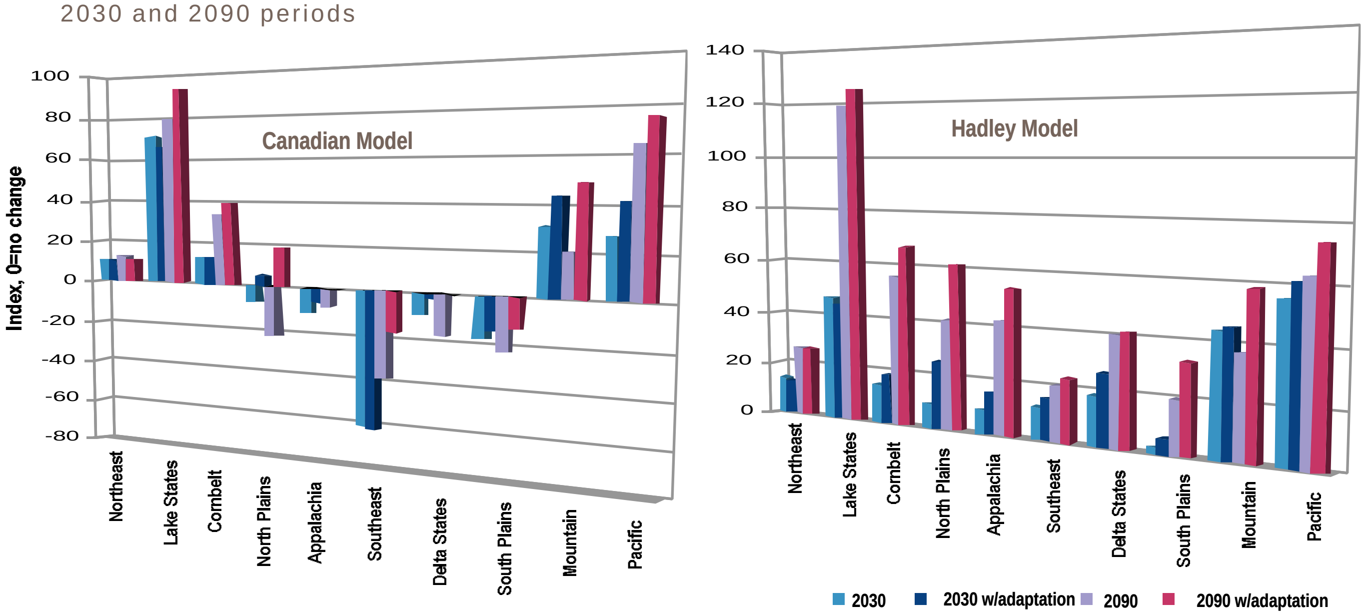
At the national level, the models used in this Assessment find that irrigated agriculture's need for water declines approximately 5-10% for 2030, and 30-40% for 2090 in the context of the two primary climate scenarios. At least two factors are responsible for this possible reduction. One is increased precipitation in some agricultural areas. The other is that faster development of crops due to higher temperatures results in a reduced growing period and thereby reduced water demand. In the crop modeling analyses done for this Assessment, shortening of the growing period reduces plant water-use enough to more than compensate for the increased water losses from plants and soils due to higher temperatures.

The picture for future agricultural water demands at the regional scale is less clear and it is possible that it will differ substantially from the national picture. At the regional level, there is the possibility that overall water use will increase in response to climate change.

Model simulations suggest that the net effects of climate change on the agricultural segment of the US economy over the 21st century are generally positive.

Regional Production Changes Relative to Current Production

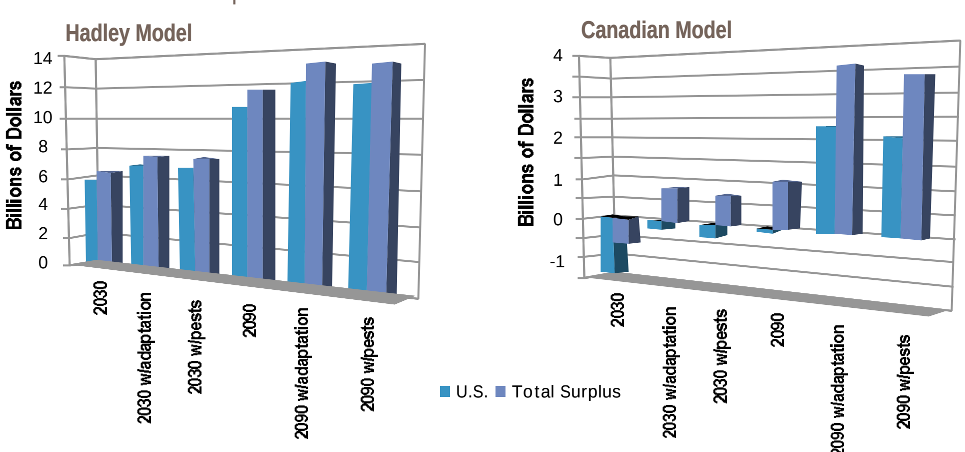
2030 and 2090 periods



Regional production change (crop and livestock production weighted by prices) from a year 2000 baseline was positive for all regions in both the 2030 and 2090 timeframes under the Hadley scenario. In contrast this index differed among regions under the Canadian scenario in both the 2030s and 2090s. It was positive for most northern regions, mixed for the northern Plains, and negative for Appalachia, the Southeast, the Delta states and the southern Plains.

Economic Impacts of Climate Change on US Agriculture

2030 and 2090 periods



Economic Impacts of climate change under the Canadian and Hadley climates. The economic index is change in welfare expressed as the sum of producer and consumer surplus in billions of dollars. US (light blue bar above) includes sales and purchases in the US, while Total Surplus (dark blue bar) also includes overseas sales by US producers.

AGRICULTURE KEY ISSUES

Surface Water Quality

A case study of agriculture in the drainage basin of the Chesapeake Bay was undertaken to analyze the effects of climate change on surface-water quality. The Bay is a highly valuable natural resource that has been severely degraded in recent decades. Soil erosion and excess nutrient runoff from crop and livestock production have played a major role in the decline of the Bay's health.

In simulations for this Assessment, under the two climate scenarios for 2030,loading of excess nitrogen into the Chesapeake Bay due to corn production increases by 17-31% compared with the current situation. These projected effects may not fully represent the effects of extreme weather events such as floods or heavy downpours that wash large amounts of fertilizers and animal manure into surface waters. Changes in future farm practices,such as better matching of the timing of plant need for fertilizer with the timing of application,could possibly help to reduce the projected impacts. Because efforts are already underway to protect the Bay, many of these practices may be required and in use before 2030.

Pesticide Use

The Assessment investigates the relationship between pesticide use and climate for crops that require relatively large amounts of pesticide. Pesticide use is projected to increase for most crops studied and in most states,under the climate scenarios considered. Increased need for pesticide application on corn is generally in the range of 10-20%,on potatoes,5-15%,and on soybeans and cotton,2-5%. The results for wheat vary widely by state and climate scenario showing changes in pesticide application ranging from approximately –15 to +15%.

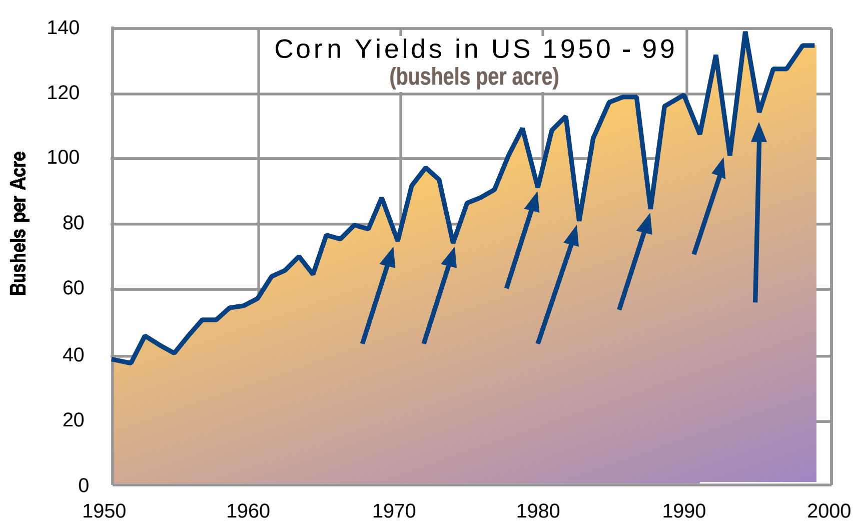
The increase in pesticide use results in slightly poorer overall economic performance,but this effect is quite small because pesticide expenditures are a relatively small share of production costs. This Assessment approach does not consider increased crop losses due to pests,implicitly assuming that all additional losses are eliminated through increased pest control measures. This may underestimate losses due to pests associated with climate change.

In addition,this Assessment does not consider the environmental consequences of increased pesticide use and it is possible that these would be substantial. In a complete economic analysis,the costs of negative impacts of pesticides on the environment would be considered.

Climate Variability

The consequences of climate change for US agriculture are very likely to be affected by changes in climate variability and extreme events. Agricultural systems are vulnerable to climate extremes,with effects varying from place to place because of differences in soils,production systems,and other factors. Changes in precipitation type (rain, snow, or hail),timing,frequency, and intensity, along with changes in wind (windstorms,hurricanes,and tornadoes),are likely to have significant consequences. Heavy precipitation events cause erosion, waterlogging, and leaching of animal wastes,pesticides, fertilizers,and other chemicals into surface and groundwater.

A major source of weather variability is the El Niño Southern Oscillation (ENSO). ENSO effects vary widely across the country. Better prediction of these events would likely allow farmers to plan ahead,altering their choices of which crops to plant and when to plant them. The value of



Reductions in corn yields often correspond to extreme climate events including droughts and floods. The record Midwest floods of 1993 resulted from this being the wettest year on record, washing out and flooding many corn fields and resulting in late replanting. In 1995, declines in yields resulted from a sequence of unusual climate events; a cool wet spring delayed planting, and a hot, dry summer affected pollination, and ultimately, yield.

improved forecasts of ENSO events under their current intensity and frequency has been estimated at approximately $500 million per year.
As climate warms, ENSO is likely to be affected. Some models project that more frequent El Niños and stronger La Niñas will have increasing impacts on US weather. The potential impacts of changes in frequency and strength of ENSO conditions on agriculture were modeled in this Assessment. An increase in these conditions is found to cost the US $320 million per year if accurate forecasts of these events are available and farmers use them as they plan for the growing season. The increase in cost is projected to be greater if accurate forecasts are not available or not used.

Adaptation Strategies

Adaptations such as changing planting dates and choosing longer season varieties are likely to offset losses or further increase yields. Adaptive measures are likely to be particularly critical for the Southeast because of the large reductions in yields projected for some crops under the more severe climate scenarios examined. Breeding for response to CO_2 will likely be necessary to achieve the strong fertilization effect assumed in the crop studies. This is an unexploited opportunity and the prospects for selecting for CO_2 response are good. However, attempts to breed for a single characteristic are often not successful, unless other traits and interactions are considered. Breeding for tolerance to climatic stress has already been heavily exploited and varieties that do best under ideal conditions usually also outperform other varieties under stress conditions. Breeding specific varieties for specific conditions of climate stress is therefore less likely to encounter success.

Some adaptations to climate change and its impacts can have negative secondary effects. For example, an examination of use of water from the Edward's aquifer region around San Antonio, Texas found increased pressure on groundwater resources that would threaten endangered species dependent on spring flows supported by the aquifer. Another example relates to agricultural chemical use. An increase in the use of pesticides and herbicides is one adaptation to increased insects, weeds, and diseases associated with warming. Runoff of these chemicals into prairie wetlands, groundwater, and rivers and lakes could threaten drinking water supplies, coastal waters, recreation areas, and waterfowl habitat.

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. Some of the possible adaptations more directly related to climate include:

- **Sowing dates and other seasonal changes:** Plant two crops instead of one or a spring and fall crop with a short fallow period to avoid excessive heat and drought in midsummer. For already warm growing areas, winter cropping could possibly become more productive than summer cropping.

- **New crop varieties:** The genetic base is very broad for many crops, and biotechnology offers new potential for introducing salt tolerance, pest resistance, and general improvements in crop yield and quality.

- **Water supply, irrigation, and drainage systems:** Technologies and management methods exist to increase irrigation efficiency and reduce problems of soil degradation, but in many areas, the economic incentives to reduce wasteful practices do not exist. Increased precipitation and more intense precipitation will likely mean that some areas will need to increase their use of drainage systems to avoid flooding and water-logging of soils.

- **Tillage practices:** A warmer climate will speed the decay of soil organic matter by bacteria and fungi. Loss of organic matter reduces the capacity of soils to store water and nutrients essential for plant growth. Tillage practices that incorporate crop residues in the soils would likely combat this loss and improve soil quality.

- **Use near-term climate predictions:** Accurate six-month to one-year forecasts could possibly reduce losses due to weather variability. For example, predictions of El Niño events have proven useful in regions where El Niño strongly affects weather.

- **Other management adjustments:** Virtually all components of the farming system from planting to harvesting to selling might be modified to adjust to climate change.