**Title**

The Impact of Global Warming on Agriculture:  Rethinking the Ricardian Approach

**Permalink**

https://escholarship.org/uc/item/4bx3m5dj

**Authors**

Fisher, Anthony C.
Hanemann, W. Michael

**Publication Date**

1998-06-01

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS AND POLICY
DIVISION OF AGRICULTURE AND NATURAL RESOURCES
UNIVERSITY OF CALIFORNIA AT BERKELEY·

WORKING PAPER NO. 842

THE IMPACT OF GLOBAL WARMING ON AGRICULTURE:
RETHINKING THE RICARDIAN APPROACH

by

Anthony Fisher and Michael Hanemann

THE IMPACT OF GLOBAL WARMING ON AGRICULTURE:
RETHINKING THE RICARDIAN APPROACH

by

Anthony Fisher and Michael Hanemann
Department of Agricultural and Resource Economics
University of California at Berkeley

June, 1998

# THE IMPACT OF GLOBAL WARMING ON AGRICULTURE: RETHINKING THE RICARDIAN APPROACH

## 1. Introduction

Many studies of the impact of global warming focus on agriculture, possibly because key climate variables, such as temperature and precipitation, directly enter the production functions for agricultural commodities, and in an empirically important way. These studies typically develop carefully calibrated crop-yield models to determine the impacts on yields of changes in temperature and precipitation predicted by climate models. As Mendelsohn, Nordhaus, and Shaw (1994)—hereafter, MNS—suggest, however, this approach will tend to overestimate the damage from an impact since it does not allow for adjustment of the mix of inputs or outputs in response to the climate change. They develop instead an alternative, Ricardian, approach that allows for appropriate substitution responses by farmers. In fact, as they note, substitution can involve a shift out of agriculture into another activity better suited to the new environment. Damages are then measured most generally by the change in land value, where the new value is generated by the adjusted optimal use of the land. This seems to us a clear improvement, in principle, over simple crop-yield impact models, but in this paper we point out difficulties that can, if not adequately considered, lead to a substantial underestimate of damages. It is also worth noting that some of the crop-yield models do allow for substitution of crops, even for optimization with respect to cropping patterns, as a means of representing adaptation to climate change. These models may, however, still not be fully responsive to the MNS criticism, in that they do not consider other sectors and types of nonagricultural land use. Within the agricultural sector, the focus is

on imputed profits, using short-run, variable costs, rather than actual, measured profits including fixed costs and costs of financing. Finally, the analysis is heavily normative in flavor, focusing on what farmers ought to do, rather than on what they actually do, and what resulting profits and land values actually are.

In the next section a simplified specification of a model of hedonic property value is set out and used to interpret results of the estimation by MNS of the impact of cross-section differences in levels of precipitation on the value of agricultural land. Following this, in section 3, we consider the implications of the results for valuing damages from projected climate change, in particular from a change in patterns of precipitation. This second issue has been addressed also by Cline (1996), who comes to a similar conclusion—namely, that the Ricardian approach may lead to an underestimate of damages—although without the benefit of a theoretical framework of the sort we develop, that sheds light also on the meaning of the cross-section results. Section 4 concludes the paper with some further thoughts on the relationship between water and land value in California and the arid west.

## 2. Interpreting the Cross-Section Results: A Simple Model of the Impact of Precipitation on Farm Land Value

Like Cline, MNS do not develop an explicit, theoretical model of the impact of precipitation on farm land value. They do, however, present the results of cross-section regressions of land values, for each county in the U.S., for the year 1982, on a large set of independent variables, including soil and other physical characteristics of the land as well as temperature and precipitation variables. In the latter category are rainfall amounts for

January, April, July, and October. To test for nonlinearities, farm land value is regressed on both precipitation and precipitation squared, for each of these months. Separate regressions are run weighting county observations by the percentage of each county in cropland, and the aggregate value of crop revenue in each county, respectively. As MNS note, the cropland weights tend to emphasize the corn, wheat, and soybean belt, and the crop revenue weights are influenced more by the fruit and vegetable farms of coastal areas such as California.

In Table 1 we reproduce the results for the precipitation variables, under both weighting schemes. Before interpreting these results, let us ask what we might have expected to see. Presumably for January, and probably also for April, the relationship between precipitation and farm land value should be positive, to reflect the benefit of soil moisture during the planting period. More precisely, we might expect the coefficient on precipitation to be positive and a smaller coefficient on precipitation squared to be negative; more moisture is good, but not beyond some point. This is essentially what the results show. (The coefficient on precipitation squared for January is positive but not significant in the cropland regression.) The negative relationship between value and precipitation squared is stronger for April, but this too might be expected: Too much rain in April is more likely to interfere with planting.

Table 1 here.

The most interesting results, in our view, are for July. Again, we might have expected a positive coefficient on precipitation during the growing season and a smaller negative coefficient on precipitation squared. Instead, what we see is just the opposite: a

-3-

negative coefficient on precipitation and a positive coefficient on precipitation squared. For sufficiently low levels of precipitation, value *decreases* with increasing precipitation and, at higher levels, it increases. For example, July rainfall in most of California, including the agricultural areas, is close to zero. What these results tell us is that modest increases in mean precipitation amounts would have a negative effect on value. In the remainder of this section, we suggest an interpretation of these anomalous results. The interpretation depends on introducing a new variable that is crucially important in California and other arid and semi-arid growing regions: irrigation. The good news is that introducing irrigation leads to an explanation of the MNS results. The bad news, suggested in the next section, is that changes in the fiscal climate faced by large water resource development projects make the results less valuable as a guide to the impacts on farm land values of future changes in patterns of precipitation. Specifically, we shall suggest that the MNS estimates would understate the impact of climate change that leaves a region hotter and drier.

To understand the role played by irrigation, we consider a highly simplified, stripped-down version of the hedonic property value model, focusing only on the impact of water. Thus, let land value, v, depend only on water but from two sources: precipitation, w, and irrigation, I, as in

$$(1) \qquad\qquad v = f(w, I).$$

Now, we know that, empirically, installed water storage capacity in a region is negatively related to precipitation. Relatively dry areas, such as California's San Joaquin Valley, and the western states generally, have a great deal of installed capacity, whereas well watered

areas, such as those in the southern and eastern parts of the United States, have relatively little. Thus, we can write

(2)                                    $I = g(w)$, where $g'(w) < 0$.

Substituting from equation (2) into equation (1), we obtain

(3)                                    $v = f(w, g(w))$

or

(4)                                    $v = h(w)$

or, in the form of an estimated regression,

(5)                                    $v = a + bw + cw^2$.

As we have suggested, one would normally expect b, the estimated coefficient on water, in a simple regression like equation (5), to be positive, and c, the coefficient on water squared, to be negative —just the opposite of the MNS results. Then, we would have

(6)                                    $dv/dw = b + 2\, cw$.

From the estimated values for b and c in Table 1, for example for July, using the crop revenue weights, which better reflect California agriculture, and a value for July rainfall of $w = 0.01$ (inches), the average for the prime agricultural areas of the state,

$$dv/dw = -116 + 2(57)\,(.01) = -114.86.$$

In fact, the relationship between v and w from equation (6) will be negative for all values of w up to just over $w = 1$. This may not seem like much but, for most of California and other parts of the arid west, it would represent a very substantial increase over normal precipitation at that time of year.

We believe these findings can be explained by a closer look at equation (3). The total derivative of v with respect to w, dv/dw, is given by

$$(7) \qquad dv/dw = \partial f/\partial w + \partial f/\partial g \; g'(w),$$

where the partial relationship between irrigation and value, $\partial f/\partial g$, is assumed positive and the relationship between irrigation and precipitation in a region, $g'(w)$, is, as given in equation (2), negative. With these assumed relationships, the second term on the right-hand side of equation (7) is negative. Therefore, the estimated relationship between w and v, as in equation (6), is more likely to be negative.

The MNS procedure appears to implicitly assume that $\partial f/\partial g = 0$ since this is in fact the first-order condition for the choice of the optimal level of irrigation. That is, investment in irrigation is implicitly assumed to have been undertaken to the point where the marginal net benefit falls to zero. Then, by the envelope theorem, $dv/dw = \partial f/\partial w$; the total derivative of land value with respect to water, $dv/dw$, is just equal to the partial derivative with respect to precipitation, $\partial f/\partial w$. Irrigation has been "maximized out."

This approach would be fine in a competitive capital market. But the "market" for irrigation capital is far from competitive. It is well known that there is a substantial subsidy embodied in construction of water resource projects, reflected in a heavily subsidized price of irrigation water to agricultural users (Burness *et al.*, 1980, and Wahl,

1989). The subsidized price, in turn, creates an excess demand for irrigation water so that $\partial f/\partial g > 0$, irrigation is not maximized out, and the expression for $dv/dw$ is given by equation (7). The second term on the right-hand side comes back into the picture, and the estimated relationship between farm land value and precipitation, as given in equation (6), is more likely to be negative, as in the calculation following equation (6).

## 3. Implications for Valuing the Damages from Future Climate Change

For a variety of reasons, both economic and political, the fiscal environment surrounding large water projects in the United States has shifted dramatically from what it was when existing irrigation capacity was installed. The traditional approach to water management, which essentially means building dams and canals, is clearly under challenge. For the last two decades, there has been a marked decline in the willingness or ability of the federal government to subsidize the construction of new water projects, perhaps, in part, because costs have escalated for reasons we shall discuss. Legally, there has been a substantial shift, starting with the Mono Lake decision by the California Supreme Court in a 1983 upholding the use of the Public Trust doctrine to disrupt otherwise established rights to divert water for off-stream uses. This was reaffirmed and expanded in a 1986 Appeals Court decision (the Racanelli Decision) in United States *vs.* State Water Resources Control Board, which set aside the board's 1978 decision on water diversions from San Francisco Bay/Delta on the grounds that it gave insufficient attention to in-stream needs and was not based on a balancing of all needs within the basin, in-stream as well as off-stream. We should emphasize that we are not saying that the problems posed by climate change for water supply in California, and in the western United States

generally, are insoluble but rather that the costs of overcoming them could be very substantial. At a minimum, delays occasioned by the need to work decisions through the legal process, and, indeed, the larger collective choice process, has led to increases in capital costs (including the cost of delay) beyond those embodied in past projects—and a corresponding unwillingness on the part of the general taxpayer to bear these costs for the few sparsely populated regions that would benefit.

Even where there is no element of subsidy, and water is priced to recover fully historical costs, these are likely to be well below current or future costs. There is some evidence that the cost of public infrastructure has risen over time relative to other types of capital and relative to the prices of other goods and services because it involves relatively labor-intensive construction activity and because it has not experienced the same rate of technical progress as the supply of other goods and services.

Now, what are the implications for using the results of a regression of land values on precipitation based on data that reflect the past willingness to build large water projects, and the subsidies embodied in these projects, for assessment of the damages from future climate change? We have just argued that new irrigation projects, for regions that become hotter and drier, are not likely to be forthcoming, certainly not on the heavily subsidized basis that characterized past projects. Suppose no new irrigation is forthcoming. We can rewrite equation (7), multiplying both sides by dw, as

$$dv = \left[ \partial f / \partial w + \partial f / \partial g \ g'(w) \right] dw$$

or

$$(7') \qquad\qquad dv = \partial f / \partial w\ dw + \partial f / \partial g\ dI,$$

where $dI = g'(w)\ dw$. Then with $dI = 0$, the second term on the right-hand side of equations $(7')$ and $(7)$ vanishes, leaving $dv/dw = \partial f/\partial w$. The relationship between farm land value and precipitation estimated on the basis of past that reflect embodied subsidies will understate the impact of a future change in precipitation. Or suppose new irrigation will be available but at an unsubsidized rate. Indeed, suppose that the level of investment in irrigation is optimized, as we suggest is implicitly assumed in MNS, cutting out excess demand, and allowing the envelope theorem to hold, again resulting in $dv/dw = \partial f/\partial w$. Less dramatically, even if the subsidy is not cut out altogether, is merely reduced, and excess demand and $\partial f/\partial g$ are not driven all the way to zero, the importance of the second term on the right-hand side of equation (7) will be diminished, and the relationship estimated from past data will, once again, understate the impact of future changes.

The difficulty here stems from use of estimates heavily influenced by inclusion of data that reflect the historical pattern of irrigation subsidies to make projections for periods, and regions, that will not experience the same subsidies. What this suggests is that it might be preferable to estimate the relationship between farm land value and precipitation on the basis of data from counties whose agriculture is not primarily dependent on irrigation. Then, we could have greater confidence in use of the results to make projections of the impact of future climate change in these regions.

## 4. The Relationship between Water and Land Value in the Arid West: Concluding Thoughts

We have suggested that proper accounting for an omitted variable—irrigation—in the cross-section regressions relating agricultural land value to precipitation can lead to a plausible interpretation of results that seem to indicate that value is negatively related to precipitation during the growing season. Due to subsidized pricing of irrigation water, irrigation is not maximized out of the system, the envelope theorem cannot be assumed to hold, and the estimated simple relationship between precipitation and land value can, indeed, be negative even though additional water would be beneficial to agriculture. Further, taking into account the dramatic difference in the fiscal climate: The drying up of subsidies for increasingly expensive regional water projects, we suggest that the negative relationship between precipitation and land value estimated on the basis of past data may not be predictive of future impacts. As some regions become hotter and drier, the value of the affected agricultural land is likely to be reduced, not increased.

The significance of this conjecture derives from a fundamental fact about the way water is used in agriculture in arid lands generally, including the western United States, and, of course, California, the most important agricultural state. There is minimal precipitation during the growing season in these regions; hence, farmers rely on pumped groundwater or stored surface water. The latter is supplied by a variety of agencies, including local irrigation districts, state water projects, and the federal government operating through the Bureau of Reclamation and the Army Corps of Engineers. Consequently, the primary effects of change in climate on the agricultural economy in these regions are not changes in soil moisture at the beginning of the growing season

and/or precipitation occurring during the growing season but rather the change in the amount of stored surface water available to be delivered to farmers during the growing season. This weakens the link between measures of precipitation during the growing season and agricultural land value.

A useful focus for future research—which we are currently undertaking—would then seem to be analysis of the operation of the major surface water storage and delivery systems in the affected region and the impact of climate change on these.

# References

Burness, H.S., Cummings, R.G., Gorman, W.D., and Lansford, R.R. "United States Reclamation Policy and Indian Water Rights." *Natural Resources Journal*, Vol. 20 (1980), pp. 807-826.

Cline, William R. "The Impact of Global Warming on Agriculture: Comment." *American Economic Review*, Vol. 86, No. 5 (1996), pp. 1309-1311.

Mendelsohn, Robert, Nordhaus, William D., and Shaw, Daigee. "The Impact of Global Warming on Agriculture: A Ricardian Analysis." *American Economic Review*, Vol. 84, No. 4 (1994), pp. 753-771.

Wahl, Richard W. *Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation*. Washington, D.C.: Resources for the Future, 1989.

## TABLE 1

### Coefficients in Regressions of Farm Land Value on Precipitation

|                     | Cropland weights | Crop revenue weights |
|---------------------|:----------------:|:--------------------:|
| January rain        | 85.0<br>(3.88)*  | 280<br>(9.59)        |
| January rain squared| 2.73<br>(0.95)   | -10.8<br>(3.64)      |
| April rain          | 104<br>(4.44)    | 82.8<br>(2.34)       |
| April rain squared  | -16.5<br>(1.96)  | -62.1<br>(5.52)      |
| July rain           | -34.5<br>(2.63)  | -116<br>(6.06)       |
| July rain squared   | 52.0<br>(9.43)   | 57.0<br>(8.20)       |
| October rain        | -50.3<br>(2.25)  | -124<br>(3.80)       |
| October rain squared| 2.28<br>(0.17)   | 171<br>(14.17)       |

*Values in parentheses are t statistics.

Source: Mendelsohn, Nordhaus, and Shaw (1994), p. 760.