An Overview of California's Agricultural Adaptation to Climate Change

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While the overall impact of climate change will be moderate, the impacts will vary by regions—with big losers and gainers. Overcoming painful costs requires the development of adaptive capacity that can take advantage of advanced tools of science, including biotechnology, markets, and construction of dams and reservoirs. In California, climate change will increase the risk of flooding, disrupt water supply, and reduce productivity—especially in the Delta, coastal counties, and inland, southern regions.

The concentration of CO_2 in the atmosphere is on the rise, and there is concrete evidence that it can be attributed to human activities. Higher CO_2 levels are contributing to climatic changes that are likely to be enhanced in the future. Agriculture is dependent on the climate; thus, it is important to understand how climate change will affect agriculture, how agriculture will adapt to climatic changes, and what the impact will be on California—all of which will be addressed here. Our analysis is based on a growing literature of conceptual and empirical research on this topic, undertaken by both economists and scientists.

Implications of Climate Change for Agriculture

The impact of climate change will have several manifestations. It is quite common to refer to climate change as global warming because, on average, temperatures are rising. However, climate change will cause precipitation patterns to change, and weather conditions are likely to be much less stable with a higher likelihood of extreme natural disasters like hurricanes and monsoons. Moreover, climate change may result in rising sea levels, leading to a loss of agricultural land as well as seawater intrusion into coastal aquifers.

Since agricultural production depends on a combination of temperature, soil conditions, and precipitation, changes in climatic conditions may affect the relative productivity of crops across locations. With temperature increases, climate "migrates" from the equator towards the poles. For example, it is expected that a 1 degree Celsius warming (about 2 degrees Fahrenheit) will shift the climate zone 200-300 km towards the poles.

In addition to changes in temperature, there will be accompanying changes in rainfall and increased snowmelt. Thus, some areas close to the equator will become quite warm and will face agricultural productivity losses. On the other hand, some areas closer to the North and South poles will become warmer and witness agricultural productivity gains.

In addition to temperature and rainfall changes, the buildup of carbon in the atmosphere will affect agriculture through other means. This "fertilization effect" will lead to increased yields, since higher carbon levels enhance photosynthesis of plants. Another effect of global warming is the "daylight effect," resulting from the movement of agriculture away from the equator and a resulting reduction in exposure to the sun—thus, reducing yields. A third effect is the "pest effect," where changes in climate will lead to pest migration, primarily towards warmer regions away from the equator. Since pests are mobile and trees are not, this effect may result in significant increases in pest damage and yield losses.

In the case of California, significant warming (3 degrees Celsius) will shift the temperature of Los Angeles towards the Bay Area and the temperature of Fresno to Napa Valley. Nationally, the climate in Oklahoma is likely to shift north to Nebraska while the climate of Nebraska will migrate to North Dakota and parts of Southern Canada.

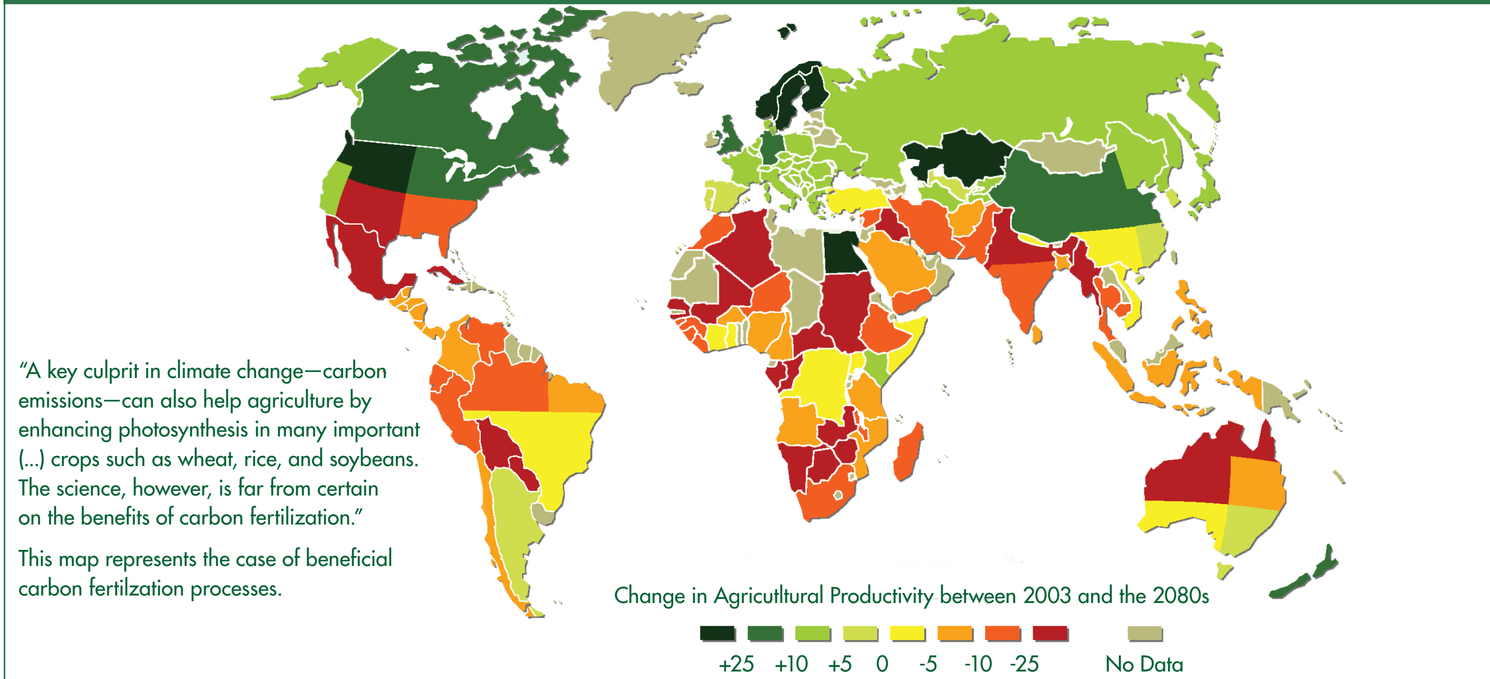
Figure 1 presents a map that illustrates how some regions across the world will fare under these changes. As one can see, the southern part of the United States will tend to lose while the northern parts of the United States, as well as Canada, will gain. Likewise, most of Africa and Latin America will lose; Russia, most of Europe, and Northern China will gain; and India and most of Australia will lose.

Farmers are not likely to take changes in climate lying down; they will change aspects of crop production they can control. There will likely be more corn production in North Dakota and Canada, and crops like sugarcane will grow in areas of Argentina. The capacity to adapt to climate change will determine its impacts to a large extent.

There is significant literature assessing the impact of climate change on agriculture. Under reasonable scenarios where the temperature does not rise above 3 degrees Celsius, most studies predict that aggregate impacts on agriculture after a period of adjustment are likely to be moderate. These predictions range from minimal impact to a 15% reduction in productivity.

However, the main concern is not over the aggregate climate effects, but about their distributional effects and the process of adjustment. Climate change may cause hundreds of millions

Figure 1. Projected Impact of Climate Change on Agricultural Yields



Source: Cline, William R., 2007. "Global Warming and Agriculture: Impact Estimates by Country." Peterson Institute Press: All Books.

in Mexico, Africa, and India to lose their livelihoods. They are unlikely to be able to take advantage of new production opportunities available in Russia, Canada, and Europe. Thus, climate change may cause substantial pressure for population migration, which may be a main trigger for major international instability.

History suggests that periods of climate change resulted in politically destabilizing population movements. For example, during a mini-ice age period, Rome was destroyed when tribes from Northern Europe migrated south to warmer regions. Likewise, the incursion of Islam into the Indian sub-peninsula was associated with periods of inhospitable climate in the Middle East.

Secondly, climate change is evolving in an unpredictable and uncertain manner. Decision makers tend to be risk averse, and as such, their level of activity tends to decline as uncertainty increases. Thus, the uncertainty surrounding climate change may lead to underinvestment in adaptation and protection mechanisms for some aspects of climate change.

Finally, the delay in adaptation to climate change may cause a short-term crisis. Periods of rapid changes in climate may result in significant reductions in productivity in regions close to the equator, without a compensating increase in productivity in regions closer to the poles—as investment in agricultural development in these regions may not have occurred or "borne fruit."

During periods of rapid climate change, aggregate supply of food will decline, food prices will increase, and the food situation will worsen. While it is likely that aggregate adjustment to climate change will occur in the long run, short-term adaptation is of critical importance and development of capacity for such adaptation is a major priority.

On the Development of Adaptive Capacity

The risks and the costs of climate change can be reduced through adaptation activities. One key element of adaptation is mitigation—activities that will reduce the likelihood and severity of climate change. These activities include reduction in carbon emissions, carbon sequestration, and geo-engineering.

However, in this article we address adaptation in the narrower sense, which includes several sub-categories of activities:

(i) innovation and adoption of new technologies: new varieties that allow crops to withstand changes in weather, as well as resist increased pest infestation due to climate change,

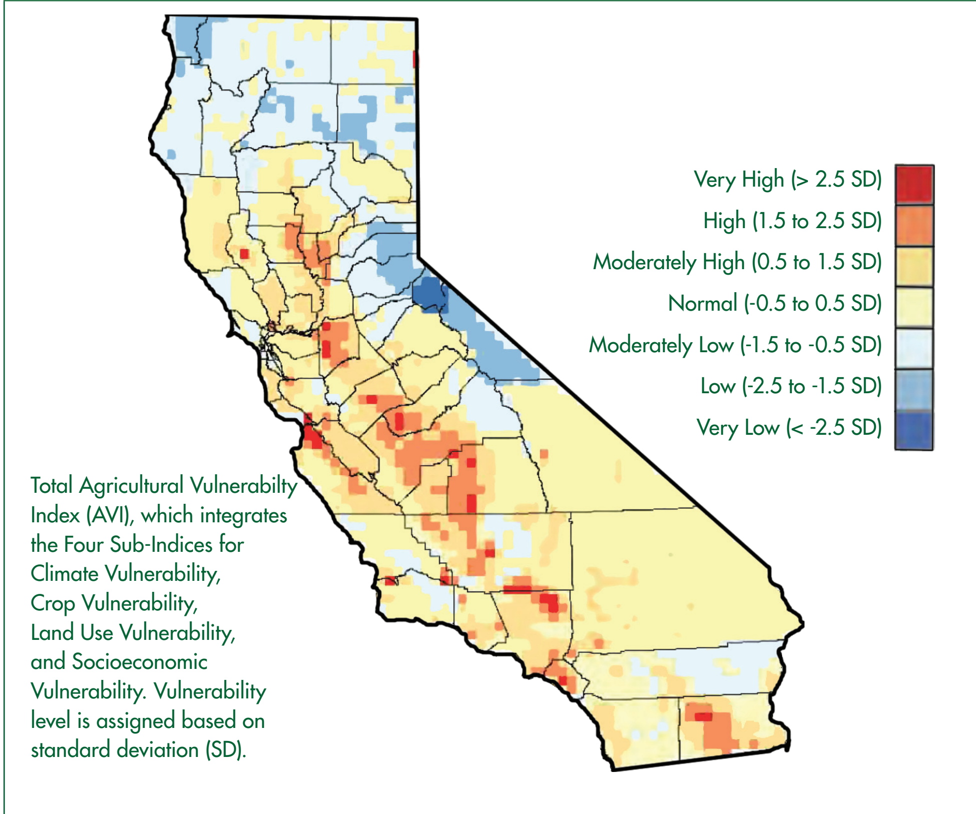
(ii) adoption and adaptation of existing technologies from different regions: as climate migrates, technologies migrate with it,

(iii) changes in land use of agricultural activities: for example, switching from wheat to corn in northern regions,

(iv) migration: both away from regions that suffer from climate change and to regions that benefit from it, and

(v) investment in protective infrastructure: such as walls and dams to protect against rising sea levels and unstable weather.

Figure 2. Total Agricultural Vulnerability Index



Source: A white paper from the California Energy Commission's California Climate Center. University of California, Davis California Energy Commission, 2012.

A key to effective adaptation is investment in basic and applied research to develop new technologies that will help society cope with a new climate reality, and removal of unnecessary barriers for their commercialization and diffusion. One of the major challenges is to overcome attitudes that oppose the adoption of innovations to adapt to climate change. Some of the environmental groups that are very concerned about climate change are the people most vehemently opposed to the use of genetic modification in agriculture.

Genetic modification takes advantage of new knowledge in molecular and cell biology to develop crop varieties and other species that can accelerate the speed and reduce the cost of adaptation to climate change. Environmental groups tend to emphasize conservation and defense of current environmental conditions, and therefore promote mitigation over adaptation. The reality is that we need both as climate change progresses, and they may be complementary. Genetic modification has already increased the productivity of agriculture, thus reducing the environmental footprint associated with it, and it also enhances carbon sequestration by enabling the adoption of technologies like no-tillage. Combatting climate change requires an open mind about technologies and the utilization of innovations in an economically efficient and environmentally sustainable manner.

Implications for California Agriculture

California has the nation's most productive agriculture, producing more than 400 different commodities, and is a major producer of many high-value fruits and vegetables. The lion's share of the value of California agriculture comes from the approximately eight million acres of irrigated cropland. Climate change is likely to affect California agriculture through its impact on water resources, as well as agro-climatic conditions in different regions.

The snowpack in the Sierras has served as a natural regulator and water storage mechanism, and will face up to 80% depletion by 2100. Even if precipitation is slightly reduced, the acceleration in snowmelt will increase the risk of flooding and result in a loss of dry-season water availability. Dams in California have played an important role in adaptation to fluctuating weather and rainfall conditions, but they are costly both in monetary and environmental terms.

Furthermore, increased weather instability associated with climate change will require expansion of conveyance facilities and the introduction of trading mechanisms that allow effective allocation of water during shortages. The reduction in water supply and the increased demand for water, as a result of further warming, will increase the value of investment in new facilities. It will also lead to the design of institutions promoting increased use of recycled wastewater for agricultural and urban uses.

One of the major consequences of climate change is rising water levels. Under plausible scenarios, seawater is expected to rise 1.4 meters by 2100. These rising water levels are likely to be accompanied by a much higher likelihood and severity of seawater intrusion, which may lead to losses of coastal aquifers. Altogether, these rising sea-levels will significantly reduce the productivity of much of the coastal regions of California, including the Monterey Peninsula and Santa Maria region.

Rising water levels are likely to lead to a massive intrusion of salinity into the San Francisco and Sacramento Delta and threaten agricultural production in the already vulnerable delta islands. Thus, seawater intrusion may lead to reductions in the production of high-value crops in some coastal areas and the delta islands.

Production practices and irrigation regimes in other parts of these regions must be modified to address changes in water quality and availability.

California agriculture's capacity to flourish and withstand severe droughts in the recent past can be attributed to the extensive system of dams, reservoirs and canals, varied utilization of groundwater, continuous improvement in irrigation systems, and gradual expansion of the capacity to trade water. But much of California's water infrastructure is aging, and the risks of climate change challenge the existing system. It took close to 50 years from the initiation of the State Water Project to actually complete it.

Adaptation to climate change will require quicker redesign of facilities and institutions, balancing the net social benefits from economic activities and environmental conservation. Adaptation may lead to construction of new dams, reservoirs and canals, as well as more intensive use of water pricing and trading mechanisms.

Studies on the impact of climate change on California agriculture assess impacts on crop yields resulting primarily from temperature increases and changes in precipitation. The impact estimates are subject to a high degree of uncertainty, yet they suggest that with a 2 degree Celsius increase in temperature, reduction in the yields of fruits like walnuts, avocados, and table grapes will be greater than 5% in all of the current growing regions in California, and in many areas it will be much larger.

A 4 degree Celsius increase in temperature will reduce yields by more than 5% for most other fruit crops; in some important regions, the yield losses may reach up to 40%. While the yield effect on wine grapes may not be very high, the high quality in premier regions may suffer because of temperature increases.

Figure 2 presents the results of a recent study undertaken by the University of California, Davis that identifies some of the most vulnerable agricultural regions to climate change from multiple perspectives. The Salinas Valley (the "salad bowl" of the United States), as well as the San Joaquin Valley, were identified by the California Energy Commission as two of the most vulnerable agricultural regions to climate change effects—including seawater intrusion and temperature increases. Agriculture in the Imperial Valley and the corridor between Fresno and Merced are identified by this study as very vulnerable to climate change. Yet at the same time, the potential for rice production is increasing, and new opportunities may open up for some of the northern regions of the state, which may provide hospitable environments for fruits (wine grapes) and vegetables.

The estimates of climate change impacts are uncertain but two elements are clear. First, the aggregate impact of climate change will depend on our capacity to adapt existing crops to rising temperatures and new pest pressures. Second, climate change will require identification of new opportunities and investment in building new infrastructure for agricultural production and processing in newly suitable areas.

Conclusion

The impacts of climate change are uncertain, and research to better understand the process and potential for adaptive capacity are major priorities. Research suggests that in general, climate change is likely to lead to modest reductions in overall agricultural productivity in the long run and its impacts will vary across regions, with major losers and gainers.

In the case of California, climate change may reduce water supply and increase the risk of floods. Agricultural production in California's coastal region, the San Francisco-Sacramento Delta, and the southern region of the state are also likely to experience substantial losses.

The adjustment to such a change may be painful; it will require costly relocations of businesses and farms as well as development of new technologies and infrastructure. The capacity to adapt to climate change can be enhanced if it takes advantage of a full arsenal of science- and technology-based tools, including advanced tools of biotechnology, markets, and construction of dams and reservoirs.

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