Science and Economic Aspects of Impact of and Adaptation to Climate Change Induced Water Scarcity in Western US Agriculture

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Introduction

The hydrologic cycle of the western United States will likely be impacted by climatic changes. Temperature increases, more frequent extreme precipitation events, snowpack decline, shifted timing of peak snowpack and runoff, and a decline in groundwater recharge have been observed over the past century, and are projected exacerbate for the next one. High-elevation mountains in the western United States receive the majority of their annual precipitation as winter and spring snow. Changes in timing of snowmelt and snowmelt-driven runoff will impact the timing of water availability. In particular, much of the southwestern United States is dependent on Colorado River water. Any changes in runoff and streamflow will have major impacts on water resources in the United States as well as in its southern neighbor – Mexico. This may increase reliance on groundwater, which is experiencing a decline in recharge due to climatic changes and with the increased pumping by users faced with increased surface water scarcity. Coupling this with the fact that the southwestern United States region is a major agricultural producer with parts almost entirely dependent on irrigation water. Agriculture accounts for 79 percent of southwestern water withdrawals – several studies have identified parts of the Southwest as highly vulnerable to climate change. The duration of the growing season has increased over the last century. The average growing season across the Southwest during 2001–2010 was 17 days longer than the twentieth century average, and one month longer than that of the first decade of the twentieth century Taking into account that the Southwest produces more than half of the nation’s high-value specialty crops, the entire nation is ultimately vulnerable.

This paper reviews three critical dimensions of climatic impacts on agriculture, which are rarely discussed in a single document: meteorological (global climate models), agronomic (crop simulations), and economic (optimization) modeling. However, only the latter two will be covered in this policy note.

Crop Simulations

Crop simulation studies suggest that yields are highly dependent on the given crop and climate variable studied. In general, horticultural crops are more sensitive to short-term environmental stresses than field crops. In California, observational data suggests warmer seasonal nighttime temperatures have increased yields of wine and table grapes, but decreased yields of avocados, walnuts, and almonds. Higher seasonal precipitation has led to
increased yields of wine and table grapes, almonds, strawberries, and Valencia oranges. The data suggest that the effect of warmer temperatures is highly seasonal for many crops.

Economic optimization

Mathematical programming and econometric approaches have been applied to the southwestern United States. Two major programming models that have been applied to study climatic impacts on agriculture in California are the SWAP and USARM models. The results from the SWAP model under two different GCMs suggest that California agriculture (and potentially agriculture in other southwestern states that are water-constrained) will shift from low (e.g., pasture, field, and grain crops) to higher value crops under climate-induced water shortages.

Econometric approaches tease out the direct statistical influence of climate on farmland value, or net farm revenue. The classic Ricardian study finds that climate variables (temperature and precipitation) have a negative impact on U.S. farmland values. Subsequent studies find that precipitation is not statistically significant in largely irrigated areas. Other studies find a statistical relationship between access to surface water and farmland value, although this relationship diminishes as water becomes more abundant.

Adaptation studies

Classic technology adoption papers have indicated that technology has been used to substitute for some natural deficit, such as a soil’s water-holding capacity. Studies have found that adaptation reduces losses from climate change. Using the WEAP model, the combined effect of improved irrigation technologies and shifting cropping patterns reduces future increases in water demand to their current level. Without such adaptations, water demand increased through the twenty-first century. Including farm-level adaptations (i.e., shifting between irrigated and rainfed production, altering water use on irrigated acreage, altering use of inputs on planted acres, fallowing land, and changing the crop mix) reduces the damage of water shortages to producers by 66 percent as compared to a simulation with fallowing alone. The other adaption studies that study farmer choice have not been implemented in the Southwest, but it would benefit the region to conduct such studies.

Implications

There is no “best” approach to modeling the climate-induced economic impacts on agricultural yield. This is likely even the wrong methodology. A review of the different modeling approaches provides the researcher with options for the most suitable approach or approaches. Indeed some models incorporate more than one approach, suggesting that studies from different authors using different modeling frameworks could complement one another. For example, consensus from different methodologies on regions that are sensitive to climate could add weight to creating effective policies in these regions. And, indeed there is consensus among economic modeling approaches, and between economic and crop simulation approaches that certain crops will be adversely affected directly by increasing temperatures, and indirectly through temperature effects on water availability and timing of supply. This, in turn, affects agricultural land values, as shown by the econometric studies.

The mathematical programming approaches suggest that, without adaptations, irrigated acreage will decline in the present century. The studies that attempt to understand farmer incentives to adopt technologies or management practices will provide additional insights to which technologies and practices may be adopted in the future.

This policy note is based on a paper of the same title.
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