Determinants of California Farmland Values and Potential Impacts of Climate Change

by
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The value of California farmland is found to be influenced by climate-related variables such as degree days and available irrigation water, controlling for other influences such as soil quality and the proximity of urban areas. A measure of the impact of global warming on California agriculture is given by the change in farmland value estimated to result from changes in temperature, which affects degree days, and patterns of precipitation, which in turn affects water availability. Preliminary findings suggest the impact will be large and negative in a "business as usual" scenario, and modest but still negative in a scenario characterized by fairly stringent controls on greenhouse gas emissions.

Many influences on the value of farmland can be hypothesized: soil quality, temperature, precipitation, encroaching urban development, and so on. Estimation of the potential impact of climate change on value needs to include variables such as temperature and precipitation. The estimation is, however, more complicated. First, measurement of the climate variables is not straightforward. Also, other possible influences on value, such as measures of soil characteristics and the proximity of urban areas with large and growing populations, need to be considered as well and held constant in order to identify the impact of the climate variables.

This article reports on work being undertaken to estimate the influence of these variables on California farmland values, and then make some inferences about the implications of changes in the climate variables under different policy scenarios—something like "business as usual," involving sustained heavy use of fossil fuels over the next several decades, versus a regime of fairly stringent control of greenhouse gas emissions, in particular the carbon dioxide that results from the combustion of fossil fuels. At this time only the first-stage estimation has been carried out, but it is possible to make a rough first cut at determining the potential impact on farmland values of the scenario-based climate changes. A detailed technical presentation is in Schlenker, Hanemann, and Fisher (forthcoming); see box for further information.

What are the consequences of the changes in temperature and patterns of precipitation for the value of California farmland?

Definition and Measurement of Climate Variables

Temperature/Degree Days. Plant growth responds to temperature in a nonlinear way. Plant growth is linear in temperature only within a certain range, between specific lower and upper bounds. This gives rise to the concept of degree days: the sum of degrees above a lower bound and below an upper bound during the growing season. Typically, these bounds are 8^0C and 32^0C. Thus, a day with a temperature below 8^0C contributes zero degree days; a day with a temperature between 8^0C and 32^0C contributes the number of degrees above 8^0C; and a day with a temperature above 32^0C contributes 24 degree days. Degree days are then summed over all days in the growing season.

In our study, which estimates the statistical relationship between farmland value (based on farm profits, in turn based on crop yield), and climate variables, we construct a degree-days variable from detailed temperature records. We find in accord with the agronomic results, that this variable outperforms raw temperature in explaining variation in farmland value.

Precipitation/Water Availability. It seems natural to hypothesize a relationship between precipitation and crop yields or profits, and indeed we have found a strong relationship in studies of the determinants of farmland values in areas of dryland, or rainfed, agriculture. More precisely, we find that increases in precipitation are beneficial up to a point, beyond which they can be harmful, in agricultural areas east of the 100th meridian in the U.S., the historical cutoff line for farming not primarily dependent on irrigation. This region comprises approximately 80 percent of U.S. counties and 72 percent of farmland value, so the impact of climate changes here clearly matters. It does not, however, include important agricultural areas in the arid West, most importantly California, where farming largely depends on irrigation.

Table 1. Hedonic Regression of California Farmland Value ($ per acre, 2000) Using Degree Days

Variable	Coefficient	t-Value
Constant	1365	(0.38)
Thousand degree days (8-32°C), April-September	5493	(2.48)
Thousand degree days (8-32°C), April-September squared	–1112	(2.78)
Precipitation, April-September (feet)	3591	(0.78)
Precipitation, April-September (feet) squared	–75.3	(0.02)
Percent clay (percentage points)	–70.2	(3.75)
K-factor of top layer	–29.7	(1.00)
Minimum permeability of all layers (inches/hour)	–130	(1.13)
Average water capacity (inches/inch)	–70.8	(1.01)
Percent high class soil (percentage points)	5.95	(1.27)
Population density	30.1	(2.32)
Depth to groundwater (feet)	–1.47	(0.37)
Federal + private water (acre-feet/acre)	656	(4.62)
Number of observations	2555	

Notes: The coefficient estimates are from a random-effects model, and t-values are in parentheses. The sample includes observations with farmland values below $15,000 per acre and water prices below $20 per acre-foot.

Source: Schlenker, Hanemann, and Fisher (forthcoming).

Other Influences on the Value of Farmland. To isolate the effect of climate-related variables on value, we need to control for other influences: soil characteristics, such as percent high-quality soil and percent clay; and a measure of population pressure, a weighted average of population in census tracts surrounding each farm. Although the latter does not contribute to agricultural productivity in the same way as soils and climate, it reflects the empirical finding that a substantial fraction of farmland value near urban areas is due to the option of converting the land to urban uses.

We might still include precipitation as an explanatory variable in our California study, supplemented by the inclusion of an appropriate irrigation variable. We would not, however, expect significant results, since precipitation is nearly nonexistent in the major farming areas in the state during the growing season of April-September. Further, this means that there is very little variation in precipitation across the farm-level observations, making it impossible to identify directly an effect of changing patterns of precipitation.

Our preferred measure of water availability is surface-water deliveries to farms in each of the state's irrigation districts. Water deliveries of course depend indirectly on precipitation, but not during the growing season, and not in the farming area, since surface-irrigation water comes largely from managed reservoirs that catch runoff from the Sierra snowpack. Thus there is a certain degree of intermediation by irrigation districts, which in turn provides the substantial variation needed to estimate a relationship between water availability, crop yields, and farmland values. We also look at access to groundwater, since farms may pump groundwater to supplement surface-water deliveries when and as needed. Groundwater is unregulated and we do not have data on groundwater use by farm, but calculate depth to groundwater at each farm as a weighted average of nearby well depths as a measure of access.

Results of Statistical Estimation

Results of the estimation of farmland value in California are given in Table 1. As a rough guide, an estimated coefficient is considered statistically significant if its t-value exceeds 2.0. The estimated coefficients on the climate-related variables are intuitively plausible. Taken together, the large positive coefficient on degree days and the smaller negative coefficient on degree days squared imply that increased degree days are beneficial up to a point but not beyond. The quadratic relationship peaks at around 2,400 degree days over a six-month growing season, or around 1,600 for the more typical four-month season for most crops, consistent with agronomic findings concerning degree-day requirements.

As expected, the coefficients on precipitation and precipitation squared are not statistically significant, though the signs and magnitudes are "correct": large and positive for the former, small and negative for the latter, implying a quadratic relationship in which a certain amount is beneficial but more is damaging. This does not mean, however, that water is not an important influence on farmland values in California. In fact, as shown by the coefficient on water availability, this is the most important influence, measured by statistical significance. Its importance is also suggested by the magnitude. The way to interpret the result is that long-run availability of an additional acre-foot of irrigation water per acre (restricting the sample to observations where the price is less than $20 per acre-foot) adds $656 to the value of an acre of farmland, or about 16 percent of the average value in our sample of $4,177 per acre. If a typical farm receives, say, two acre-feet per acre, then access to water would account for 32 percent of the value of an acre, and so on. The estimate is mildly sensitive to the cutoff price for irrigation water, but most of our observations fall well below $20, due to implicit subsidies.

Table 2. Predicted Impacts of Various Climate-Change Scenarios

Model	Scenario	Time Period	Change in Temperature	Impact on Value per Acre	t-Value
PCM	B1	2020-2049	1.2	–155	(1.67)
PCM	A1	2020-2049	1.4	–189	(1.76)
HadCM3	B1	2020-2049	2.2	–347	(2.09)
HadCM3	A1	2020-2049	3.1	–564	(2.43)
PCM	B1	2070-2099	2.15	–336	(2.07)
PCM	A1	2070-2099	4.1	–845	(2.72)
HadCM3	B1	2070-2099	4.6	–997	(2.83)
HadCM3	A1	2070-2099	8.3	–2166	(3.12)

PCM: Parallel Climate Model HadCM3: U.K. Met Office Hadley Centre Climate Model
Source: Schlenker, Hanemann, and Fisher (2006b).

As hypothesized on the basis of both theory and previous empirical findings, population pressure plays a role in determining farmland value. The estimated coefficient is positive and significant. Of the soil variables, only percent clay is strongly significant, and negative. Higher clay percentages are undesirable as they imply drainage problems, especially on the west side of the Central Valley. Percent high-class soil has the expected positive sign, but is not statistically significant. Interestingly, these results are reversed in our study of farmland values east of the 100th meridian; percent best-soil class is strongly significant and percent clay is not.

Potential Impact of Climate Change: Preliminary Estimates

Here we provide some preliminary calculations of the potential impacts of climate change on the average value of farmland in California. More definitive results require more complete and accurate data on water rights, prices and deliveries, and how these will be affected under different change scenarios. Initially, climate scientists speculated that the increase in annual precipitation under most major climate scenarios would moderate the pressure on water resources. However, recent studies for California suggest instead a modest decrease in annual precipitation. More importantly, the runoff during the main growing season between April and September is expected to decrease dramatically, even for a given amount of precipitation. Relatively more precipitation will fall as rain, rather than snow, and runoff from a melting snowpack will occur earlier in the spring. Both changes will result in reduced availability of water when needed most, in the late spring and early summer.

What are the consequences of the changes in temperature and patterns of precipitation for the value of California farmland? We look at two climate-change scenarios developed by the Special Report on Emissions Scenarios for the Intergovernmental Panel on Climate Change (IPCC): B1, representing a low-emissions future characterized by rapid switches to non-fossil energy sources and greater energy efficiency, and A1, representing a world of rapid fossil-fuel intensive growth, with the introduction of new and more efficient technologies toward the end of the century.

Results for the two scenarios, using two different global climate models, are given in Table 2. The PCM, or Parallel Climate Model, is a low-sensitivity model developed in the United States by the National Center for Atmospheric Research and the U. S. Department of Energy. HadCM3, the U.K. Met Office Hadley Centre Climate Model, is a relatively high-sensitivity model, where sensitivity refers to the effect on global mean temperature resulting from a given change in the atmospheric concentration of greenhouse gases. The column "change in temperature" shows a projected impact on average annual temperature in California of one to three degrees Celsius toward the middle of the century, and two to eight degrees Celsius toward the end of the century. We translate these numbers to a projected change in degree days, which is then used with our regression equation (Table 1) to determine the impacts on farmland value per acre. This is shown in the column "impact on value per acre" in Table 2. Since the average per acre value of all observations in our sample is $4,177, the impact toward the end of the century in the ”business as usual” A1 scenario, $2,166, represents a loss of more than half the value, with correspondingly lower but still substantial losses in the near term and even under the low-sensitivity and low-emissions scenarios.

We also calculate the impact on farmland value of projected changes in surface-water deliveries. Here we need to be very tentative, since we do not (yet) have information on how deliveries will be affected at a disaggregated level, that is, at the level of the individual farm or irrigation district. We do, however, have a very recent estimate of the impact on the ability of the major California water projects, the Central Valley Project and the State Water Project, to deliver water to agricultural users in the major growing area, the Central Valley south of the Delta. Due to the changes in the volume and timing of runoff, toward the end of the century deliveries fall by 15 to 30 percent in the lower temperature scenarios and by 40 to 50 percent in the medium and higher temperature scenarios.

Assuming these numbers apply across districts and farms, and an average pre-warming level of water use of approximately two acre-feet per acre, and given our estimate in Table 1 of a capitalized value of the long-run availability of an acre-foot per acre of $656, we can calculate the impacts toward the end of the century on the value of an acre of farmland under each of the scenarios and each of the models. Thus we associate a reduction in deliveries of 15 percent with PCM/B1, 30 percent with PCM/A1, 40 percent with HadCM3/B1, and 50 percent with HadCM3/A1.

These reductions in turn imply losses in value per acre of $197, $394, $525, and $656, respectively. The losses are to be added to those due to the changes in temperature and degree days. For example, under the A1 scenario in the HadCM3 model, the impact on value due to the changes in both degree days and water availability would be $2166 + $656, or $2,822 per acre, which represents a loss of just over two-thirds of the current value. This is of course a ”worst case” outcome. On the other end of the range of outcomes is the impact associated with the B1 scenario and the PCM model: $336 due to the change in temperature/degree days, and $197 due to reduced water deliveries, for a total of $533 per acre, or about 13 percent of the current value.

It should be emphasized that none of these impacts are predictions of what California or the world will look like in, say 2085, the mid-point of the 2070-2099 period. Rather, they can be understood as estimates of impacts given a set of assumptions, such as, in the case of the A1 scenario, continued heavy use of fossil fuels and rapid growth over the next several decades. It may well be that the results of studies such as this one will have some influence on policymakers in the direction of greater reliance on alternative energy sources and improved energy efficiency, that is, in the direction of the B1 scenario.

For additional information, the author suggests the following sources:

Hayhoe, Katherine et al. “Emissions Pathways, Climate Change, and Impacts on California.” *Proceedings of the National Academy of Science,* Vol. 101, No. 34 (August, 2004), pp. 12422-12427.

Schlenker, Wolfram, Hanemann, W. Michael, and Fisher, Anthony C. “Water Availability, Degree Days, and the Potential Impact of Climate Change on Irrigated Agriculture in California.” *Climate Change,* forthcoming.

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________. “Will U.S. Agriculture Really Benefit from Global Warming? Accounting for Irrigation in the Hedonic Approach.” *The American Economic Review,* Vol. 95, No. 1 (March, 2005), pp. 395-406. Ê

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