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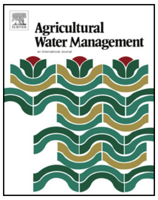

Where's the salt? A spatial hedonic analysis of the value of groundwater to irrigated agriculture

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ABSTRACT

Groundwater provides many valuable services to society, especially as a source of irrigation water. However, over-extraction and degradation threaten the ability of many groundwater systems to continue to provide such valuable services to society. As governments consider the costs and potential policy adjustments to address this issue, information on the benefits of maintaining these resources, or the damages associated with further degradation, can be helpful. Reported results from hedonic methods that have estimated the potential benefits of groundwater to irrigated agriculture, though, are rather mixed. While there are a number of reasons such disparities might arise across studies, a significant factor may be related to the quality of the groundwater, a somewhat surprisingly overlooked factor in these studies. The objective of this paper is to highlight the role of groundwater quality, and in particular salinity, in influencing the estimated value of groundwater to irrigated agriculture, using the hedonic valuation approach. Using a rich data set of parcel-level characteristics and market values for irrigated agricultural land located in California's Central Valley — an irrigation-intensive region with significant heterogeneity in both groundwater depth and salinity — we find that failure to include salinity as an argument explaining land values can lead to poor assessments as to the marginal value of the groundwater. Furthermore, we highlight the importance of accounting for the non-separability between groundwater depth, groundwater quality, and land values by showing how the marginal value of changes in groundwater and salinity are influenced by one another. Damages associated with projected increases in groundwater salinity by the year 2030 are estimated also.

1. Introduction

Groundwater constitutes a major part of the world's irrigation supply, with approximately 40% of the global irrigated area equipped with irrigation infrastructure relying on groundwater (Siebert et al., 2010). As pointed out by Tsur and Graham-Tomasi (1991), groundwater provides multiple services to irrigated agriculture, including as a primary and perhaps sole source of water supply in some instances, and as a secondary source, or "buffer," in others. Unfortunately, over-extraction and degradation of groundwater systems threaten their ability to continue to provide such valuable services to society. Between 1960 and 2000, for instance, annual extraction of groundwater resources more than doubled, from 126 to 284 km^3 in semi-humid to arid regions (Wada et al., 2010). Salinity and poor groundwater water supply conditions, meanwhile, affect between 15% and 36% of irrigated lands worldwide. With a future comprised of rising populations, potentially more variable and lower water supplies due to climate change, and more intensively farmed land, the sustainability of groundwater systems is a significant concern in many regions globally. This has motivated a number of studies to investigate issues affecting water use efficiency in agriculture (Adamson and Loch, 2014). Indeed, further groundwater degradation and overdraft will likely lead to losses of large tracts of prime farmland, such as is happening in California's Central Valley, with consequent impacts on food supplies, employment, and income.

In response to these challenges, numerous studies have estimated the economic impact of changes in groundwater supplies on irrigated agricultural sustainability using hedonic methods (Hartman and Taylor, 1989; Torell et al., 1990; Bjornlund, 1995; Faux and Perry, 1999; Mendelsohn and Dinar, 2003; Stage and Williams, 2003; Schlenker et al., 2007; Brozovic and Islam, 2010; Hornbeck and Keskin, 2011) and programming approaches (Dinar and Knapp, 1986; Provencher, 1993; Knapp et al., 2003; Characklis et al., 2005; Knapp and Baerenklau, 2006; Palazzo and Brozovic, 2014). The motivation behind many of these studies is to identify the potential losses from continued over-extraction of groundwater systems, or the benefits of maintaining them, so as to better

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inform policy and perhaps justify alternative management strategies or potentially costly mitigative measures.[1] Efforts to justify such costly measures by relying on estimates from the hedonic literature, though, might prove difficult given the mixed results from such studies.[2] Hartman and Taylor (1989), for instance, find a statistically insignificant relationship between groundwater and farmland values while Torell et al. (1990) find a positive effect. Neither Mendelsohn and Dinar (2003) nor Schlenker et al. (2007) find statistically significant signs on their groundwater variables, yet Stage and Williams (2003) and Hornbeck and Keskin (2011) find positive and statistically significant relationships.

While there are a number of reasons the findings from hedonic valuation studies might give such disparate results for the value and statistical significance of groundwater, including differences in location and whether one is measuring changes in the depth, access to groundwater, or other characteristics of groundwater (e.g., volume of water in the aquifer, fraction of land over the aquifer), such differences may also arise due to the quality of the groundwater.[3] The main objective of this paper, then, is to highlight the importance of accounting for quality when estimating the value of groundwater to irrigated agriculture. Using a rich geospatial data set that includes actual sales data on approximately 700 agricultural parcels in the Central Valley, California (Fig. 1), we illustrate how the value of groundwater can differ greatly depending upon its depth *and* salinity. Our results even show that close proximity to a groundwater table can lower land values if there are limited drainage opportunities available to growers and the groundwater is moderately saline. This information could be useful for better water management and planning within the Central Valley, especially since groundwater accounts for approximately 30% of the region's applied water on average, and 60% during drought years (Dale et al., 2013). As such, access to alternative sources of water supply, increases in surface water allocation, or investment in salinity and drainage mitigation programs could be prioritized for the regions within Central Valley where we find higher damages from groundwater salinity and drainage limitations.

As a secondary objective, we then use our model to estimate the damages to irrigated agricultural land values from projected increases in groundwater salinization. Elevated salinity in groundwater is an increasing problem confronting many regions throughout the world. In California's Central Valley, the State Water Resources Control Board and the Central Valley Regional Water Quality Control Board are initiating efforts to address this problem and are considering a variety of long-term solutions. To provide planners information on the potential impacts of salinity increases, we estimate the impacts on agricultural land values using projected increases in groundwater salinity by 2030 as reported in Schoups et al. (2006). Such estimates can be useful to regional and state agencies as they look to justify costly groundwater salinity management plans.

2. Literature review

A number of studies have estimated the value of surface water in irrigation using hedonic methods (Faux and Perry, 1999; Mendelsohn and Dinar, 2003; Schlenker et al., 2007). A consistent finding across these studies is a positive and statistically significant relationship between surface water access (and use) and some measure of farmland value. Somewhat perplexing, then, are the mixed findings from hedonic studies that have estimated the value of groundwater to agriculture (Stage and Williams, 2003; Hornbeck and Keskin, 2011; Schlenker et al., 2007; Brozovic and Islam, 2010). Hartman and Taylor (1989), for instance, find a statistically insignificant relationship between groundwater and farmland values, while Torell et al. (1990) find a positive effect. Neither Mendelsohn and Dinar (2003) nor Schlenker et al. (2007) find statistically significant signs on their groundwater variables, yet both Stage and Williams (2003) and Hornbeck and Keskin (2011) find positive and statistically significant relationships.

Table 1 provides some clarity as to why we might not expect there to be much consistency associated with the estimated results surrounding the value of groundwater to irrigated agriculture. First, the geographic differences, which span from the southwest to the southern cornbelt in the United States to different countries, are most certainly associated with different levels of water scarcity and marginal productivities. For instance, Sunderland et al. (1987) and Torell et al. (1990) investigate the impact of the Ogallala aquifer on irrigated agricultural land values using the same two groundwater variables (i.e., groundwater depth and volume of water in the aquifer). Sunderland et al. focus their analysis on New Mexico and find no statistically significant relationship between groundwater and land values, while Torell et al. expand their analysis to include other states with farmland situated above the aquifer and find that the amount of water in the aquifer does have a statistically significant impact on farm values. Second, the significance of groundwater may depend on the definition of the dependent variable and the unit of analysis. As shown in Table 1, the dependent variable definition ranges from assessed values, grower-reported values, and sales prices, while the unit of analysis is sometimes at the county level, but more often at the farm level.

Third, we see that the definition of the groundwater variable varies quite significantly. Some studies focus on groundwater characteristics like groundwater withdrawal, saturated thickness of the aquifer, and fraction of land over the groundwater aquifer. Alternatively, some studies use access to groundwater, while others use depth to the groundwater table. Studies such as Hartman and Taylor (1989), for instance, focus on saturated thickness of the aquifer and find that it does not have any impact on agricultural land values in Colorado. As mentioned above, Sunderland et al. (1987) and Torell et al. (1990) focus both on the amount of water in the aquifer and depth in meters to the aquifer. Hornbeck and Keskin (2011), meanwhile, use information on the fraction of a county's area overlaying the Ogallala aquifer as a measure of access to groundwater. They find that groundwater — defined in this manner — has a positive and statistically significant impact on farmland values. Stage and Williams (2003) also find a positive and statistically significant impact of groundwater on farm sales price in Namibia, yet their groundwater variable is measured as total groundwater yield per hectare.

Mendelsohn and Dinar (2003), who investigate the impacts of climate change on irrigated agriculture in California, do not find any relationship between groundwater withdrawal and reported land values per hectare. The authors ultimately drop the groundwater variable from their analysis, suggesting that its insignificance is likely due to endogeneity or that it is collinear with local climate. In addition to Sunderland et al. (1987) and Torell et al. (1990), Schlenker et al. (2007) and Brozovic and Islam (2010) define their

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[1] Alternatively, many of these studies are investigating the impacts of changing water supply conditions due to increasing water scarcity, environmental restrictions, or climate change.

[2] While there have been a number of studies that have used programming approaches to study the impact of groundwater and groundwater salinity on farm profits, crop yields, and regional net benefits, there also is a significant literature using a hedonic approach to evaluate the impacts of changes in water supplies, including groundwater, and climate on agriculture (Deschenes and Greenstone, 2004). We focus on these latter studies, given their prominence in the literature and the debate surrounding the impact of changes in water supply characteristics.

[3] Bjornlund (1995) found, using two-way correlations, groundwater salinity to be negatively correlated with land prices. The groundwater salinity variable, however, was not included in his hedonic model, as it was not found to be statistically significant, an outcome the author suggests might be related to farmers possibly not fully accepting the consequences of increasing salinity.

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