Can We Adapt to Climate Change? Lessons from Past Agricultural Challenges

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Evidence mounts that farmers will face enormous challenges to adapt to climate change and to the accompanying increase in pest and disease problems. California farmers have faced many serious crises in the past. This paper highlights a few of those past episodes and some of the lessons garnered from those experiences.

Evidence from the North and South Poles and many points in between signals the enormity of the climatic change underway. Climate models forecast over the next century significant increases in temperatures, a rising sea level (with accompanying salinity problems for coastal water supplies), and changing precipitation patterns—some areas will receive more precipitation and others less. Moreover, the timing of the precipitation over the course of the year may change; California will likely receive less snow—making water storage more of a problem. In addition, changing climatic conditions will likely bring a significant worsening in the pest and disease environments beyond what would otherwise have happened. These changes will present significant challenges to agriculturalists.

There have been no experiences with climate change affecting agriculture in the past equivalent to what we expect to confront in the next 50 to 100 years. Nevertheless, history offers valuable insights into the ability of farmers (aided by scientists) to adjust to different climatic conditions and to pests and diseases.

A key lesson of general importance is California farmers are not alone in facing new and more variable conditions and shocks. Climate change will also affect the state's competitors in the United States and around the world. Some competitors may benefit, but many will suffer deteriorating conditions. Thus, the outcome in California will depend crucially on how climate change affects the *comparative advantage* of California farmers. This, in turn depends not just on the physical elements, but also on how the state's farmers adapt to the new challenges relative to how others adapt.

Farmers live and work in a complex physical, economic and political environment, and the quality of markets, transportation networks, legal institutions, research infrastructures and so on govern their ability to adapt. Successful adaptation on farms will depend on substantial advances in policy off the farm.

This principle of comparative advantage has often favored California farmers during past weather shocks and pest invasions. As examples, the spread of the boll weevil in the American South gave impetus for the spread of cotton production in California in the early 20th century. In addition, California citrus growers were major beneficiaries of the "Great Florida Freeze" of 1894/1895.

California farmers have repeatedly benefited from the state's relatively progressive research infrastructure to adapt successfully to environmental shocks. One of the most destructive threats, cottony cushion scale, was first observed in the Golden State in 1868 during the infancy of the citrus industry. By the 1880s, the damage was so extensive that the entire industry appeared doomed.

Growers burned thousands of trees and helplessly watched their property values fall. Farmers tried all manner of remedies, including alkalis, oil soaps, arsenic-based chemicals and other substances, but the pest continued to multiply. Many experimented with fungicides. The preferred approach was to cover the trees with giant tarps or tents and pump in cyanide solutions, which was both costly and environmentally hazardous.

The record suggests that farmers and scientist have adjusted production in the past to meet enormous challenges; whether they can adapt to the new conditions remains to be seen, but the past record should give us hope.

In 1888 the USDA entomologist, Albert Koebele, discovered that a ladybird beetle in Australia consumed the scale. Within a couple of years, another entomologist had conducted experiments in Southern California, distributing the beetles in large numbers to growers. A year after the general release, the voracious beetle had reduced cottony cushion scale to an insignificant troublemaker, thereby contributing to a three-fold increase in orange shipments from Los Angeles County in a single year. Figure 1 (on page 10) shows a patented fumigating tent made redundant by ladybird beetles.

There are many other examples of signature California industries being saved by research. One of the more significant was the early struggle with phylloxera, which threatened the grape (and wine) industry. The pest gained

Figure 1. The Culver Fumigator

The introduction of the ladybird (vedalia) beetle reduced the need to fumigate to kill cottony cushion scale.
Source: Olmstead and Rhode, Creating Abundance, 2008

notice in California in the mid-1870s. It was already inflicting great damage in Europe to the benefit of California growers. The infestation affected most California grape-growing regions by 1880. By this date, farmers in Sonoma County alone had already dug up over 400,000 vines. By 1890 the future of viticulture in California looked bleak.

Researchers experimented with hundreds of biological, chemical, and cultural cures (including applying toad venom) without success. Salvation only came after researchers (in Missouri, California, and France) hit on and perfected the idea of grafting European vines onto resistant native-American rootstocks. This research began in the 1860s, but adoption of this technique was slow because of the enormous investment required. By 1915 about 250,000 acres of vines had been destroyed in California, and little land had been replanted with resistant stock. The process of replacing vines continues today.

At the time when cottony cushion scale and phylloxera were on the march, the future probably looked as dire as it does today for many observers. Predicting the future and anticipating new technologies that may be over the horizon was as difficult in the past as it is today. In some cases, shocks just brought hardship—researchers were not always able to help ward off pests and diseases.

The inability to protect against Pierce's disease in the 1880s and 1890s offers a prominent example of a failure. This bacterial disease wiped out the thriving grape/wine industry first in the Anaheim area and then in most of Southern California. As a postscript, the disease now plagues the industry in Northern California and short of attacking the sharpshooter vector that carries the malady, there is still no effective control. One consequence of the 19th-century disaster in Southern California was a greater expansion of the citrus industry in the region—this was a major adjustment.

There are other cases—such as the collapse of the Golden State's bonanza wheat sector—where research did not ride to the rescue in time. By 1890 California ranked second in the nation as a wheat producer. As Figure 2 highlights, a rapid collapse occurred in the first decade of the 20th century. California's transition out of wheat is generally attributed to other higher value crops enticing farmers to change their cropping patterns.

However, there was another side to the story. California grain farmers had focused their innovative efforts on mechanization and evidently did little to introduce new wheat varieties, improve cultural practices, or even maintain the quality of their planting seed. Decades of mono-cropping mined the soil of nutrients and promoted the spread of weeds. By the 1890s, there were widespread complaints that the land no longer yielded a paying crop. In addition, the grain deteriorated in quality and value, becoming starchy and less glutinous.

The mono-cropping and soil-mining methods may have made economic sense given the high interest rates at the time, but this cannot explain the inattention to seeds by both farmers and researchers. Our study of the research conducted at the California State Experiment Station shows that there was little wheat-breeding work until after 1905, which was much later than what was the norm in other major wheat-producing states.

History offers many other examples of agricultural adaptation to challenges and shocks—some of the most sensational deal with the underlying forces allowing for the settlement of the North American continent. The story of settlement as usually told focuses on the perseverance of rugged pioneers, hacking out the wilderness to make farms, the railroad, the displacement of Native American populations, and the like.

But the spread of agriculture onto new lands in new regions was first and foremost a gigantic and difficult exercise in biological learning and adaptation. Without crops that could survive in the new environments, the history of the West would have been far different.

Focusing on wheat will illustrate the difficulties that farmers had to overcome and how this ties to possible adjustments to global warming. One widely reproduced map offers predictions of where wheat is apt to be produced in 2050—just 36 years from now. It shows the region suitable for wheat stretching into Alaska with a northern frontier several hundred miles north of the current frontier in Canada. The southern frontier of suitable land barely dips into the northern United States. By this account the great producing areas in Kansas, the Dakotas, the Palouse, Alberta, Saskatchewan, and Manitoba will be unsuitable for wheat.

A check of the actual research paper cited suggests that the popularized account exaggerates the shift and that many wheat growing areas in the United States and Canada will still be in production at mid-century. How do these predicted changes compare to past changes? The surprising answer is that even the most extreme predictions about the changing location of production probably do not surpass the changes that occurred in the past.

Wheat was brought to North America by early European settlers, but we pick up the story of its geographic evolution in 1839 when county-level data first became available. At that time, the geographic center of wheat production in North America (the United States and Canada) was in eastern Ohio, near what is now the West Virginia border. New York and Ohio accounted for the greatest concentration of wheat cultivation and little was produced west of Illinois. By 2007 the center of production had moved to west-central South Dakota, or about 1,100 miles.

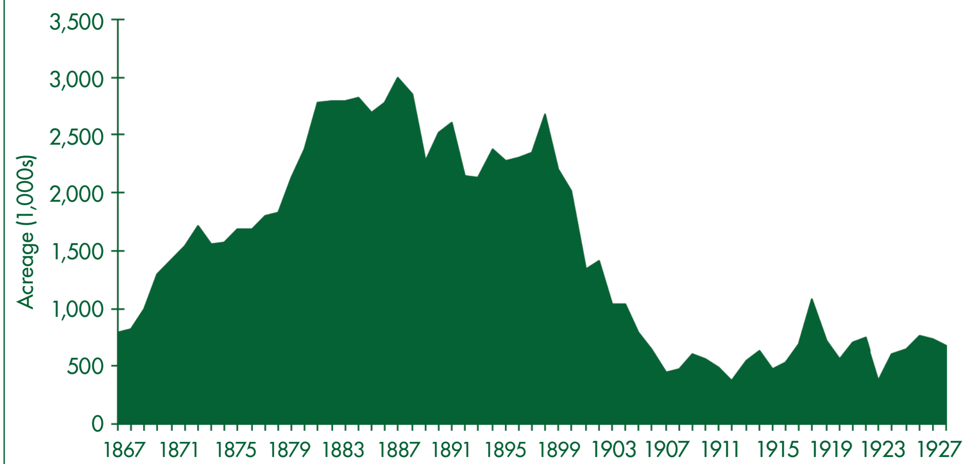
The movement of the fringes of production was also impressive. In 2007, 10% of the wheat grown in North America was grown west of 115 degrees longitude (roughly a north-south line running from Calgary, Alberta through Las Vegas, Nevada and into northern Mexico). Another 10% was grown north of 52 degrees latitude (an east-west line about 200 miles north of the U.S.-Canadian border west of Minnesota). Given the increase in total wheat output, 10% of production in 2007 represented more wheat than was grown in North America in 1839. In addition, by 2007 considerable wheat was also grown in northern Mexico. What is more remarkable, most of these changes in the location of production had occurred by 1910—well before the era of modern plant breeding guided by an understanding of advanced genetic engineering.

Granted, wheat production moved over vast distances but what does this have to do with global climate change? A lot! The many generations of farmers who moved wheat onto the moving frontier typically had little knowledge of the different climatic conditions that they would face. Farmers generally brought wheat seed with them from the already settled areas of the United States and Canada. These varieties typically failed in the harsher and more variable climates encountered in the West. Only after a long period of experimentation and adaptation—sometimes through careful observation, sometimes as a result of serendipity, and sometimes with the help of plant breeders—did farmers hit on new varieties suitable for the different conditions they faced.

The climatic differences were enormous and rivaled the changes predicted over the next century. In 1839 the average wheat grown in North America occurred in places that typically received 39.4 inches of precipitation, and places receiving less than 31 inches grew almost no wheat. In 1929 one-half of North American wheat was grown in places that received 20 inches or less of precipitation, and more wheat was grown at that later date in areas with 14 inches or less of precipitation than was grown in all of North American in 1839. If anyone had told farmers in Ohio in 1839 that people would be growing wheat with only 40% of the rainfall they were accustomed to, they would have thought the idea was daffy.

Wheat production also moved into much colder and hotter regions. In 1839 the median wheat produced in North America thrived in a zone where the average annual temperature was 52 degrees. In 1929 median wheat production occurred with an average of about 44 degrees. Given the concern with hotter temperature in the future, let's look at the differences in conditions confronted in moving

Figure 2. California Wheat Acreage, 1867–1929



Source: Paul W. Rhode, 1995

production from Columbus, Ohio to Ciudad Obregon in Senora, Mexico.

In 1839 wheat farmers around Columbus probably received over 38 inches of precipitation and experienced an average annual temperature of about 52 degrees Fahrenheit. The average conditions in the years 1981–1990 (before considerable global warming affected measurements) in Ciudad Obregon were 13.1 inches of precipitation and 74.5 degrees. These *differences* in conditions are much greater than the *changes* predicted by most models for the next century for wheat growing regions in North America. These findings do not mean that there will not be serious challenges in the future—there will be. The record does suggest that farmers and scientists have adjusted production in the past to meet enormous challenges; whether they can adapt to the new conditions remains to be seen, but the past record should give us hope.

The historical record offers several lessons. To adapt appropriately, farmers need the right incentives—this means that they must face prices that reflect the real cost of the resources they use and the products they produce. Subsidies of various forms might be politically convenient and ease some short-run burdens of adjustment, but they will also likely slow adjustments creating longer-run competitive disadvantages. Once in place, subsidies will be hard to terminate.

In the past, scientists played an important role in helping farmers adjust to challenges. Research contributed to increased productivity, but the movement into less hospitable environments, or the damage caused by pests and pathogens, offset some of the potential increases in efficiency. There is much research and adaptation that just allows farmers to maintain their productivity.

The expectation of more adverse conditions and unexpected negative shocks in the future because of global warming suggests that there might be an even greater need for "maintenance research." If so, society should allocate more (public and private) funding for scientific research than would otherwise have been the case. Given the long time lag between the commencement of research and the payoffs, it would be wise to invest more in research now instead of waiting for the crisis to hit.

Many issues such as pests and disease control, making more efficient use of water supplies, more public research, and the like will probably necessitate collective action, which will require more, not less, government involvement. As resources become scarcer—especially resources for which there are not good markets (water) or which have a large common-property element (clean air)—we can expect more distributional disputes and calls to change historic, but perhaps increasingly inefficient, legal systems. Farmers residing in states and nations that make adjustments to their institutions will fare better in a profoundly changed climatic environment.

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For additional information, the authors recommend:

Alston, J.M., J.M. Beddow, and P.G. Pardey, 2009. "Agricultural Research, Productivity, and Food Prices in the Long Run," *Science* 325: 1209–1210. This offers a sense of the need for more agricultural research and the time lags between starting new projects and the diffusion of useful results.

Olmstead, A.L. and P.W. Rhode, 2008. *Creating Abundance: Biological Innovation and American Agricultural Development*. New York: Cambridge University Press. Pages 223-261 deal with environmental adaptation and pest problems in California.

Olmstead, A.L. and P.W. Rhode, 2011. "Adapting North American Wheat Production to Climatic Challenges, 1839-2009," *Proceedings of the National Academy of Sciences*, 108(2): 480-85. This deals with the adaptation of wheat to varying conditions in North America.

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For an example of misinformation on the possible future shift in wheat production see the map in Richard Black. "New Crops Needed to Avoid Famines," BBC News, December 3, 2006, http://news.bbc.co.uk/2/hi/science/nature/6200114.stm.