AN ABSTRACT OF THE THESIS OF

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Abstract approved:

Penelope L. Diebel

The recent 2013 Oregon State Board of Agriculture report identified several ways to improve agricultural income in Oregon. Recommendations to improve water development are at the top of the report's list of objectives. In this study, I analyze the relationship between net cash farm income (NCFI) and a cross-sectional set of climate, production, and water policy variables for an eleven western state region and a four-state subset representing the Pacific Northwest region. County-level farm data from 2007 are used. The results indicate that agricultural water use and policy strongly influence county NCFI. Contributions to income from climate and production characteristics are also considerable but differ depending on the study region. Although the results confirm the positive relationship between NCFI and water development, new projects face a difficult regulatory environment and uncertain access to water.

Net Farm Income and the Role of Water Development Projects

by
William J. Anderson

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APPROVED:

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Director of the Applied Economics Graduate Program

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

William J. Anderson, Author

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DEDICATION

I would like to dedicate this thesis to my friends and family, who helped me push forward. Thank you.

Net Farm Income and the Role of Water Development Projects

Chapter I: Introduction

I.A: Western Agriculture and Water

Water is a critical input to agricultural production and inextricably linked to farm income. In the arid and semiarid lands that are integral to agricultural productivity in the Western United States (from here, the West), precipitation and agricultural water demands occur at different time intervals. Stream flows tend to be highest in the winter months, while crop demand occurs primarily in the spring and summer months. This disparity between water availability and agricultural need is one of the most significant threats to western agricultural success (USOTA 1983). In this region, where growing season precipitation is low, supplemental water application to sustain crop growth is necessary.

In the twentieth century, the U.S. population expanded westward and began densely populating areas defined by wet winters and hot, dry summers, resulting in increased competition for water resources. Competition primarily between agriculture and domestic uses helps to characterize water as an increasingly scarce resource in the West (USOTA 1983; Green and Sunding 1997).

I.B: The United States Bureau of Reclamation

Within the western appropriative allocation system, in part summarized by the phrase "first in time, first in right," the United States Bureau of Reclamation (USBOR) emerged in the beginning of the twentieth century to provide oversight of water diversion, delivery and storage projects (Gopalakrishnan 1973, 63). Today, the USBOR continues to have a significant influence on western water resource management, providing one in five farmers with irrigation water and generating substantial hydroelectric power (USBOR 2013).

Since its inception, the USBOR has guided water development, policy, and provision in the seventeen states west of the Mississippi River. As the nation's largest irrigation water supplier and a federal agency within the U.S. Department of the Interior, the USBOR has evolved over the years alongside changes in agriculture, water, and environmental policy. With its establishment in 1902 by the Reclamation Act, the USBOR historically promoted "sustainable western settlement through development of the West's rivers for irrigated agriculture" (Moore 1991, 145). The agency encouraged settlement by subsidizing the water supply, through the elimination of construction cost interest payments from water project repayment (Sax 1965; Burness et al. 1980). Additional legislation created a second subsidy, which charged irrigation users based on their "ability to pay" (Sax 1965). In application, the "ability to pay" principle defined the method for calculating repayment capacity and provided the USBOR with flexibility in spreading multiple-purpose project costs across different user groups (Kananzawa 1993). Specifically, ability to pay "assesses the financial capability of an irrigation district to pay for existing or increased Reclamation water charges and services" and is defined as "the farm-level payment capacity aggregated to the entire district, minus district existing obligations, operation and maintenance costs, power costs, and reserve fund requirements (USBOR 2004, 2). These two payment principles disconnected Reclamation water prices from the true long-run cost of water infrastructure construction (Moore 1991).

With subsidies in place to defray full water costs, the USBOR expanded water available to agriculture. By 1987, the agency had constructed "355 water storage reservoirs, 254 diversion dams, and over 50,000 miles of conveyance canals, pipelines, tunnels and laterals," with additional USBOR services including "annual irrigation water delivery to roughly 10 million acres of cropland; municipal and industrial water service to over 22 million people; hydroelectric generating capacity of 50 power plants; and 286 river- and reservoir-based recreation areas" (Moore 1991, 145). Today, the USBOR estimates that 140,000 farmers receive USBOR water, producing some 25% of U.S. fruit and nut crops and 60% of the nation's vegetables (USBOR 2013).

More recently, the USBOR has reshaped its management policy beyond development to accommodate multiple resource uses. Whereas the USBOR initially focused on water development, the agency has increasingly given credence to water conservation projects. In regard to these water policy adjustments, as most recently highlighted in Oregon's Klamath Basin, where Native American water interests were granted seniority over farms irrigating pasture, agricultural incomes could change in the face of limited water availability. In 2001, when irrigation deliveries were curtailed in the Klamath Basin Project, the estimated cost to farmers was over $35 million (Jaeger 2004).

Although there is a rich literature on the USBOR and its influence and development within western agriculture, it is confined mostly to subsidy impacts, allocation improvements and how water source affects irrigation production decisions. Largely absent from this literature is an inquiry into how USBOR water affects net farm income and how income will change to adjustments in federal USBOR water policy.

I.C: Study Region

Water Development in the Pacific Northwest

Recent recommendations from the Oregon 2013 State of the Agriculture Industry Board of Agriculture Report highlight the need to find "creative ways to conserve, capture and make available more irrigation water" as the first policy action that will bolster agricultural economic growth and thus net farm income (OSBA 2013, 12). However, I hypothesize that this recommendation would be enhanced by acknowledging county level heterogeneity in factors affecting agriculture, including soil quality, precipitation, temperature, irrigation use and crop choice. An extended examination of this policy action is required to fully understand the magnitude by which USBOR water affects agricultural income.

This study considers how access to USBOR water and other factors affect net farm income in eleven contiguous U.S. states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming (Figure 1.1). These factors are then analyzed solely for a Pacific Northwest region, defined here as Idaho, Montana, Oregon and Washington. Each of these states is home to numerous

USBOR projects, dams, and power plants situated along river networks (Figure 1.2).

Individual farm operations draw water from these larger projects (Table 1.1).

Table 1.1 The 2007 Census of Agriculture Number of Farm Operations Receiving Water from the USBOR (USDA 2009).

State	Farm Operations (No.)
Arizona	893
California	9500
Colorado	4003
Idaho	6946
Montana	2830
Nevada	510
New Mexico	3076
Oregon	3799
Utah	3439
Washington	5639
Wyoming	1991

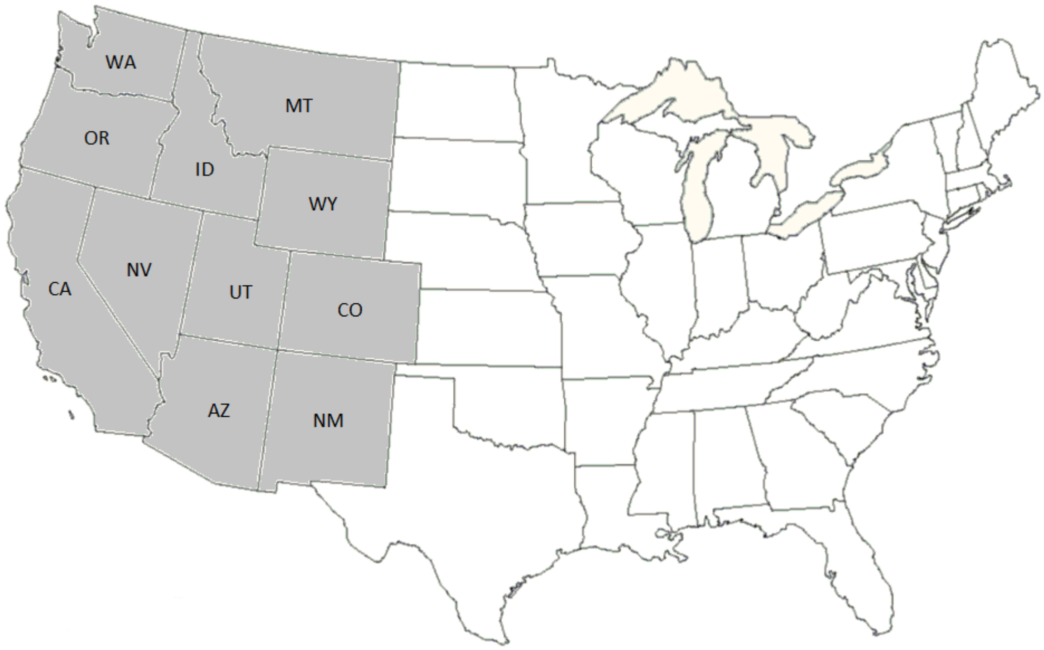

Figure 1.1 Map of Study Region Highlighted in Gray

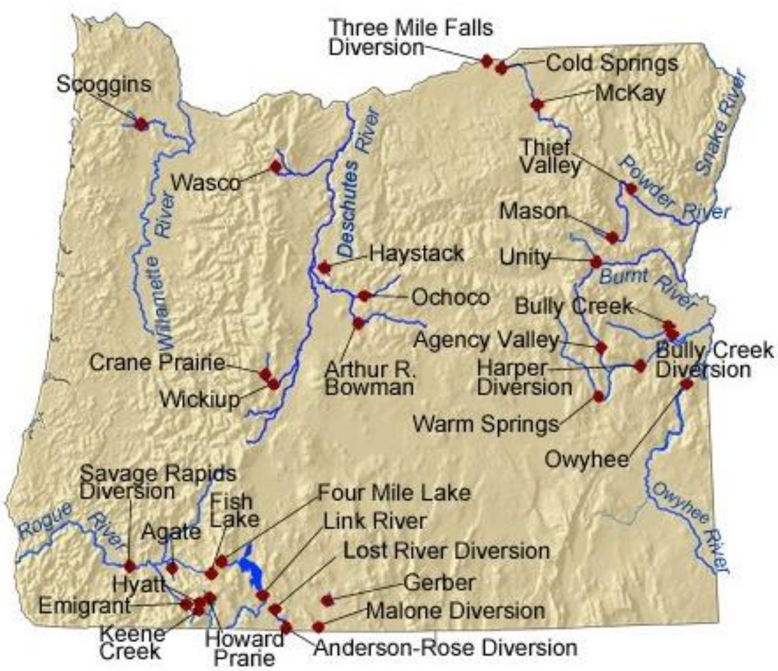

Figure 1.2 Map of USBOR Dams in Oregon (USBOR 2007).

Physical Characteristics

Geographically, this eleven-state territory is heavily defined by mountain ranges that span the western U.S. and influence each state's precipitation and temperature ranges. On the West coast, the Oregon Coast Range and California Coast Range border the Pacific Ocean, as does California's Sierra Nevada range. The Cascade Range is located from northern Washington through to northern California. The Rocky Mountain Range extends from western Canada to New Mexico. As depicted in Figure 1.3, California's Central Valley stands out as a large, low-lying expanse in contrast to Colorado's generally rugged landscape.

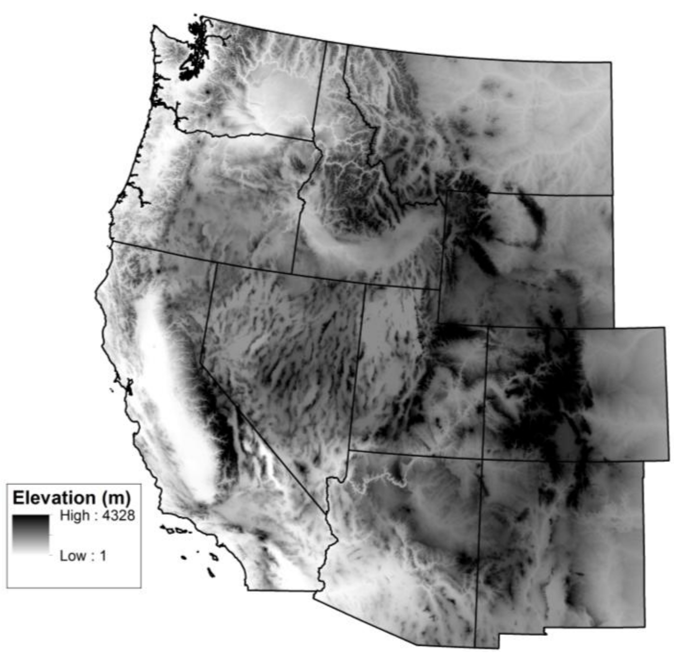

Figure 1.3 Elevation Profile Across Study Region (USGS 1996).

Temperature

The coastal regions in Washington, Oregon, and California support higher average minimum temperatures than the majority of the western study region, with California's Central Valley and southern portion, and Arizona as the exceptions (Figure 1.4). These latter regions boast higher average annual maximum temperatures as well (Figure 1.5).

Precipitation

Washington and Oregon coastal regions receive substantial rainfall in comparison to the majority of the study area (Figure 1.6). However, this precipitation occurs primarily during the winter months and not in the summertime, when crop water requirements are highest.

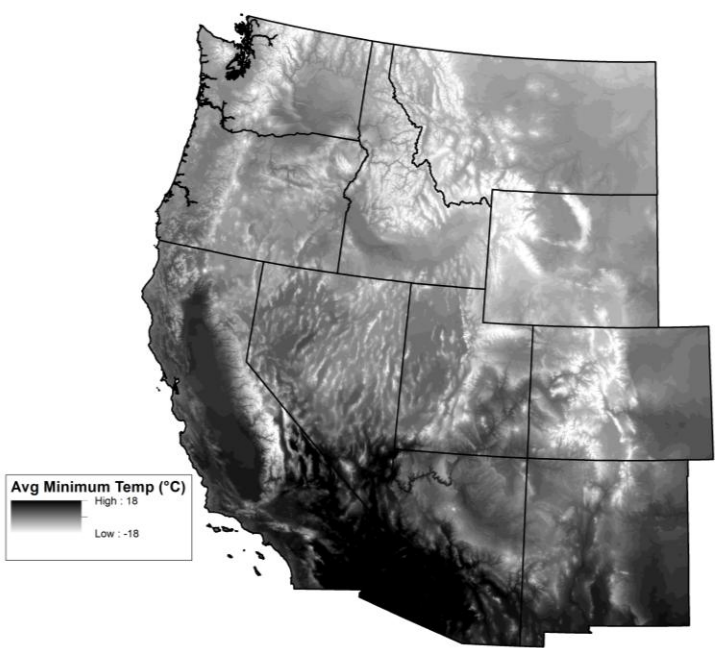

Figure 1.4 Average Annual Minimum Temperature Across Case Study Region, 1981 – 2010 (OSU 2007).

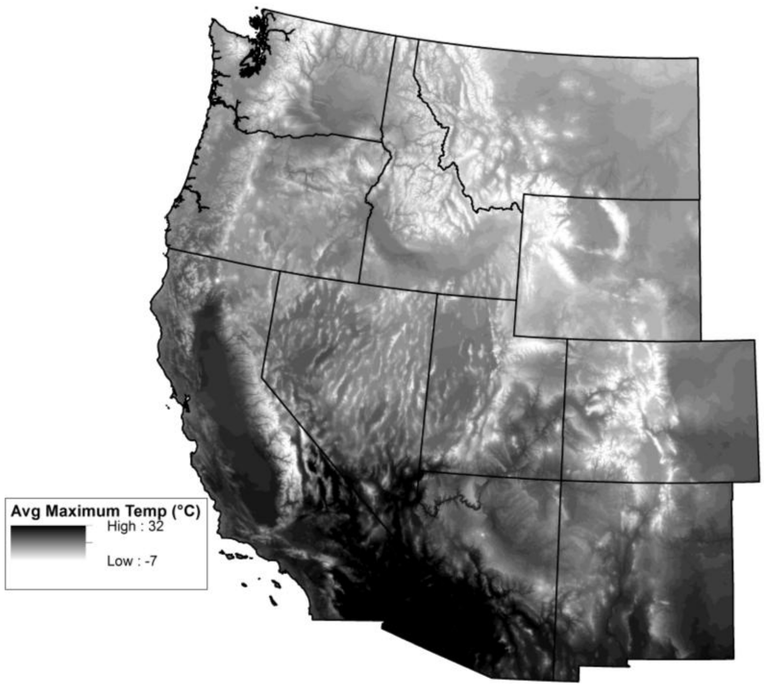

Figure 1.5 Average Annual Maximum Temperature Across Case Study Region, 1981 – 2010 (OSU 2007).

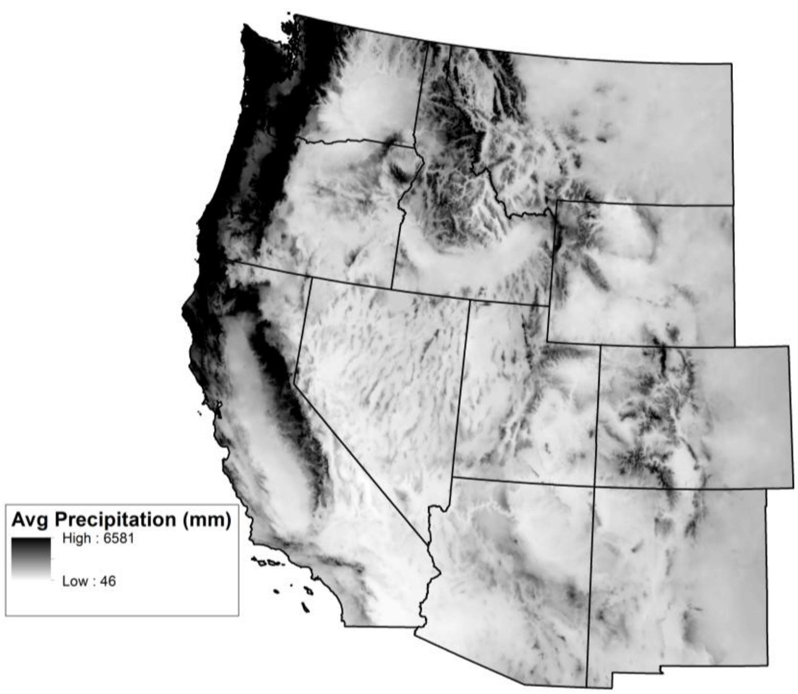

Figure 1.6 Average Precipitation Across Case Study Region, 1981 – 2010 (OSU 2007).

Agriculture

The study region is agriculturally diverse (Table 1.2). Although California has less land allocated in farm acreage compared to other states, it has the highest number of farm operations and an aggregate market value of sold agricultural products greater than the other ten states combined. In contrast, Nevada has the fewest farms, least land in farms, and lowest market value of sold agricultural products but has the fourth-highest average net cash farm income. Although Oregon and Washington have similar numbers of farms and land in farms, Washington outpaces Oregon in agricultural product market value and has an average net cash farm income of almost twice that of Oregon. Utah has the lowest average net cash farm income at $15,533 per operation.

Table 1.2 The 2007 Census of Agriculture Study Region Farm Statistics (USDA 2009).

State	Farms	Land in Farms (acres)	Market Value of Agricultural Products Sold ($1,000)	Net Cash Farm Income of Operation (Average per Farm)($)
Arizona	15,637	26,117,899	3,234,552	37,344
California	81,033	25,364,695	33,885,064	98,518
Colorado	37,054	31,604,911	6,061,134	26,149
Idaho	25,349	11,497,383	5,688,765	53,720
Montana	29,524	61,388,462	2,803,062	28,016
Nevada	3,131	5,865,392	513,269	40,138
New Mexico	20,930	43,238,049	2,175,080	17,558
Oregon	38,553	16,399,647	4,386,143	23,441
Utah	16,700	11,094,700	1,415,678	15,533
Washington	39,284	14,972,789	6,792,856	45,454
Wyoming	11,069	30,169,526	1,157,535	24,909

I.D: Thesis Summary

Net cash farm income is theorized to be a function of water development policy, geophysical, demographic and production variables. Specifically, this study seeks to explain how access to USBOR water influences net agricultural producer income at the county level. I will provide an econometric analysis of cross-sectional data from eleven western states for the year 2007. The USBOR project variable was not available until the 2007 Census of Agriculture. By controlling for agricultural land characteristics and county demographics, I attempt to examine the ceteris paribus effect of USBOR-provided water as well as other production factors, including soil quality, temperature, precipitation, irrigation source, and crop choice. Study results can provide policy makers with more information about net farm income determinants and how altering water policy without considering other factors might affect county aggregate agricultural income.

A literature review is provided in Chapter II, with an emphasis on the motivation and theoretical justification for the model presented in this paper. In this discussion, the model is linked to the economic theory of derived demand and the "fertility of land" that Alfred Marshall first wrote about in his 1890 seminal work, *Principles of Economics*. Following this discussion is an overview of existing net farm income models. Chapter III examines net cash farm income and its determinants. In this chapter, I review how I collected, organized, and/or manipulated the data for the model. Chapter IV reports the model results and interprets their significance. Chapter V concludes the thesis with a broad discussion of the policy implications underlying the model, emphasizing the assumptions, data limitations, and future research directions.

Chapter II: Literature Review

Here, I examine the USBOR within the context of the environmental and natural resource economics literature and discuss where this study fits in among previous work. From there, I present relevant economic theory to help motivate the models presented in Chapter III. The review concludes with summaries of related studies that analyze farm success through net farm income or other closely related measures.

II.A: U.S. Bureau of Reclamation and Study Motivation

As outlined in the introduction, the USBOR has influenced production decisions in western agriculture. Moore and Negri (1992) found that market prices for three major crops irrigated by USBOR water would likely change 0.8% to 4.6% from restrictions in the available water supply. Conducting a microeconomic analysis by modeling firm behavior with multicrop profit functions, the authors analyzed mandatory conservation policy action applied to the USBOR water supply in its six defined production regions, which encompass the entire seventeen western states. Their simulation reduced the available water supply 10% and showed positive price effects on rice and vegetables and negative price effects for fruit and nut prices.

In earlier work, Moore (1991) discussed the two pricing subsidies motivating USBOR water acquisition: zero-interest payments on construction cost repayment and per-unit water charges priced at the user's "ability to pay". From provisions of the 1939 Reclamation Act, the "ability to pay" derived a formula for calculating project repayment capacity and limited irrigators' financial obligations to their share of project costs. It further stipulated that costs beyond "ability to pay" could come from other project revenue sources, mostly from electrical power generation (Young 1978). The USBOR's pricing policy, controversial among economists for its assumed departure from economic efficiency, shielded farmers from the water's true cost (Kanazawa 1993). As a result, western water users have been encouraged to overuse water. Kanazawa cites the three commonly discussed consequences stemming from this pricing policy, including overly water-intensive production decisions, too much farm entry into the agricultural sector and farmers incentivized to apply political pressure to secure additional projects (1993).

Building upon this work, Moore (1999) employed an econometric approach, in contrast to the traditional farm budget study, to estimate both irrigator profit and "ability to pay". Moore's model utilized indirect profit functions to estimate water shadow prices, or the revenue generated from an additional acre-foot of water applied. These shadow prices were previously believed to proxy for the "ability to pay" numbers derived from the conventional budget approach. However, Moore found the shadow price estimates for California multi-output farms to be greater than previously generated "ability to pay" values. This result seems to suggest that irrigators would be willing to pay more to get the same water quantity and further, that they would also tend to irrigate more since USBOR water is subsidized.

In considering how water source (e.g. USBOR, Army Corp of Engineers, private well, etc.) influences agricultural production decisions, Olen et al. (2012) found evidence that individual farmers using government supplied water irrigated their land more extensively and intensively. Using individual farm-level data for 1,461 West Coast farms, the authors found that irrigators receiving federally subsidized water irrigated a higher proportion of land and used a greater application rate (e.g. acre-foot water) than those without federal water. This dual result suggests that irrigation water source unequivocally factors into farm-level production choices, ultimately impacting producer net farm income, the focus of this study.

Paralleling these results, Ward and Velazquez (2008) found that water conservation subsidies for irrigation technology could actually increase water use rather than mitigate it. Using a hydro-economic optimization model for the Upper Rio Grande Basin with several agronomic, water and environmental policy constraints, the authors varied potential subsidy rates to farmers and found that increasing subsidies reduced water applied to agricultural lands but increased overall use due to “depletion”, where diverted and applied water cannot return to a hydrological basin. Additionally, the authors concluded that increased water efficiency often causes private irrigators to expand current production acres or to switch to more water-intensive crops. Along with higher subsidy levels, the authors predicted that net farm incomes in the basin area would increase due to the subsidy but also from higher yields related to drip irrigation practices. These results provide further confirmation of water subsidy effects both on water use and income.

More recent work by Pfeiffer and Lin (2010) showed that irrigation technology subsidies from the Environmental Incentives Quality Program (EQIP) increased groundwater extraction by altering cropping patterns. Using an empirical approach for

Western Kansas, where groundwater is extracted from the Ogallala Aquifer, the authors combined aquifer hydrological characteristics with advanced groundwater well level data. They modeled farmers' extraction decisions and found strong evidence indicating that adoption of more efficient irrigation systems increases groundwater removal via changing cropping patterns or expanding irrigated acreage. These two studies, Pfeiffer and Lin (2010) and Ward and Velazquez (2008), confirm that subsidized water (via technology payments) affects irrigation production decisions.

Investigation into net farm income determinants, including the effect from the USBOR, is a natural extension from the existing literature (Figure 2.1). Thus far, studies have analyzed government programs and agencies and how agriculture is subsidized in terms of water (Moore 1991; Ward and Velazquez 2008; Pfeiffer and Lin 2010). Moore (1999) further showed the depth of the USBOR "ability to pay" subsidy. The presence of subsidized water causes changes in irrigation practices. Olen et al. (2012) found that irrigators supplied by a federal agency (i.e., USBOR) irrigated a higher proportion of agricultural land and applied more water. In the case of EQIP, research has demonstrated that the program has led to expanded irrigated acreage and/or cropping pattern changes (Ward and Velazquez 2008; Pfeiffer and Lin 2010). In some instances, research has identified net farm income impacts linked to the subsidies (Ward and Velazquez 2008). In the case of the USBOR, this final linkage remains unexplored largely in the empirical literature. By disaggregating income into factors considered to be critical determinants of farm income, this study seeks to identify how the number of farms irrigating with USBOR water impacts net farm income and its magnitude in relation to other important deterministic factors (e.g., production factors). The results of the study are interpreted in the context of land use regulations and environmental policy.

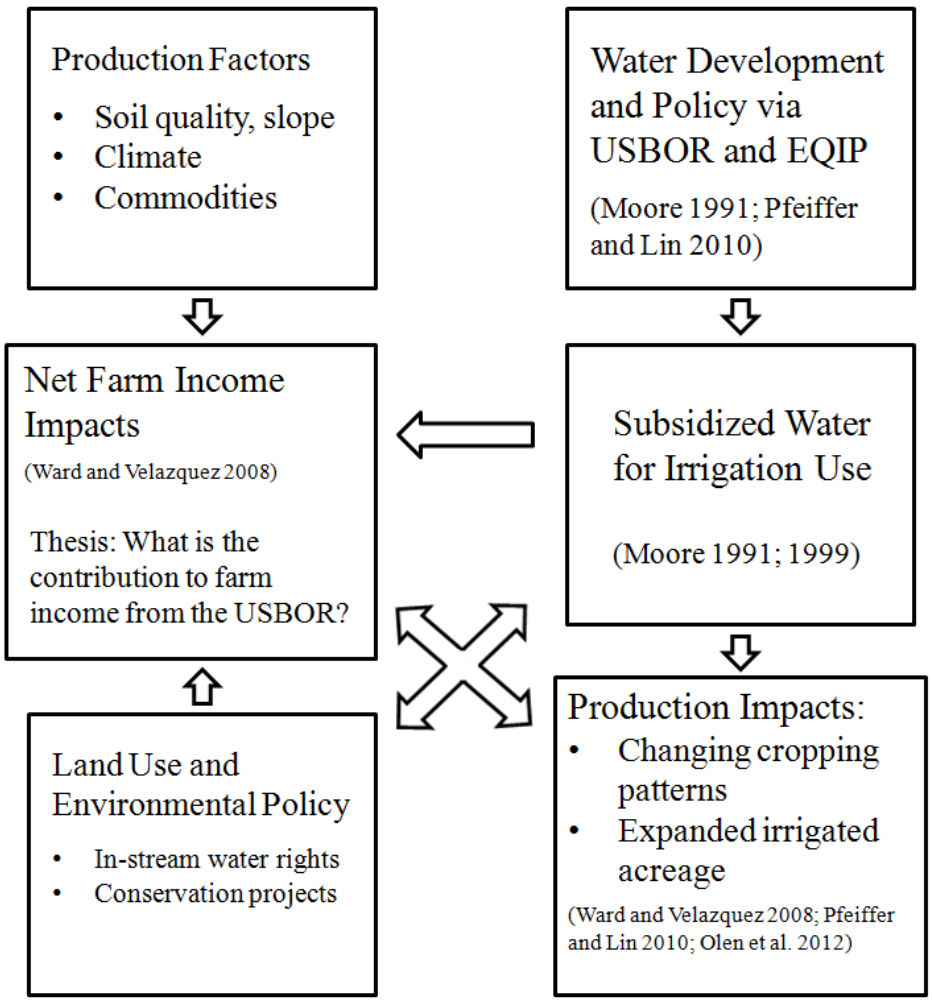

Figure 2.1 Flow Chart of Existing Literature

II.B: Economic Theory

Economics has long scrutinized land, a resource and production factor with an inherently fixed supply. In particular, economists have long studied land "rents," which describe payments related to land ownership. David Ricardo considered rent payments for agricultural land and discussed differences in rent due to the "original and indestructible powers of the soil" and capital invested (Ricardo 1821, 39). For areas with similar "powers of the soil," differences in rent payments may reflect capital invested. Although land rents are not modeled in this study, I model farm income and control for physical characteristics to try and capture contributions to income from public and/or invested capital (e.g., water infrastructure, EQIP).

Marshall also provides further justification into this inquiry from an agricultural production standpoint. In Book IV on "The Agents of Production," he discusses land, labor and capital, the classic production agents. Specifically, in "The Fertility of the Land," Marshall establishes an economic framework to view the production agents, including "the original or inherent properties, which the land derives from nature, and the artificial properties which it owes to human action" (Marshall 1890, 90). The *inherent* properties result from the fact that "Every acre has given to it by nature an annual income of heat and light, of air and moisture; and over these man has but little control," while a*rtificial* properties are manipulated by human action (Marshall 1890, 90). In this investigation, the USBOR water supply can be categorized as an *artificial* property. Since irrigation projects dam, divert, deliver and/or store water, these efforts represent water resource infrastructure shaped by humans and not attributable to nature alone. Infrastructure capital, used in the production of agricultural output, should create benefits recognizable as income (Marshall 1890). These agents of production are further elaborated in Chapter 3.

II.C: Net Farm Income Models

In order to set the stage for the net farm income model presented in this study, previous models are analyzed in this section. The models are separated into two distinct categories: development and industry. This categorization emerged through a literature search.

Development Models

Net farm income models are strongly represented within the development economics literature. In developing countries, these models provide unique insight into local agricultural communities, offering governments a set of policy tools to augment agricultural income. Similarly, net farm income models can provide relevant policy prescriptions for agricultural economies in developed countries.

For example, Mafimisebi (2008) found farm size, hired labor quantity, amount spent on inputs, and crop variety cultivated (e.g., cassava-type) to be statistically significant and positively correlated with income. Farm size influenced household income by the largest magnitude, followed by quantity of hired labor. The author examined factors that affect income from cassava farms in Ondo State, Nigeria, where the government had recently advocated for specific production volume targets. Based on extensive household interviews, Mafimisebi constructed a double log ordinary least squares (OLS) regression model to isolate factors important to net farm income and incorporated a cross-section of data on farm size, household size, quantity of hired labor, farmers' experience in cassava production, amount spent on inputs, and the variety of cassava cultivated. In the model I present in the next chapter, I include variables for farm size and crop variety similar to those used in Mafimisebi's study.

Ugwumba et al. (2010) found that education, experience and integrated farm system (IFS) type (e.g., partial- or full-integration) were positively correlated with net cash farm income. The results for experience contrasted with Mafimisebi's findings of insignificance (2008). Using random sampling techniques to select respondents from five different local government areas in Anambra State, Nigeria, the authors conducted questionnaires and analyzed IFS profitability using the whole farm budget accounting method to calculate gross income. To assess IFS effects on net cash farm income, calculated by subtracting fixed costs from gross margin, the authors adopted a regression approach and modeled net cash farm income as a function of several different independent variables: farmer age, household size, education level, experience, farm input costs, gender, and degree of IFS implemented. The methodology outlined in Ugwumba et al. (2010) and their results for experience provided model insight for this study.

Additional work by Mather (2005), Ibekwe (2010), Xiong and Niu (2010), and Jalil et al. (2011) analyzes factors affecting farm income in rural Mozambique, Nigeria, China, and Pakistan, respectively. These studies empirically analyze farm income and its determinants similar to the cases described above. However, since rural agricultural communities are not all the same, policy implications vary slightly depending on the nature of the crop grown and the local socioeconomic conditions.

Industry and Other

Another category of studies focuses on farm industry profitability, financial performance or net farm income variability.

For example, Langemeier et al. (1992) studied the determinants affecting cattle finishing profitability and found sale prices, feeder prices, corn prices, interest rates, feed conversion, and average daily gains responsible for 98% of profit variability. With time-series data from one western Kansas feedlot from January 1980 to December 1989, the authors used regression analysis to explain the importance of price and performance to cattle profits. Although Langemeier et al. (1992) had no application to water development, I found their approach to modeling variability in profits useful to conceptualize the model for net cash farm income presented in this study.

Ford and Shonkwiler (1994) analyzed the effect of managerial ability on farm financial success in the dairy sector and found dairy management (i.e., efficiency factors including milk sold per cow and milk sold per man) and herd size influenced net farm income more than financial or crop management indicators. Using a cross-section of 880 Pennsylvania commercial dairy farms for the year 1990, the authors modeled net farm income as a function of financial, dairy, and crop management indicators, where each indicator represented a vector of variables. I incorporate the authors' use of vector categorization in my own theoretical representation of net farm income but consider different factors.

As detailed here, studies examining net farm income determinants often overlook physical factors like temperature, precipitation and soil quality. Furthermore, due to differences in intent and purpose, these studies also leave out water use, a critical input to agriculture. In this sense, this study expands on existing models. I employ a regression approach similar to studies mentioned in this literature review to control for physical factors and account for water use.

Chapter III: Methods and Data

Chapter 3 details the econometric methods used to explain farm income and interpret the effect of USBOR water on farm income. This chapter describes each variable included in the model and cites the data's origins explaining how, if necessary, I manipulated the data to fit the model. I provide summary statistics at the end of the chapter.

III.A: Theoretical Model

This study uses an agricultural income model run for two different geographic regions to explore the role of USBOR water and other factors in explaining net farm income.

Model: Agricultural Income

Farm income is modeled for the eleven western states and then solely for the Pacific Northwest region (Idaho, Montana, Oregon, and Washington). Prior literature, which focuses mostly on developing countries, suggests that farm income depends on farm size, crop varieties and output, input production costs, and experience (Mafimisebi 2008; Ugwumba et al. 2010). Although few studies from the U.S. directly model farm income as the dependent variable, most find that prices (Langemeier et al. 1992) and irrigation practices (Pfeiffer and Lin 2010) are primary. Additionally, policy and geophysical conditions influence farmer decisions and help determine farm income.

In this study, factors related to water use and water policy that affect farm income are denoted by the vector **W**. This vector includes variables for water policy, water development, and irrigation. Irrigation practices are assumed to affect farm production and net cash farm income, and their inclusion in the model is particularly necessary in the arid and semiarid West where supplemental water application is vital. These practices are best classified as *artificial* properties under Marshall's framework, since to a degree they represent manipulation by humans (Marshall 1890).

Geophysical conditions that affect farm income are denoted by the vector **P**, and include variables for total farmland, soil quality, slope, average precipitation, average minimum temperature, and average maximum temperature. Climate factors such as precipitation and temperature define the growing season of a region, which could be several states, a state, or a county, dictating what and when crops can be grown. Alfred Marshall first described these factors as *inherent* properties, which affect agricultural land but are exogenous from the farmer's perspective (1890). Precipitation amount is especially important due to the fact that it mitigates need for irrigation water. Areas with abundant water are likely to support more agricultural diversity and thus, more robust agricultural economies. With climatic heterogeneity (Figure 3.1) across the study region, temperature and precipitation provide critical information that influence farmers' production practices and ultimately, farm income.

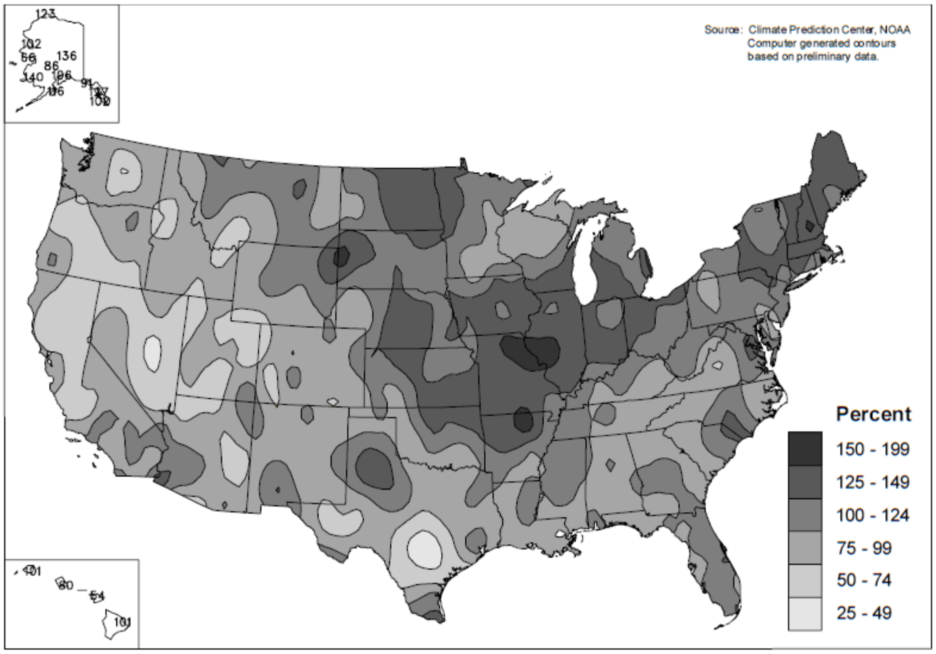

Figure 3.1 Percent of National Precipitation, January – December 2008 (USDA 2010).

Vector **C** represents commodity-related variables. Final commodities produced and sold to the market generate farm revenues, the primary source of income to the farmer. All farm income studies included in the literature review incorporate commodity related information in their analyses. For example, Langemeier et al. (1992) include important input and output price information related to cattle, while Ugwumba et al. (2010) use type of agricultural system to account for variation in which commodities are grown.

Demographic data comprise vector **D**. For example, Mafimisebi (2008) incorporates household size and farm experience, and Ugwumba et al. (2010) use household size, farm experience, and level of education to describe farm income.

Standard multiple linear regression models fitted using the ordinary least squares (OLS) method can explain farm income statistically. For example, Mafimisebi (2008) utilizes a log-log OLS model and Ugwumba et al. (2010) and Langemeier et al. (1992) use linear models. Due to the nature of the data, specifically the presence of negative farm income numbers, I use a level-level model. I follow standard multiple regression analysis from Kennedy (2008) to explain farm income.

The model is specified as follows:

(1) $$Farm\ Income = f(\boldsymbol{W}, \boldsymbol{P}, \boldsymbol{C}, \boldsymbol{D}),$$

where **W**, **P**, **C** and **D** are vectors representing water development and policy, geophysical factors, farm output and inventories, and demographic variables, respectively. Equation (1) is estimated for the eleven western states and for the Pacific Northwest.

III.B: Specific Model

I elaborate on the theoretical model presented in Equation (1) with a more specific model. This notation is presented in Equations (2) and (3), and I later provide the expected signs for the functions in Equations (4) and (5).

(2)

$$NCFI = f(USBOR, EQIP, Groundwater\ Irrigation, Surface\ Water\ Irrigation, Experience, Total\ Farmland, Soil\ Quality\ Proportion, Slope, Precipitation, Minimum\ Temperature, Maximum\ Temperature, Hay, Wheat, Corn, Beef\ Cattle, Dairy\ Cattle)$$

For the less heterogeneous Pacific Northwest region, I include state dummy variables that identify to which state each county belongs (i.e., Idaho, Montana, Oregon, and Washington). Other than the state identification dummies, Equation (2) and (3) are identical.

(3)

$$NCFI = f(USBOR, EQIP, Groundwater\ Irrigation, Surface\ Water\ Irrigation, Experience, Total\ Farmland, Soil\ Quality\ Proportion, Slope, Precipitation, Minimum\ Temperature, Maximum\ Temperature, Hay, Wheat, Corn, Beef\ Cattle, Dairy\ Cattle, State\ ID)$$

Net cash farm income, or *NCFI*, measures agricultural income in this model. Within the water development and water policy vector that influences *NCFI*, I include data from water development programs and agencies, (i.e., USBOR and EQIP) and irrigation practices. Irrigation water typically comes either from storage in underground aquifers (e.g., groundwater) or from above ground storage that collects runoff (e.g., surface water); the USBOR evolved from the latter.

Data regarding farm experience are the only data included in the vector of demographic information. For the geophysical factors vector, I include county level measures for total farmland, the proportion of high quality agricultural soils, slope, and climate data (i.e., precipitation, minimum temperature, and maximum temperature).

For the commodities vector, I use county data on hay, wheat, corn, beef cattle, and dairy cattle. These five commodities encompass the majority of total land in farms for the entire study region.

A Priori Expectations

In Equations (4) and (5), I indicate the expected signs the coefficients. I hypothesize positive contributions to county income in both study regions from the four water policy and development variables: *USBOR*, *EQIP*, groundwater irrigation, and surface water irrigation. In particular, I think that the latter two will have large coefficients due to the importance of irrigation source to agricultural production. Irrigated acres have additional expenses over dryland acreage but can produce higher-value crops.

(4) $$NCFI = \beta_0 + \beta_1 USBOR + \beta_2 EQIP + \beta_3 Irrigation_{Ground} + \beta_4 Irrigation_{Surface} + \beta_5 Experience + \beta_6 TotalFarmland + \beta_7 SoilQualityProportion - \beta_8 Slope + \beta_9 Precipitation - \beta_{10} Precipitation^2 + \beta_{11} MinTemperature - \beta_{12} MinTemperature^2 + \beta_{13} MaxTemperature - \beta_{14} MinTemperature^2 + \beta_{15} Hay + \beta_{16} Wheat + \beta_{17} Corn_{Feed} + \beta_{18} BeefCattle + \beta_{19} DairyCattle$$

(5) $$NCFI = \beta_0 + \beta_1 USBOR + \beta_2 EQIP + \beta_3 Irrigation_{Ground} + \beta_4 Irrigation_{Surface} + \beta_5 Experience + \beta_6 TotalFarmland + \beta_7 SoilQualityProportion - \beta_8 Slope + \beta_9 Precipitation - \beta_{10} Precipitation^2 + \beta_{11} MinTemperature - \beta_{12} MinTemperature^2 + \beta_{13} MaxTemperature - \beta_{14} MinTemperature^2 + \beta_{15} Hay + \beta_{16} Wheat + \beta_{17} Corn_{Feed} + \beta_{18} BeefCattle + \beta_{19} DairyCattle - \beta_{20} Idaho - \beta_{21} Montana - \beta_{22} Oregon$$

For increases in the demographic variable *Experience*, I predict higher *NCFI* per county. This expectation is consistent with Ugwumba et al. (2010). Intuitively, counties whose principal operators have more aggregate experience likely run their farm operations more efficiently. I expect to see similar results across the West and Pacific Northwest models.

For total land in farms and proportion of high quality agricultural soils, I predict large and positive contributions across the West and Pacific Northwest. As the percentage of high quality soils increases, net farm income is hypothesized to increase by a large magnitude. I hypothesize that the slope variable will have the opposite sign of soil quality. Land with higher slope is more susceptible to erosion and has less water storage capacity. Therefore, increasing slope is expected to limit productivity and negatively impact net farm income.

Generally, I anticipate that some of the climate variables will show quadratic relationships with a local maximum value. Higher precipitation amounts are expected to increase net farm income, since natural precipitation and irrigation water are substitutable for one another, and growing season precipitation in this study measures rainfall on agricultural lands. However, I expect that the returns to rainfall will eventually taper off. The same relationship is hypothesized for the temperature variables as well. Differences in the study region will likely change the positioning of the quadratic curve so that the maximum value occurs at a different temperature or precipitation amount.

For the commodity variables, I hypothesize all positive contributions toward county income. I expect hay to contribute the least income of all the commodities. In part, this is due to the definition of hay in this study, which aggregates numerous hay crops (i.e., irrigated, non-irrigated, native, cultivated). Although corn is grown mostly in the Midwest, I anticipate that the coefficient for corn will be higher than wheat, largely due to biofuel mandates. Values for cattle are expected to bring the largest returns to income with results that could differ by region. For example, the beef cattle sector has seen good market prices in the Pacific Northwest in recent years and might contribute more to income there, where states like Oregon and Montana have above average cattle numbers.

For the state identification dummy variables, I drop a term for Washington state in order to avoid perfect multicollinearity. I hypothesize that the variable signs for Idaho, Montana, and Oregon will be negative relative to Washington. At the state level, Washington has the highest value of agricultural products sold (Table 1.2) and the highest average aggregate *NCFI* per county (Appendix).

III.C: Variables

This section details all the variables included in the models, for which results are presented in the following chapter.

Net Cash Farm Income (NCFI)

Net cash farm income is the specific measure of farm success analyzed here. Net cash farm income for an operation, as defined in the 2007 USDA Census of Agriculture, is derived by:

> Subtracting total farm expenses from total sales, government payments, and other farm-related income. Depreciation is not used in the calculation of net cash farm income. Net cash farm income of the operation includes the value of commodities produced under production contract by the contract growers. For publication purposes, farms are divided into two categories: 1) Farms with net gains (includes those operations that broke even) and 2) Farms with net losses (USDA 2009).

Within the Census of Agriculture county-level data represent the aggregation of farm producers within the county, with the exception of farms producing less than $1,000 in agricultural products (USDA 2009). Since farm income is aggregated across all farm operations for a county, whether it is positive or negative depends on the composition of returns and losses. As evidenced by the Census data, farm profitability differs not only from state to state (Table 1.1) but from county to county. Even at the county level, there is substantial variation (Table 3.1). Approximately 96% of the NCFI data fall within two standard deviations of the mean.

Number of Operations Receiving Water from the USBOR

The 2007 Census of Agriculture provides the number of county-level farm operations receiving water from the USBOR. Individual farm operations receive water from larger USBOR infrastructure projects (for example see Figure 1.2). The number of farm operations receiving water from the USBOR may not provide the most accurate representation of actual water use from the USBOR. However, no volumetric water data from the USBOR were available at the county level. Here, I assume that higher numbers of operations with USBOR water correlate with higher volumetric water use for the county.

USGS Irrigation Estimates

The USGS publishes its *Estimated Use of Water in the United States* report every five years. The two most recent data years available are 2005 and 2000, with 2010 data to be released in 2014 (Hutson et al. 2005; Kenny et al. 2009). In this study, I average 2000 and 2005 data years to provide the estimate for 2007 irrigation use. I hypothesize that this average provides a better estimate rather than 2005 irrigation data for two reasons: irrigation withdrawal trends show that current water withdrawals have more or less peaked (Figure 3.2), and that averaging two-years of data likely reduce the presence of an abnormal county irrigation year. Irrigation estimates are measured in millions of gallons per day.

The USGS data include surface water and groundwater irrigation. I separate surface water from groundwater and assess their effects independently in the model. Surface water withdrawals include farms that receive water from the USBOR and so these data overlap. Although these variables are correlated with another, the USGS data measure more than simply the USBOR water supply since the USBOR serves approximately one-half of surface water irrigated area in the West (Moore 1991).

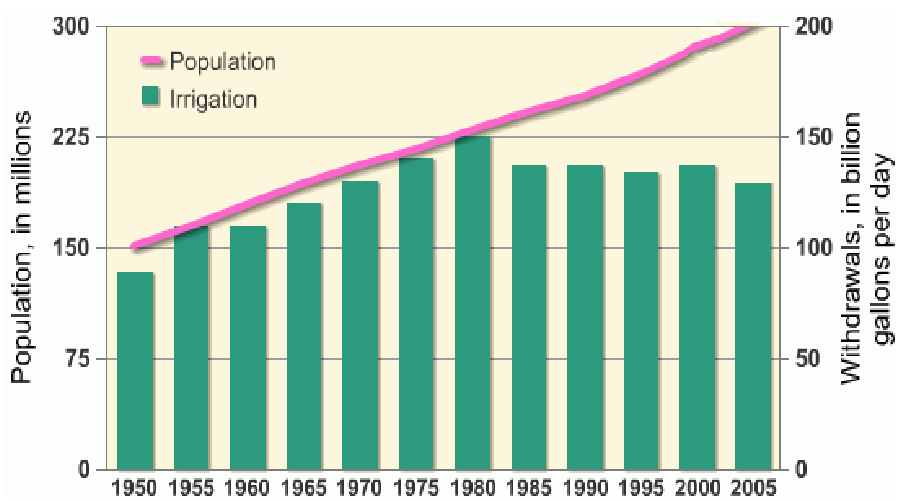

Figure 3.2 Trends in Population and Irrigation Withdrawals, 1950-2005 (USGS 2013).

Environmental Quality Incentives Program (EQIP)

Other federal agencies and programs provide water-related support and development to agriculture. EQIP, a voluntary program established by the 1996 Farm Bill and administered through the U.S. Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS), offers financial and technical assistance to farmers to implement conservation measures related to soil, water, air, plants, and wildlife (USDA 2008). EQIP offers farmers direct payments (i.e., subsidies) for "Ground and Surface Water Conservation" through a cost-sharing mechanism, in contracts of up to ten years. Projects are meant to improve operational efficiencies and environmental performance. Recent studies by Ward and Velazquez (2008) and Pfeiffer and Lin (2010) suggest that EQIP contributes to farm income.

Data on direct payments for the EQIP "Ground and Surface Water Conservation" program are available through the Census Bureau's *Consolidated Federal Funds Reports*, which track annual expenditures and obligations obtained from federal government agencies (USBOC 2008). These data, measured in total direct dollar payments, are available at the county level.

Total Land in Farms

Data on total agricultural land is from the Census of Agriculture, reported as "Land in Farms." Total agricultural land primarily consists of land used for crops, pasture, or grazing, but does include some woodland and wasteland acreage not under cultivation or pasture. The Census definition of a farm applies only to places producing and selling more than $1,000 in agricultural products for the Census year.

Soil Quality

This study uses the National Soil Survey Handbook's land capability classification (LCC) system, an index defined as "a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time" (NRCS 2013). The LCC designates soil types as classes I through VIII, where class I soils have the fewest limitations in their use and are typically well drained with moderate permeability and little erosion susceptibility. Classes VII and VIII have greater limitations that prevent commercial agricultural use and tend to be used for livestock-grazing or wildlife activities. The rationale for using land capability class to measure soil quality is backed by work by Olen et al. (2012) and more broadly justified by Marshall's (1890) chapter "The Fertility of Land."

Soil quality measures were developed from the Gridded Soil Survey Geographic (gSSURGO) dataset. The gSSURGO database, collected by the National Cooperative Soil Survey, contains information displayable in maps or tables that "describe(s) soils and other components that have unique properties, interpretations, and productivity" (NRCS 2012b). Soils data are distributed at 30-km resolution and are described in outlined areas called map units, which are based on physical characteristics rather than municipal distinctions. These map units span the entire extent of a state, regardless of land use. To develop a meaningful measure of soil quality using land capability class information, I restricted the soils data to agricultural zones.

In this study, the specific soil quality metric used is the percentage of agricultural soils classified in non-irrigated capability class I through III for the eleven western states and classes I and II for the Pacific Northwest.

Slope

Although the gSSURGO data express soil quality in one metric, additional information such as slope helps to provide a more complete representation. I used the digital elevation model (DEM) GTOPO30 to calculate slopes for the model. GTOPO30, a global DEM developed by the U.S. Geological Survey's (USGS) Center for Earth Resources Observation and Science, was "developed to meet the needs of the geospatial data user community for regional and continental scale topographic data" (USGS 1996). The elevation data are distributed approximately at a one-kilometer resolution and are measured in meters.

For this particular study, the two GTOPO30 tiles w140n40 and w140n90 provided full coverage of the study region. From the original DEM layer, I used the Surface Slope Spatial Analyst (Slope) tool to generate a second raster layer for slope. The Slope tool calculates the slope inclination in degrees based on the original elevation data. I calculated county-level slope averages by summarizing the raster slope layer.

Climate Data and Growing Season

The climate variables, including precipitation amount and temperature averages are from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) database (OSU 2007). The PRISM model, developed by Dr. Christopher Daly, professor at Oregon State University and Director of the PRISM Climate Group, is a "knowledge-based system that uses point measurements of precipitation, temperature, and other climate elements to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters" (PRISM 2013). PRISM products used in this analysis include digital raster data for precipitation and average maximum and minimum temperatures. These data were calculated through the PRISM analytical model using point data and a digital elevation model (DEM), and are approximately distributed at a four-kilometer resolution. Precipitation data are measured in millimeters and temperature data in degrees Celsius.

PRISM data are spatially and temporally integrated with the study area. To account for the climatic effect on net cash farm income, monthly averages for 2007 precipitation, minimum temperature, and maximum temperature were calculated and developed into a growing season spanning May to September (Myneni et al. 1997). Growing season averages, rather than annual averages, capture the actual conditions during which crops were grown.

Only maximum temperature variables are included for the less heterogeneous Pacific Northwest region. Olen et al. (2012) demonstrate favorable empirical results using this specification.

Commodities

The Census of Agriculture tracks numerous commodities by total sales and production. Commodities are included in the models in quantity terms, whether in harvested acreages or in cattle inventory numbers. Commodities included in this model are: wheat, hay, corn grain, beef cattle, and dairy cattle. Although these commodities certainly do not account for all agricultural products grown or raised within any given county, they represent more than 70% of the total harvested cropland for both the eleven western states and the Pacific Northwest. I exclude other high value crops (e.g., orchards, floriculture, and horticulture) due to limited data observations, which could be a major problem given the high contribution of these crops to *NCFI* in Oregon and Washington counties.

Experience

Data on farm experience are available through the Census of Agriculture. In this model, experience is expressed as the county average for the principal operator's experience in years.

State Dummies

In the Pacific Northwest region, I include dummy variables to identify each state. Since this region is less heterogeneous than the overall West, the variables may be able to provide additional insight on characteristics that distinguish states from another but that are otherwise not accounted for in the model (e.g., state-level differences in access to markets).

III.D: Data Source Description

Here, I discuss methods related to the data collection and data manipulation in this study. At the end of the section, the variables from the econometrics models are summarized statistically for the eleven western states and then for the Pacific Northwest. Individual state data are summarized in the Appendix.

Census of Agriculture Data

Variables from the 2007 Census of Agriculture were queried from the USDA National Agricultural Statistics Service (NASS) Quick Stats 2.0 server. The NASS Quick Stats 2.0 "is the most comprehensive tool for accessing agricultural data published by NASS," including all individual state agricultural censes (USDA 2013b). I collected all NASS data at the county level for each state included in the analysis. In cases where no published record existed for a variable, such as an absent observation for the number of beef cattle within a county, the observation was zero. However, in cases where a variable observation was published as "(D)," the entire county observation dropped from the model to satisfy the statistical requirements. In the Census of Agriculture, (D) indicates data withheld to avoid individual farm identification.

Missing Data

To avoid dropping numerous counties from the model due to withheld data, and to avoid misrepresenting the eleven western state study region, I populated these missing data using extrapolation rules. For counties missing an observation for a particular commodity, I used existing information from surrounding counties (sharing some border) to generate the observation, assuming that in more cases than not, adjacent counties provide a reasonable estimate. For the 345 counties modeled for the West (Table 4.2), I used all original hay data. For the other commodities, I generated 56 observations for feed corn, 61 for wheat, 81 for dairy cattle and 82 for beef cattle.

For example, if county “X” had a withheld wheat observation reading (D) from the Census of Agriculture, the county would drop from the model despite containing relevant information for all other model variables. To estimate this observation and retain county “X” in the model, I applied weighted averages. For each surrounding county, the number of “harvested wheat acres” was divided by the corresponding the “total harvested cropland.” I averaged these weighted averages from surrounding counties to develop a percentage, which I applied to the “total harvested cropland” for county “X” to generate the missing wheat observation. Similarly, I used the same process for cattle inventories but replaced “total harvested cropland” with “total farmland” in the denominator.

To test the validity of this method, I used the extrapolation rule to predict county commodities not withheld from the Census. Using a paired t-test to compare estimated versus actual values yielded inconclusive results. Estimated values for harvested corn grain acreage and dairy cattle inventories were statistically the same, whereas estimated values for harvested wheat acreage and beef cattle inventories were statistically different. The beef cattle variable was ultimately the most problematic commodity variable, because it had the most withheld observations and required the highest number of generated values. However, excluding beef cattle altogether, an important commodity across both study regions, could constitute omitted variable bias. Further, allowing counties with withheld observations for beef cattle and other commodities to drop from the model altered the study region dramatically. Losing information for all other variables due to unpublished commodity variables was too great an expense.

Geographic Information Systems (GIS) Variables

I constructed several variables using ArcMap 10.0, a geographic information systems (GIS) system software package that enables geographically referenced data to be displayed, stored and analyzed. State-level data for soil quality, slope, precipitation, average minimum temperature, and average maximum temperature variables were all collected and constructed using GIS.

For each state, I restricted GIS data solely to agricultural land. To determine each state's agricultural land extent, I used additional data from the 2006 National Land Cover Dataset (NLCD). The NLCD "is a 16-class land cover classification scheme that has been applied consistently across the conterminous United States" (Fry et al. 2011). Although the NLCD dataset contains data for all land classification types, I only used the land types "Pasture/Hay" and "Cultivated Crops" in this analysis, the two land categories that comprise the "Planted/Cultivated" class. Of all the possible land types, these two most consistently describe agricultural land. Therefore, to ensure that geographical data uniquely described agricultural land, I restricted these data to the “Planted/Cultivated” land using the ArcMap 10.0 Clip Tool. I constructed all climate, elevation (used to calculate slope) and soil quality data using this NLCD agriculture definition.

The ArcMap Zonal Spatial Analyst (ZSP) tool then permitted county-level summary analysis for the clipped data, yielding averages for each respective variable. Therefore, each variable created using GIS is either a percentage or an average expressed in terms of county agricultural land.

In sixteen counties, due to the combined impreciseness of the ZSP and the corresponding data, observations for climate variables were not available. In these instances, in order to avoid dropping the county from the model altogether, I estimated data by averaging observations from all surrounding counties.

Table 3.1 Descriptive Information and Statistics for the Western States Model

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	37,900,000.000	99,900,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	103.211	205.580	Number of farm operations receiving water from the USBOR
EQIP	63,750.300	160,187.300	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	57.003	141.808	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	165.806	271.091	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	20.432	2.869	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	662,386.600	712,747.800	Total farmland operated (acres)
LCC 1-3	0.283	0.299	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.818	0.601	Slope of agricultural land (°)
Precipitation	135.760	83.600	Average precipitation for growing season (mm)
Minimum Temperature	9.771	3.248	Average minimum temperature for growing season (°C)
Maximum Temperature	27.052	10.939	Average maximum temperature for growing season (°C)
Commodities			
Hay	29,354.730	31,291.710	Hay cropland harvested (acres)
Wheat	31,553.730	69,996.580	Wheat cropland harvested (acres)
Corn	4,263.470	16,903.910	Corn grain cropland harvested (acres)
Beef Cattle	16,033.850	15,172.470	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	10,604.100	36,476.090	Cows/heifers that have calved (per head cattle inventory)

Table 3.2 Descriptive Information and Statistics for the Pacific Northwest Model

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	27,900,000.000	46,000,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	109.794	223.091	Number of farm operations receiving water from the USBOR
EQIP	50,297.370	101,186.400	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	34.038	78.215	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	164.794	247.001	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	20.903	2.602	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	595,761.600	608,970.200	Total farmland operated (acres)
LCC 1-2	0.082	0.150	Proportion of farmland in non-irrigated Land Capability Class 1-2
Slope	0.999	0.588	Slope of agricultural land (°)
Precipitation	137.909	75.765	Average precipitation for growing season (mm)
Minimum Temperature	8.448	1.719	Average minimum temperature for growing season (°C)
Maximum Temperature	24.567	2.357	Average maximum temperature for growing season (°C)
Commodities			
Hay	33,684.030	31,397.670	Hay cropland harvested (acres)
Wheat	53,486.800	91,393.790	Wheat cropland harvested (acres)
Corn	1,800.476	5,584.194	Corn grain cropland harvested (acres)
Beef Cattle	17,158.150	16,203.270	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	6,072.841	16,657.720	Cows/heifers that have calved (per head cattle inventory)

Note: See Appendix for descriptive information and statistics on individual states.

Chapter IV: Results and Discussion

This chapter presents the results from the models and interprets their importance to policy in the context of western agriculture. Afterwards, it addresses limitations in the study and offers future research directions.

IV.A: Results

Model 1: Agricultural Income

Estimation results for the agricultural income models are reported in Tables 4.1 and 4.2. Including commodities in the models (Table 4.2) increases the performance of the F and R-square statistics. Both models are reported here to demonstrate development. For the models in Table 4.1, which include vectors of water use and policy, geophysical factors, and demographic variables, the results for the eleven western states and the Pacific Northwest are similar.

Table 4.1 NCFI OLS Model Coefficients Using Water Development and Policy, Geophysical, and Demographic Variables

Variable	Western States	Pacific Northwest
USBOR	68581.84***	113469.93***
	(16931.70)	(14794.63)
EQIP	55.53*	52.41*
	(24.81)	(30.99)
Groundwater Irrigation	409011.70***	110992.47***
	(28930.78)	(41005.01)
Surface Water Irrigation	45164.37***	-13538.16
	(14275.04)	(12576.83)
Experience	1185539.31	3921149.55***
	(1085083.72)	(1121440.25)
Total Land in Farms	14.17***	14.95***
	(4.90)	(5.15)
LCC Proportion 1 – 2		70307291.67***
		(16652649.65)
LCC Proportion 1 – 3	18387475.57*	
	(10759196.95)	
Slope	11264586.29**	1940688.47
	(5487854.72)	(5122161.43)
Precipitation	-599570.94***	-359849.13**
	(126541.36)	(164741.90)
Precipitation Squared	1596.18***	867.91
	(407.33)	(518.05)
Minimum Temperature	15515665.05***	
	(4963179.15)	
Minimum Temperature Squared	-480695.23*	
	(276867.27)	
Maximum Temperature	-21264639.47	-37222961.06**
	(14391938.83)	(16500989.52)
Maximum Temperature Squared	299572.44	734433.25**
	(290876.29)	(341578.48)
Constant	237277567.0	408051799.9**
	(169539810.4)	(190092489.7)
N	386	174
F-Statistic (df)	82.27 (371)***	22.57 (161)***
R-square	0.756	0.627
Adjusted R-square	0.747	0.599

Note: Standard errors in parentheses

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

The water use and policy variables are all significant and positively correlated with income as hypothesized in Equations (4) and (5). The sole exception is surface water irrigation in the Pacific Northwest region, which is insignificant. Results show that *NCFI* for the county increases by approximately $68,580 and $113,470 per county for each additional farm operation receiving water from the USBOR, for the West and Pacific Northwest, respectively. For every EQIP dollar invested in a county, *NCFI* increases by roughly $55. Groundwater and surface water irrigation use exhibit a strong, direct relationship with farm income in the West. Groundwater irrigation use contributes more to *NCFI* than surface water by a factor of eight. The insignificant result for surface water irrigation in the Pacific Northwest is unexpected and possibly due to the region's smaller sample size. This result could reflect greater policy restrictions in the West, including limitations from conservation and in-stream water uses.

Additionally, although the water use and policy variables capture important and distinct variation, mild multicollinearity exists between the USGS irrigation variables (i.e., groundwater and surface water) and the *USBOR* variable since there is some overlap. I include all water usage and policy variables for the Pacific Northwest region. A larger sample size for this region might yield a different result, but results here suggest general surface water irrigation (i.e., more than USBOR surface water alone) is not an important explanatory factor for *NCFI* in this region.

For the geophysical variables, soil quality and the total land in farms are significant and directly relate to income for both study regions. These results align with prior expectations. As total land in farms increases one acre, ceteris paribus, there is approximately $14 more in *NCFI* regardless of the region. Soil quality results are not directly comparable across regions since they are measured differently (i.e., soil proportion in classes one through three for the West, and one through two for the Pacific Northwest). However, both models show considerably large, positive coefficients for soil quality indicating its importance to *NCFI*.

Contrary to the hypothesized sign, slope is significant for the West and inversely related to farm income. However, in the Pacific Northwest model slope is insignificant. The insignificant result for the Pacific Northwest region may exist due insufficient data points for the area, which had 212 fewer county observations than the West region. In the West, results show that as slope for agricultural land increases by one degree, income increases by roughly $11.2 million. This result is confusing since lands with more incline are generally more susceptible to erosion compared to soils on flatter planes. Few data points show high *NCFI* and high slope together. Furthermore, counties with this relationship vary substantially geographically and in the types of crops they grow.

For the climate measures, precipitation and its square term are significant for the West. The linear precipitation term is significant for the Pacific Northwest, in contrast to the quadratic relationship. The negative sign indicates that more growing season precipitation negatively influences *NCFI*. I expected more growing season precipitation to increase *NCFI*, ceteris paribus, rather than reduce income. For the western states, the precipitation result estimates that *NCFI* is minimized at 25 mm (~ 7.4 inches). For precipitation levels either lower or higher than 25 mm, *NCFI* increases. This result indicates that counties with little growing season precipitation must generally grow crops that favor dry weather and/or irrigate their crops to earn high *NCFI*. More thorough data examination confirms this result. For example, the first seven counties with the highest *NCFI* all show minimal growing season precipitation but host above average USBOR-serviced farm numbers and EQIP dollars. USGS irrigation estimates for these counties also indicate substantial irrigation use. As a county moves in the other direction (greater than 7.4 inches), higher growing season precipitation mitigates the need for irrigation. Actual data points for counties with both high *NCFI* and growing season precipitation are fewer. Although these counties generally have low numbers of farms with USBOR water and irrigate less, their NCFI is also substantially lower. Overall, the data suggest that the controlled application of water (i.e., irrigation) is more important.

As expected, the temperature results differ by region. However, results differ from a priori expectations. For the West, higher average minimum temperatures are positively correlated with income. Minimum temperature squared is only mildly significant. Interpreting only average minimum temperature shows income increasing by $15.5 million for every 1°C increase in this variable. If the minimum temperature square term is considered in the relationship, the result shows that *NCFI* is maximized at 16°C or 60.8°F, a reasonable result for the growing season. This quadratic result aligns with prior hypotheses. Results for the Pacific Northwest, however, do not. Maximum temperature and its square are significant in the model but show a quadratic result with a minimum. The results show that *NCFI* is minimized at an average maximum temperature of 25°C or 77°F. For temperatures greater or less than 77°F, *NCFI* increases. If this is in fact true, the temperature range away from 77°F must be small.

The sole demographic variable *Experience* appears significant and positively correlated with income in the model for the Pacific Northwest. *Experience* is insignificant for the overall West. Mean *Experience* is roughly the same across both study regions at approximately 20.5 years. However, the minimum value for county *Experience* in the West is 6.4 years compared to 14.2 in the Pacific Northwest. Insignificance in *Experience* for the West in the model is potentially due to this variation in *Experience* years.

Model 2: Agricultural Income with Commodities

The three models in Table 4.2 include general commodities grown throughout the West. These commodities include harvested crop acreages for hay, feed corn, and wheat, and cattle inventories for dairy and beef cattle. The second model for the Pacific Northwest includes dummy variables for the states. Due to noticeable improvements in R-square and F statistics, I attribute more emphasis to the results of these models over those in Table 4.1.

Table 4.2 NCFI OLS Model Coefficients Using Water Development and Policy, Geophysical, Demographic, and Commodity Variables

Variable	Western States	Pacific Northwest	Pacific Northwest with State Variables
USBOR	29715.23*	62232.91***	64376.21***
	(16142.51)	(11882.98)	(11448.50)
EQIP	69.23***	51.18**	45.33**
	(24.24)	(22.97)	(22.15)
Groundwater Irrigation	273202.67***	57181.38*	61553.76**
	(30571.98)	(29579.30)	(29423.17)
Surface Water Irrigation	59693.39***	-6750.90	-3675.11
	(15176.55)	(9564.26)	(9446.54)
Experience	-66158.40	169333.65	1222953.10
	(1118408.44)	(930913.46)	(979687.49)
Total Land in Farms	27.21***	20.84***	17.41**
	(7.189)	(7.84)	(7.78)
LCC Proportion 1 – 2		51030828.19***	65497574.71***
		(11644222.10)	(14732424.49)
LCC Proportion 1 – 3	23469535.84**		
	(10513502.78)		
Slope	8129103.79	366009.70	786901.36
	(5224538.69)	(3777520.95)	(3759324.40)
Precipitation	-516045.18***	-184285.6310	-16849.0933
	(122127.54)	(126974.37)	(149124.26)
Precipitation Squared	1291.34***	518.36	67.01
	(392.92)	(403.35)	(444.53)
Minimum Temperature	7736924.86		
	(4849369.64)		
Minimum Temperature Squared	-195107.73		
	(266526.25)		
Maximum Temperature	-3474079.14	23720336.27*	34190924.85**
	(13660829.32)	(13211958.42)	(13405737.34)
Maximum Temperature Squared	-31347.16	-555453.97**	-727907.55**
	(276344.92)	(274784.31)	(279079.85)
Hay	-67.56	58.22	33.77
	(146.90)	(114.47)	(114.38)
Wheat	58.46	82.41***	63.471788237**
	(43.96)	(28.85)	(28.40)

Table 4.2 NCFI OLS Model Coefficients Using Water Development and Policy, Geophysical, Demographic, and Commodity Variables (Continued)

Variable	Western States	Pacific Northwest	Pacific Northwest with State Variables
Corn for Grain	193.15	2042.19***	1801.71***
	(282.48)	(443.63)	(443.04)
Beef Cattle	-849.77**	-563.09*	-322.24
	(355.12)	(294.63)	(305.30)
Dairy Cattle	962.73***	1203.65***	1203.40***
	(97.57)	(123.18)	(118.63)
ID			-17843593.31**
			(7353411.42)
MT			-21640362.49***
			(8009987.79)
OR			-23373904.10***
			(6506014.86)
Constant	75111965.61	-242429142.7	-413818917.0***
	(161261118.9)	(151368650.9)	(155378550.1)
N	345	163	163
F-Statistic (Prob > F)	81.30 (325)***	44.04 (145)***	41.26 (142)***
R-square	0.826	0.838	0.853
Adjusted R-Square	0.816	0.819	0.833

Note: Standard errors in parentheses
Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

As in the models presented in Table 4.1, the water use and policy variables are all significant and positively correlated with income as hypothesized in Equations (4) and (5). Again, the sole exception is surface water irrigation in the Pacific Northwest region, which is insignificant whether state dummy variables are included or not. The results show that an additional farm receiving water from the USBOR is correlated with $29,715 more in farm income per county for the West, and between $62,233 and $64,376 per county for the Pacific Northwest. An additional EQIP direct payment dollar is correlated with approximately $69 and between $45 and $51 more in *NCFI* for the West and Pacific

Northwest, respectively. If the average EQIP direct payment is $63,750 for the West, then the average county receives approximately $4.4 million in income from EQIP. For the Pacific Northwest, the average EQIP payment is $50,297 per county, which relates to increases in income between $2.3 and $2.6 million per county. For irrigation practices, increasing groundwater irrigation use increases income in the West and the Pacific Northwest. The coefficient estimates differ substantially for the two regions, with an additional million gallons per day influencing *NCFI* by $273,202 for the West and $61,554 for the Pacific Northwest. As in the prior model for the West, surface water irrigation is positively correlated with farm income but the coefficient size is several times smaller than groundwater. Surface water irrigation in the Pacific Northwest shows no significance. The results again suggest that general surface water irrigation (i.e., more than USBOR surface water alone) is not an important explanatory factor for *NCFI* in the Pacific Northwest.

For the geophysical variables, soil quality and total land in farms are significant and directly correlated with *NCFI* for both study regions, as hypothesized. The results are similar in magnitude, with an additional farm acre adding roughly $27 and between $17 and $21 to county *NCFI* for the West and Pacific Northwest, respectively. Coefficients for the soil quality measure are large in magnitude and positively correlated with income for both regions. In the West, a one percent increase in the percentage of land in non-irrigated land capability classes I through III leads to a $23.5 million increase in *NCFI*. A similar increase in the Pacific Northwest but for classes I and II shows increases in *NCFI* between $51 million and $65.5 million.

Despite significance in soil quality, slope measures are insignificant across both models. This reverses a prior model result (Table 4.1), where increases in slope positively correlated with *NCFI* for the West. This second result more closely aligns with the original hypothesized sign. In general though, slope estimates fail to meet a priori expectations. *Slope* might hold more explanatory power at the individual farm level, rather than at the county.

Climate factors for the two regions show similar *NCFI* effects from the first set of models in Table 4.1. For the West, precipitation and its square term are significant, showing that NCFI is minimized at 199 mm or approximately 7.8 inches. This result is almost identical to the prior model (Table 4.1). For the Pacific Northwest, results depict similar sign changes, but the variables are insignificant. These findings contrast to original a priori expectations of a quadratic relationship between *NCFI* and precipitation.

The temperature variables perform with mixed results in these models. For the West, all temperature variables become insignificant. Even when one set of temperature variables is used (i.e., minimum temperature or maximum temperature, not both), the model shows no temperature significance either way. No temperature findings conform to a priori expectations for the West. For the Pacific Northwest region, maximum temperature and maximum temperature squared are significant and important. The quadratic relationship is the opposite from the previous result in Table 4.1. However, the results are more intuitive and consistent with original expectations, despite a seemingly low estimate. *NCFI* is maximized at 23.5°C or 74.3°F. For average maximum temperatures above and below 74.3°F, *NCFI* decreases.

The sole demographic variable *Experience* appears insignificant across both regions, in slight contrast to the prior model depicted in Table 4.1. Since *Experience* years didn't show significance for the Pacific Northwest again, and due to the improvement in model performance noted earlier, I conclude that *Experience* is not an important determinant at least for county level *NCFI.* Overall, there are few differences in *Experience* across both regions, with exception to the difference in minimum observation values mentioned earlier. The data are possibly too aggregated to capture any meaningful difference. Similar to *Slope*, *Experience* might hold more explanatory power at the individual farm-level data.

Introducing commodity acres and inventories into the agricultural income model improves model performance in terms of R-square and F statistics. However, the results are mixed and mostly fail to align with a priori expectations. Hay is insignificant across all models. Wheat is a significant determinant for *NCFI* in the Pacific Northwest, with each additional harvested wheat acre contributing between $63 and $82. Harvested acreage for feed corn is only significant for the Pacific Northwest as well, with each additional harvested acre correlated with an increase in *NCFI* between $1802 and $2042. Feed corn estimates are higher than wheat as hypothesized.

Beef cattle inventories are significant in the West and in the Pacific Northwest model without the state dummy variables. Signs across all models show an inverse relationship with *NCFI*, where increasing inventories by one beef animal leads to $850 less in *NCFI*. These results are large in magnitude but hold signs opposite of original expectations. The results for dairy cattle are significant in the hypothesized direction across all regions and models. Increasing dairy cattle inventories are positively correlated with farm income, with each additional dairy animal improving *NCFI* by $963 and $1204 for the West and Pacific Northwest, respectively.

State dummy variables were tested in all models but performed well only for the Pacific Northwest region. The three states of Idaho, Montana, and Oregon all significantly lagged behind Washington in *NCFI*, a result mostly anticipated from the 2013 Oregon State of the Agriculture Industry Report. However, relationships between these three states with one another were all inconclusive in subsequent models tested.

Taken together, the result suggests that counties in Washington have some structural advantages that lead to higher *NCFI* than in other counties in the region. For example, Washington has more railroad miles and longer lines than in Oregon (OSBA 2013). Since rail is the second most efficient shipping mode behind barging, this offers Washington lower transportation costs and easier access to coastal ports to ship agricultural products (OSBA 2013).

IV.B: Discussion

Water Development and Farm Income

Policy implications stemming from this study involve water development, water policy, geophysical factors, and farm characteristics. Results from the models that include commodities (Table 4.2) indicate that the provision of USBOR water is positively correlated with county aggregate net farm income. Prior analysis at the state level suggests this same finding through summary statistics (State Board of Agriculture 2013).

I built on these results with the use of a model that accounts for county level heterogeneity (i.e., differences in county farmland, climate, soil quality, commodities) and found that an additional county farm operation receiving water from the USBOR increases county farm income between $29,715 and $64,376. The positive correlation between county *NCFI* and *USBOR* reflects increased investment in USBOR water and USBOR infrastructure. Holding all else constant, increases in these *artificial* properties are correlated with higher incomes. As suggested in the literature review, USBOR infrastructure capital appears to create benefits in the form of higher incomes.

When framed using the original *USBOR* farm operation numbers, the estimated contribution from *USBOR* is considerable. For example, the state of Oregon has a mean of 106 operations receiving USBOR water per county with maximum of 691 operations in Malheur county. Based on my model, the USBOR water supply contributes between $5.3 million and $11.5 million toward total aggregate net cash farm income for the average county. For Malheur county in particular, the estimated water supply increases farm income between $20.5 million and $44.5 million. Since Malheur county documented roughly $50.4 million in *NCFI* for 2007, the $44.5 million upper bound water supply is likely an overestimate.

As noted by the Oregon State Board of Agriculture report, the state of Washington outpaces Oregon substantially in average county *NCFI* (2013). Average *NCFI* for counties in Washington is $45.8 million, compared to $25.1 million in Oregon. As expected, summary statistics for Washington reveal that the USBOR presence is greater as well (Tables A.8 and A.10 in Appendix). The mean number of USBOR-serviced farm operations per county is 145, compared to 106 in Oregon. On a percentage basis, 14.4% farms in Washington counties receive water from the USBOR, while only 9.9% of Oregon farms do. The results regarding the relationship between *NCFI* and *USBOR* are similar for Idaho as well. In Idaho, the average *NCFI* per county is $30.9 million, approximately $5.8 million more than Oregon. The USBOR presence in Idaho is greater than Oregon. The average county in Idaho hosts 158 farm operations with USBOR water, about 50 farms per county more than in Oregon. On a percentage basis, 27.4% of farms in Idaho receive water from the USBOR. At the state level, Idaho and Washington each exceed Oregon in the number of farms receiving water from the USBOR by more than 1800 operations (Table 1.1).

The results from the models and summary statistics presented in this study indicate that the disparity in agricultural incomes between Oregon and neighboring states may be, in part, explained by this difference in USBOR water projects. Access to lower cost water improves production and overall agricultural *NCFI*. Ceteris paribus, if Oregon can increase the number of farms that receive USBOR water relative to Idaho and Washington, disparities in *NCFI* may diminish. There are caveats to future water acquisition and development though, and these are mentioned later in the discussion. Results from this study can be used to understand agricultural income. If irrigators are shut off and fewer farm operations receive water from the USBOR, aggregate county *NCFI* will likely trend downward as farmers are either forced out of business or left to adapt to less water availability. Other broader impacts are likely as well. For example, Moore and Negri (1992) estimated that prices for some major commodities would change alongside a shrinking USBOR water supply. Reduced farm incomes have the ability to produce multiplier effects in surrounding communities and businesses. The initial loss of farm income could be smaller than the total societal loss of income, since less farm income could lead to decreased consumption spending in other areas.

Other Determinants of Farm Income

In general, the results highlight the importance of water development projects to agriculture. Water use and water policy variables comprise four separate water-related measures that are consistently significant across all models. However, there is more to *NCFI* than just water development and this model helps to understand the importance of other factors. The results indicate that other major determinants drive county *NCFI*: the volume of groundwater irrigation, EQIP dollars, which commodities are grown, and the *inherent* properties of soil quality and climate. The latter two *inherent* properties are derived from nature and reflect the "powers of the soil" first described by Ricardo (1821, 39). In most instances, these contributions are non-negligible.

For example, the model shows considerable returns to income for each EQIP dollar invested in a county. Oregon attracts more EQIP dollars than Washington but in comparison to Idaho, Oregon brings in fewer total state EQIP dollars and fewer dollars per county, as shown in summary tables A.4 and A.8 (Appendix). In addition to more aggressive negotiations with the USBOR, as the State Board of Agriculture report suggests, Oregon counties might increase *NCFI* by seeking out more *EQIP* dollars. Since Oregon has a relatively strong livestock sector and rangelands are often eligible for

EQIP-funded projects (USDA 2008), the state could improve its *NCFI* with additional EQIP investment.

Groundwater irrigation also positively correlates with income and for every one million gallon per day increase in a county's water usage, income increases dramatically. On average, Idaho counties used 40 million gallons of groundwater per day more than Oregon counties (Tables A.4 and A.8 in Appendix), although Washington counties used less than 20 million gallons of groundwater per day compared to Oregon counties. Some of the variation in *NCFI* between Oregon and Idaho is likely attributable to these differences in groundwater irrigation usage. No clear policy action necessarily stems from this result. However, the difference is important when considering baseline production capacity and the availability of natural resources that might favor higher per county average incomes in one state versus another.

For the Pacific Northwest region, the models show that which commodities are produced positively correlate with agricultural income. In the region, wheat, corn, and dairy cattle show significant coefficients with variable magnitudes (Table 4.2). On average, Oregon counties have fewer harvested acres of corn and wheat and less dairy cattle than both Idaho and Washington (Appendix). These crop differences can explain part of the variation in *NCFI* between the counties in these three states. It should be taken into account though that land allocation decisions may in part reflect the availability of water.

Furthermore, small proportional increases in soil quality explain substantial variation in *NCFI* per county. Summary statistics show that the average county in Idaho and Washington has more agricultural land in higher quality soils (i.e., non-irrigated capability classes one and two). Therefore, counties in Oregon may lag behind Washington and Idaho in farm income due to heterogeneity in soil quality. Oregon farmers could take additional steps to protect and enhance local soil quality. For example, cover cropping, no-till, and crop rotation practices increase organic matter in soil and act as natural buffers against erosion and pests (NRCS 2012a). The downside of these practices is that they require additional management and time and only increase soil quality in small increments. For state soil quality totals though, Oregon has more agricultural land in higher quality soils, raising some questions as to why Oregon has less aggregate *NCFI* at the state-level. Interaction with other deterministic factors, such as climate or irrigation water, could be important here as well.

Limitations of Water Development Policy

Although these other determinants of farm income explain important variation in *NCFI*, some are exogenous to farms or difficult to change at the county level (e.g., climate, soil quality). Irrigation water development differs in one major respect: water can be controlled, channeled, and managed to produce quick and dramatic changes in the ability of a county to support agriculture.

At present and for the foreseeable future, even current commitments of water for agriculture are by no means guaranteed. In the West and Southwest, drought, recent reductions in melted snowpack, and historically low inflows have left the nation's two largest water reservoirs, Lake Mead above Hoover Dam and Lake Powell above Glen

Canyon Dam, at less than half their original capacity (Hawkes 2013). Additional competition for water from cities, industry, and the environment (e.g., Endangered Species Act) further stresses future water supplies. In the Pacific Northwest, protections for salmon and in-stream water rights limit surface water withdrawals for irrigators. The Conservation Reserve Enhancement Program also introduces conservation practices that limit water use, although participation in the program is voluntary (USDA 2013a).

In June of this year, the Klamath Tribes and the Klamath Project shut off water access to irrigators in the upper Klamath Basin to restore tribal in-stream water rights (Tipler 2013). Enforcing the water adjudication, which ruled in favor of the Klamath Tribes to retain prior-held senior water rights once removed in 1954, leaves irrigators without water access (Schwartz 2013). In the Klamath Basin, farm incomes will likely drop as farmers and ranchers adjust to changes in the available water supply. Some extra-marginal farms might be forced out of the industry, altering the Basin’s agricultural profile permanently.

Complicating matters more, climate change threatens seasonally to constrain water available to all uses. Some climate change models for the Pacific Northwest predict wetter winters and drier summers (Mote and Salath 2010). These conditions will intensify competition for water resources and possibly reduce water currently available to agriculture.

Although this study suggests that income is positively related to the number of farms receiving water from the USBOR, future water project development is also costly and complicated given construction costs, environmental and zoning regulations, and whether or not water is physically available in the first place. Numerous studies and impact assessments are required to determine whether a project is feasible or not. These studies must all confirm that a project meets particular hydrological, geological, biological, engineering, and land use regulations. Complying with all of these criteria, if possible, requires time, ample financial resources, and patience.

IV.C: Limitations

Data and Econometric Issues

Data limitations and time constraints restricted the capacity of this study in a few ways. The 2007 Census of Agriculture for the first time collected the number of county farms receiving USBOR water. Since the 2012 report awaits release in 2014, I only analyzed one year of data. Using a single year overlooks trends (e.g., changes in the supply and demand of wheat or another commodity, or changes in climate or demographics) that not only develop and fluctuate overtime, but that consequently cause farm income to vary from year to year.

I encountered issues with identifying a county's commodity profile due to data withheld from the Census of Agriculture to avoid farm disclosure. As a result, I was forced either to drop the entire county observation or use extrapolation techniques based on information from surrounding counties. The results of paired t-tests for estimated data versus actual data available revealed that this extrapolation rule applied well to harvested corn grain acreage and dairy cattle inventories but not to wheat acreage or dairy cattle inventories. It was outside the scope of this study to consider another extrapolation technique, such as a regression approach to estimating harvested acreages and cattle inventories for counties with missing observations. Despite flaws in the extrapolation method used here, this study produced similar results whether observations were dropped or retained. Consequently, they were retained here to maximize the coverage of the study region.

Using counties as the analysis unit also necessarily aggregates data, allowing for illustrative results but masking possible heterogeneity within any one individual county. Claassen and Just (2011) argue that spatial and temporal heterogeneity in county level agricultural economics studies can be a problem. The authors describe systematic and random variation important to intra-county farm-level crop yields. Intra-county heterogeneity could also be important to this study as well. For example, due to the fact that data for the USBOR variable are not farm-level, it's difficult to understand each farm's water use. This could lead to a scenario where some counties have only a handful of operations that use substantial irrigation water from the USBOR while other counties have numerous USBOR-serviced farm operations that are small water users. Depending on the scenario, the model might overestimate or underestimate the value of USBOR water as a result. These issues are generally avoidable with individual farm level data.

Although it is typical in econometric studies to subject data to transformations, such as logging dependent and independent variables, the presence of negative *NCFI* data posed difficulty for estimating a model of this type. As a result, a log-log model was not available to confirm the robustness of the results.

Finally, this model does not fully address endogeneity concerns. In this study, I assume that the *USBOR* and commodity variables non-randomly influence *NCFI* and that there is no causal loop between the variables. In other words, there is no simultaneity. Although I believe it is possible that more county *NCFI* might increase the number of farm operations receiving water from the USBOR (e.g., higher NCFI indicates greater political power to harness more federal development dollars), documented evidence of this effect is lacking. Concerns related to endogeneity from the commodity variables are not fully addressed in this study. For example, each year, farmers determine which crops they will grow. Part of this decision reflects the amount of income available. Since commodity choices are partly a function of income, the two are simultaneously determined. With only a single year of data analyzed here, this endogeneity issues still persists.

IV.D: Future Research

This study explores agricultural income and its ties to water in a compelling way but the approach needs refinement. A second year of data would reduce bias in the model and considerably improve the results by addressing existing endogeneity concerns. Specifically, a fixed-effects regression model would add clarity to the directional nature of the relationship between water policy and commodities, and farm income by treating the explanatory variables as non-random.

In order to improve the estimation of coefficients, future income studies would benefit from more detailed panel, micro-level data (i.e., individual farm) rather than aggregated cross-sectional data. It would be interesting to see if the effect of USBOR water on *NCFI*, observed both at the state (OSBA 2013) and county level (current study), are also reflected at the farm level. Studies should also model different crops and examine how the USBOR water supply affects income for specific commodities, while controlling for heterogeneity at an even smaller scale.

Studies in natural resource and environmental economics frequently calculate shadow prices, where the shadow price reveals the marginal benefit to society from relaxing a constraint (e.g., availability of a natural resource, such as water). Since this is not an optimization study and no constraint is imposed, no shadow prices are calculated for USBOR water. However, results from this study, which calculates income values for farm operations receiving water from the USBOR, are similar in that they try to measure the true value of the subsidized water. Future studies might set up a constrained optimization problem for these farms, where income is maximized subject to a USBOR water supply constraint. Strengthening the water constraint would reveal marginal cost effects in terms of income. Equivalently, relaxing the constraint would reveal the marginal benefits in income terms. These studies could incorporate additional relevant constraints, including policy (e.g., zoning or environmental regulations) or natural resource limits. Ultimately, these studies might be able to calculate USBOR water contributions to income in actual volumetric terms, rather than in terms of farm operations receiving water from the USBOR.

Chapter V: Conclusion

In this study, I addressed net farm income determinants with a focus on effects from water use and policy but in the context of other important climate, land, and demographic characteristics. To do this, I analyzed the relationship between *NCFI* and a cross-sectional set of climate, production and water policy variables for an eleven state western region and a Pacific Northwest region in the year 2007. The results indicate that agricultural water use and water development strongly influence county aggregate *NCFI*. Contributions to income from climate and farmland characteristics are also considerable.

Results show that favorable water policies, particularly those that subsidize water development to agriculture through the USBOR, improve farm income, at least when considered at the county level. Prior state-level analysis finds a similar result but without controlling for county-level heterogeneity (OSBA 2013). Empirical estimates in this study show that an additional farm operation receiving water from the USBOR, ceteris paribus, contributes approximately $29,715 to county aggregate *NCFI* in the western states and $64,376 in the Pacific Northwest region. However, additional water development explains only part of the difference in *NCFI*. Model results also show the importance of other federal programs (i.e., EQIP), soil quality, climate, and cropping system.

Some of the variables in the models, including *Experience* and *Slope*, conflict with a priori expectations. In the case of *Experience*, all results were insignificant except for one model in the Pacific Northwest region. For *Slope* in the West, the results showed a direct relationship with *NCFI* in one model, rather than the hypothesized inverse relationship. However, all other *Slope* results were insignificant. These variables likely hold more explanatory power at the individual farm level rather than as county level averages.

Although the results emphasize the importance of water use and development and generally support the conclusion from the Oregon State Board of Agriculture report, the availability of future water to agriculture is uncertain. Water development projects are costly and complicated given construction costs, environmental and land use regulations, competition from other sources, and whether or not water is physically available in the first place. Simply creating new water storage or developed water delivery systems to improve farm income, as suggested by the Oregon State Board of Agriculture Report, ignores the complexity behind future water development. Future climate change related events and phenomenon (e.g., drought, shrinking snowpack) threaten to further constrain availability.

Bibliography

Burness, H. S., R. G. Cummings, W. D. Gorman, and R. R. Lansford. "United States Reclamation Policy and Indian Water Rights." *Natural Resources Journal* 20 (1980). http://heinonline.org/HOL/Page?handle=hein.journals/narj20&id=837&div=&collection=journals.

Claassen, Roger, and Richard Just. "Heterogeneity and Distributional Form of Farm-Level Yields." *American Journal of Agricultural Economics* 93, no. 1 (2011): 144–160.

Ford, Stephen A., and John Scott Shonkwiler. "The Effect of Managerial Ability on Farm Financial Success." *Agricultural and Resource Economics Review* 23, no. 2 (1994): 150–157.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. "Completion of the 2006 National Land Cover Database for the Conterminous United States." *PE&RS* 77, no. 9 (2011): 858–864.

Gopalakrishnan, Chennat. "The Doctrine of Prior Appropriation and Its Impact on Water Development: A Critical Survey." *American Journal of Economics and Sociology* 32, no. 1 (1973): 61–72. doi:10.2307/3485791.

Green, Gareth P., and David L. Sunding. "Land Allocation, Soil Quality, and the Demand for Irrigation Technology." *Journal of Agricultural and Resource Economics* 22, no. 2 (1997): 367–375.

Hawkes, Logan. "Dramatic Water Changes Coming for the Southwest." *Southwest Farm Press*, August 13, 2013. http://southwestfarmpress.com/management/dramatic-water-changes-coming-southwest?page=2.

Hutson, S.S., N.L. Barber, J.F. Kenny, K.S. Linsey, D.S. Lumia, and M.A. Maupin. *Estimated Use of Water in the United States in 2000*. USGS, 2005. http://pubs.usgs.gov/circ/2004/circ1268/.

Ibekwe, U.C. "Determinants of Income Among Farm Households in Orlu Agricultural Zone of Imo State, Nigeria." *Report and Opinion* 2, no. 8 (2010).

Jaeger, William K. "Conflicts over Water in the Upper Klamath Basin and the Potential Role for Market-Based Allocations." *Journal of Agricultural and Resource Economics* 29, no. 2 (2004): 167–184.

Jalil, Athar, Manzoor Ahmad, Azhar Abbas, and A. D. Sheikh. "Economic Factors Responsible for Net Income Variation on Small Farms in Southern Punjab, Pakistan." *Journal of Agricultural Research* 49, no. 3 (2011): 419–427.

Kanazawa, Mark. "Pricing Subsidies and Economic Efficiency: The U.S. Bureau of Reclamation." *Journal of Law & Economics* 36 (1993). http://heinonline.org/HOL/Page?handle=hein.journals/jlecono36&id=211&div=&collection=journals.

Kennedy, Peter. *A Guide to Econometrics*. Sixth. Wiley-Blackwell, 2008.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. *USGS Water Use in the United States in 2005*. USGS, 2009. http://water.usgs.gov/watuse/.

Langemeier, Michael, Ted Schroeder, and James Mintert. "Determinants of Cattle Finishing Profitability." *Southern Journal of Agricultural Economics* 24 (1992): 41–41.

Mafimisebi, T.E. "Determinants and Uses of Farm Income from the Cassava Enterprise in Ondo State, Nigeria." *Journal of Human Ecology* 24, no. 2 (2008): 125–130.

Marshall, Alfred. *Principles of Economics*. Vol. 1. 8th ed. London: Macmillan and Co., Limited, 1890. http://oll.libertyfund.org.

Moore, Michael R. "Estimating Irrigators' Ability to Pay for Reclamation Water." *Land Economics* 75, no. 4 (1999): 562–578.

———. "The Bureau of Reclamation's New Mandate for Irrigation Water Conservation: Purposes and Policy Alternatives." *Water Resources Research* 27, no. 2 (1991): 145–155.

Moore, Michael R., and Donald H. Negri. "A Multicrop Production Model of Irrigated Agriculture, Applied to Water Allocation Policy of the Bureau of Reclamation." *Journal of Agricultural and Resource Economics* 17, no. 1 (1992): 29–43.

Mote, Philip W., and Eric P. Salathé Jr. "Future Climate in the Pacific Northwest." *Climatic Change* 102, no. 1–2 (2010): 29–50. doi:10.1007/s10584-010-9848-z.

Myneni, Ranga B., C. D. Keeling, C. J. Tucker, G. Asrar, and R. R. Nemani. "Increased Plant Growth in the Northern High Latitudes from 1981 to 1991." *Nature* 386, no. 6626 (1997): 698–702.

Olen, Beau, JunJie Wu, and Christian Langpap. "Irrigation Decisions for Major West Coast Crops : Water Scarcity and Climatic Determinants." Thesis/Dissertation, Oregon State University, 2012. http://ir.library.oregonstate.edu/xmlui/handle/1957/34295.

Oregon State Board of Agriculture (OSBA). *2013 Oregon State of the Agriculture Industry Report*. Salem, Oregon: State Board of Agriculture, January 2013. http://www.oregon.gov/ODA/.

Oregon State University (OSU). "PRISM Climate Group," 2007. http://www.prism.oregonstate.edu/.

Pfeiffer, Lisa, and C.-Y. Cynthia Lin. *Does Efficient Irrigation Technology Lead to Reduced Groundwater Extraction?: Empirical Evidence*. 2010 Annual Meeting, July 25-27, 2010, Denver, Colorado. Agricultural and Applied Economics Association, 2010. http://ideas.repec.org/p/ags/aaea10/60927.html.

Ricardo, David. *On the Principles of Political Economy and Taxation*. Third. Library of Economics and Liberty: London: John Murray, 1821. http://www.econlib.org/library/Ricardo/ricP.html.

Sax, Joseph L. "Selling Reclamation Water Rights: A Case Study in Federal Subsidy Policy." *Michigan Law Review* 64, no. 1 (1965): 13–46. doi:10.2307/1287115.

Schwartz, Devan. "Tribal Celebration Restores Good Cheer." *Herald and News*, August 24, 2013, sec. Community. http://www.heraldandnews.com/news/local_news/community/article_cd90612a-0d47-11e3-8687-0019bb2963f4.html.

Tipler, Samantha. "No Water, No Food: Cattle Are Being Shipped from Upper Klamath Basin Early in the Year." *Herald and News*. August 14, 2013. http://www.therepublic.com/view/story/d7ad338140f04397af929ed83556d40b/OR--Klamath-Drought-Cattle.

U.S. Bureau of Reclamation (USBOR). "Bureau of Reclamation: About Us." *Bureau of Reclamation: About Us*, 2013. http://www.usbr.gov/main/about/.

———. "Facilities by State." *Facilities by State*, 2007. http://www.usbr.gov/projects/FacilitiesByState.jsp?StateID=OR.

———. *Technical Guidance For Irrigation Ability to Pay and Irrigation Payment Capacity*. U.S. Bureau of Reclamation, 2004.

U.S. Bureau of the Census (USBOC). *Consolidated Federal Funds Report for Fiscal Year 2007: State and County Areas*. U.S. Department of Commerce, 2008. http://www.census.gov/govs/pubs/topic.html#federal_programs.

U.S. Congress Office of Technology Assessment (USOTA). "Chapter 2: Agricultural Production in the Western United States." In *Water-Related Technologies for Sustainable*

Agriculture in U.S. Arid/Semiarid Lands. Congress of the United States, Office of Technology Assessment, 1983.

U.S. Department of Agriculture (USDA). 2008. “Environmental Quality Incentives Program.” *USDA NRCS - Natural Resources Conservation Service*. http://www.nrcs.usda.gov.

———. 2009. “2007 Census of Agriculture: United States Summary and State Data”. AC-07-A-51. United States Department of Agriculture. http://www.agcensus.usda.gov/Publications/2007/Full_Report/.

———. 2010. “2007 Census of Agriculture: Farm and Ranch Irrigation Survey (2008)”. AC-07-SS-1. United States Department of Agriculture. http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.php.

———. 2013a. “Conservation Reserve Enhancement Program.” *Farm Service Agency*. https://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=cep.

———. 2013b. “Quick Stat Tools.” *NASS: National Agricultural Statistics Service*. http://www.nass.usda.gov/.

U.S. Geological Service (USGS). “Global 30 Arc-Second Elevation (GTOPO30).” *Global 30 Arc-Second Elevation (GTOPO30) | the Long Term Archive*, 1996. https://lta.cr.usgs.gov/GTOPO30.

———. 2013. “Irrigation Water Use.” *The USGS Water Science School*. http://ga.water.usgs.gov/edu/wuir.html.

U.S. Natural Resources Conservation Service (NRCS). 2012a. “Soil Quality / Soil Health Management.” *NCRS: Soil Quality*. http://soils.usda.gov/sqi/management/management.html.

———. 2012b. “SSURGO/STATSGO2 Structural Metadata and Documentation | NRCS Soils.” http://soils.usda.gov/survey/geography/ssurgo/.

———. 2013. “Part 622 - Interpretative Groups.” *NRCS Soils*. http://soils.usda.gov.

Ugwumba, C.O.A., R.N. Okoh, P.C. Ike, E.L.C. Nnabuife, and E.C. Orji. “Integrated Farming System and Its Effect on Farm Cash Income in Awka South Agricultural Zone of Anambra State, Nigeria.” *American-Eurasian Journal of Agricultural and Environmental Science* 8, no. 1 (2010): 1–6.

Ward, Frank A., and Manuel Pulido-Velazquez. "Water Conservation in Irrigation Can Increase Water Use." *Proceedings of the National Academy of Sciences* 105, no. 47 (November 25, 2008): 18215–18220. doi:10.1073/pnas.0805554105.

Xiong, Zhang-lin, and Ying Niu. "Factors Affecting the Income of Farmers." *Asian Agricultural Research* 2, no. 5 (2010). http://ideas.repec.org/a/ags/asagre/94268.html.

Young, Robert. "Economic Analysis and Federal Irrigation Policy: A Reappraisal." *Western Journal of Agricultural Economics* 3, no. 2 (December 1978).

Appendix

Appendix: Descriptive Information and Statistics by State

Table A.1 Descriptive Information and Statistics for Arizona

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	38,900,000.000	83,200,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	59.533	100.268	Number of farm operations receiving water from the USBOR
EQIP	86,568.270	267,864.200	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	167.095	270.073	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	173.324	303.963	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	19.787	4.106	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	1,445,529.000	1,878,689.000	Total farmland operated (acres)
LCC 1-2	0.000	0.001	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.000	0.001	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.328	0.191	Slope of agricultural land (°)
Precipitation	143.490	81.453	Average precipitation for growing season (mm)
Minimum Temperature	17.578	3.686	Average minimum temperature for growing season (°C)
Maximum Temperature	48.829	52.891	Average maximum temperature for growing season (°C)
Commodities			
Hay	19,840.930	27,544.410	Hay cropland harvested (acres)
Wheat	5,667.531	10,454.310	Wheat cropland harvested (acres)
Corn	1,683.291	4,248.919	Corn grain cropland harvested (acres)
Beef Cattle	18,299.520	27,355.990	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	23,175.960	34,801.770	Cows/heifers that have calved (per head cattle inventory)

Table A.2 Descriptive Information and Statistics for California

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	143,000,000.000	224,000,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	163.793	283.834	Number of farm operations receiving water from the USBOR
EQIP	155,501.500	294,982.100	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	174.637	278.608	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	298.303	484.006	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	18.738	2.222	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	437,322.300	440,827.300	Total farmland operated (acres)
LCC 1-2	0.004	0.020	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.327	0.357	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.731	0.648	Slope of agricultural land (°)
Precipitation	22.888	22.492	Average precipitation for growing season (mm)
Minimum Temperature	12.473	3.198	Average minimum temperature for growing season (°C)
Maximum Temperature	29.518	3.628	Average maximum temperature for growing season (°C)
Commodities			
Hay	26,386.620	41,861.330	Hay cropland harvested (acres)
Wheat	6,480.217	11,744.540	Wheat cropland harvested (acres)
Corn	3,332.503	7,910.528	Corn grain cropland harvested (acres)
Beef Cattle	11,453.600	9,972.840	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	38,228.050	83,477.960	Cows/heifers that have calved (per head cattle inventory)

Table A.3 Descriptive Information and Statistics for Colorado

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	15,900,000	31,200,000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	63.540	131.064	Number of farm operations receiving water from the USBOR
EQIP	43,930.950	120,357.500	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	35.506	76.154	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	152.917	197.064	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	20.278	2.914	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	501,665.300	501,091.400	Total farmland operated (acres)
LCC 1-2	0.032	0.115	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.193	0.244	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.570	0.639	Slope of agricultural land (°)
Precipitation	211.320	39.496	Average precipitation for growing season (mm)
Minimum Temperature	9.029	2.968	Average minimum temperature for growing season (°C)
Maximum Temperature	26.125	3.025	Average maximum temperature for growing season (°C)
Commodities			
Hay	25,753.130	25,394.050	Hay cropland harvested (acres)
Wheat	37,693.500	68,941.850	Wheat cropland harvested (acres)
Corn	17,625.790	39,030.020	Corn grain cropland harvested (acres)
Beef Cattle	11,749.400	9,985.641	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	2,594.195	10,104.730	Cows/heifers that have calved (per head cattle inventory)

Table A.4 Descriptive Information and Statistics for Idaho

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	30,900,000.000	40,100,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	157.864	233.076	Number of farm operations receiving water from the USBOR
EQIP	83,568.610	125,593.400	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	86.236	128.305	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	295.799	369.734	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	20.632	2.062	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	261,304.200	180,691.000	Total farmland operated (acres)
LCC 1-2	0.028	0.068	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.261	0.266	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	1.109	0.581	Slope of agricultural land (°)
Precipitation	89.259	36.632	Average precipitation for growing season (mm)
Minimum Temperature	8.209	1.838	Average minimum temperature for growing season (°C)
Maximum Temperature	25.983	2.123	Average maximum temperature for growing season (°C)
Commodities			
Hay	29,226.640	19,727.760	Hay cropland harvested (acres)
Wheat	27,612.690	32,871.980	Wheat cropland harvested (acres)
Corn	2,459.850	4,380.344	Corn grain cropland harvested (acres)
Beef Cattle	11,195.500	8,585.583	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	13,041.450	26,971.170	Cows/heifers that have calved (per head cattle inventory)

Table A.5 Descriptive Information and Statistics for Montana

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	14,800,000.000	13,800,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	50.536	78.807	Number of farm operations receiving water from the USBOR
EQIP	29,031.000	68,181.340	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	1.995	2.460	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	155.375	161.013	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	22.729	2.828	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	1,096,223.000	715,345.500	Total farmland operated (acres)
LCC 1-2	0.002	0.015	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.482	0.208	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.841	0.648	Slope of agricultural land (°)
Precipitation	217.872	42.551	Average precipitation for growing season (mm)
Minimum Temperature	8.150	1.950	Average minimum temperature for growing season (°C)
Maximum Temperature	24.764	1.630	Average maximum temperature for growing season (°C)
Commodities			
Hay	50,377.750	33,021.000	Hay cropland harvested (acres)
Wheat	90,433.110	115,793.000	Wheat cropland harvested (acres)
Corn	763.925	1,524.576	Corn grain cropland harvested (acres)
Beef Cattle	28,033.240	17,507.450	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	360.438	821.665	Cows/heifers that have calved (per head cattle inventory)

Table A.6 Descriptive Information and Statistics for Nevada

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	8,380,933.000	7,491,771.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	30.000	82.029	Number of farm operations receiving water from the USBOR
EQIP	39,777.060	86,058.590	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	36.381	47.698	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	69.651	97.141	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	18.571	3.413	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	387,892.400	551,237.100	Total farmland operated (acres)
LCC 1-2	0.000	0.000	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.001	0.006	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.650	0.287	Slope of agricultural land (°)
Precipitation	45.259	24.776	Average precipitation for growing season (mm)
Minimum Temperature	8.834	1.800	Average minimum temperature for growing season (°C)
Maximum Temperature	28.573	2.048	Average maximum temperature for growing season (°C)
Commodities			
Hay	33,367.070	33,116.970	Hay cropland harvested (acres)
Wheat	709.473	1,743.072	Wheat cropland harvested (acres)
Corn	5.163	21.289	Corn grain cropland harvested (acres)
Beef Cattle	17,808.920	23,824.300	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	1,902.312	3,980.072	Cows/heifers that have calved (per head cattle inventory)

Table A.7 Descriptive Information and Statistics for New Mexico

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	11,100,000.000	25,800,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	93.212	201.037	Number of farm operations receiving water from the USBOR (#)
EQIP	22,434.360	72,282.360	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	37.827	59.896	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	48.191	71.446	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	21.139	3.734	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	1,310,244.000	704,857.900	Total farmland operated (acres)
LCC 1-2	0.001	0.003	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.047	0.129	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.487	0.309	Slope of agricultural land (°)
Precipitation	213.504	63.077	Average precipitation for growing season (mm)
Minimum Temperature	12.020	3.128	Average minimum temperature for growing season (°C)
Maximum Temperature	29.131	2.623	Average maximum temperature for growing season (°C)
Commodities			
Hay	10,671.360	10,509.590	Hay cropland harvested (acres)
Wheat	10,136.040	28,583.690	Wheat cropland harvested (acres)
Corn	1,304.041	5,223.247	Corn grain cropland harvested (acres)
Beef Cattle	16,207.870	8,916.688	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	13,992.840	23,746.310	Cows/heifers that have calved (per head cattle inventory)

Table A.8 Descriptive Information and Statistics for Oregon

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	25,100,000.000	32,600,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	105.528	179.398	Number of farm operations receiving water from the USBOR
EQIP	50,603.940	80,511.090	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	37.853	55.530	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	125.870	173.594	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	19.847	1.614	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	455,545.800	411,922.800	Total farmland operated (acres)
LCC 1-2	0.253	0.226	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.533	0.330	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	1.090	0.443	Slope of agricultural land (°)
Precipitation	101.576	46.527	Average precipitation for growing season (mm)
Minimum Temperature	8.258	1.569	Average minimum temperature for growing season (°C)
Maximum Temperature	24.214	1.906	Average maximum temperature for growing season (°C)
Commodities			
Hay	27,723.750	32,796.500	Hay cropland harvested (acres)
Wheat	24,381.680	60,300.000	Wheat cropland harvested (acres)
Corn	971.068	3,434.195	Corn grain cropland harvested (acres)
Beef Cattle	17,388.340	18,569.710	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	4,475.639	7,692.200	Cows/heifers that have calved (per head cattle inventory)

Table A.9 Descriptive Information and Statistics for Utah

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	8,945,000.000	12,600,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	118.586	160.176	Number of farm operations receiving water from the USBOR
EQIP	43,446.140	138,742.100	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	14.789	27.252	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	120.695	101.621	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	22.021	1.782	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	402,009.900	471,153.400	Total farmland operated (acres)
LCC 1-2	0.010	0.031	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.090	0.138	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	1.296	0.515	Slope of agricultural land (°)
Precipitation	126.121	28.229	Average precipitation for growing season (mm)
Minimum Temperature	9.745	2.220	Average minimum temperature for growing season (°C)
Maximum Temperature	26.783	2.234	Average maximum temperature for growing season (°C)
Commodities			
Hay	23,472.720	20,637.620	Hay cropland harvested (acres)
Wheat	5,395.308	11,749.700	Wheat cropland harvested (acres)
Corn	759.502	1,252.297	Corn grain cropland harvested (acres)
Beef Cattle	12,448.590	8,735.342	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	3,792.922	4,862.143	Cows/heifers that have calved (per head cattle inventory)

Table A.10 Descriptive Information and Statistics for Washington

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	45,800,000.000	77,500,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	144.590	344.498	Number of farm operations receiving water from the USBOR
EQIP	43,013.900	119,715.400	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	17.636	39.713	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	66.448	167.404	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	19.562	2.075	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	383,917.700	448,211.100	Total farmland operated (acres)
LCC 1-2	0.100	0.097	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.488	0.214	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	1.019	0.593	Slope of agricultural land (°)
Precipitation	113.567	78.708	Average precipitation for growing season (mm)
Minimum Temperature	9.314	0.975	Average minimum temperature for growing season (°C)
Maximum Temperature	23.017	2.849	Average maximum temperature for growing season (°C)
Commodities			
Hay	20,244.210	29,188.710	Hay cropland harvested (acres)
Wheat	56,655.780	103,916.600	Wheat cropland harvested (acres)
Corn	3,472.358	10,423.720	Corn grain cropland harvested (acres)
Beef Cattle	8,039.473	7,462.706	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	7,710.851	16,624.240	Cows/heifers that have calved (per head cattle inventory)

Table A.11 Descriptive Information and Statistics for Wyoming

Variable	Mean	Std. Dev.	Variable Definition (units)
Farm Income			
NCFI	12,000,000.000	11,200,000.000	Aggregate net cash farm income of the operations ($)
Policy and Water			
USBOR	86.565	131.337	Number of farm operations receiving water from the USBOR
EQIP	76,743.090	145,978.000	Direct payment for Environmental Quality Incentives Program Ground and Surface Water Conservation Program ($)
Groundwater irrigation	18.168	38.096	Groundwater irrigation withdrawals in millions of gallons per day (M/gal/day)
Surface water irrigation	166.490	117.230	Surface water irrigation withdrawals in millions of gallons per day (M/gal/day)
Demographic			
Experience	20.326	1.981	Principal operators average years on present operation (yrs)
Physical			
Total land in farms	1,311,719.000	690,337.500	Total farmland operated (acres)
LCC 1-2	0.002	0.010	Proportion of farmland in non-irrigated Land Capability Class 1-2
LCC 1-3	0.211	0.263	Proportion of farmland in non-irrigated Land Capability Class 1-3
Slope	0.586	0.320	Slope of agricultural land (°)
Precipitation	165.008	53.917	Average precipitation for growing season (mm)
Minimum Temperature	7.799	2.335	Average minimum temperature for growing season (°C)
Maximum Temperature	25.345	2.112	Average maximum temperature for growing season (°C)
Commodities			
Hay	51,593.170	28,868.170	Hay cropland harvested (acres)
Wheat	6,237.532	15,114.900	Wheat cropland harvested (acres)
Corn	2,735.974	6,426.248	Corn grain cropland harvested (acres)
Beef Cattle	34,971.580	16,077.280	Cows/heifers that have calved (per head cattle inventory)
Dairy Cattle	387.332	715.287	Cows/heifers that have calved (per head cattle inventory)