The Endangered Species Act and Agriculture: A Study of Water Restrictions

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Abstract:

The periodic curtailment of water exports from the Sacramento-San Joaquin Bay Delta to protect fish species listed under the Endangered Species Act represents a perennial source of conflict between environmental and agricultural interests in Central California. This paper seeks to quantify the relationship between the restriction of water exports and the resulting economic losses to farmers measured in terms of employment and value of production. Using a difference-in-difference framework to compare the San Joaquin Valley to the neighboring Sacramento Valley, this paper finds that there are demonstrable losses to employment but not annual value produced. It then makes the inference that these results occur because farmers have the ability to re-optimize crop mixes in response to the amount of available water.

Introduction

In this paper I examine the effects of court-ordered restrictions on irrigation exports from the Sacramento-San Joaquin Bay Delta to the San Joaquin Valley. The restrictions were ordered in 2008, 2009, and 2013 in order to protect critical habitat of the delta smelt, an endangered fish species listed under the Endangered Species Act (ESA). I use Sacramento Valley as a control region, running a difference-in-difference regression to determine the effects of the reduced water supply on agricultural value and employment.

The San Joaquin Valley might feasibly be considered the heartbeat of California's agricultural economy. In 2011, California produced the most agricultural value of any state in the county with $43 billion in cash receipts, nearly $15 billion more than the next highest state. The same year, 7 of the 10 highest agriculture-producing counties in California belonged to the San Joaquin Valley, with Fresno County topping the list at nearly $7 billion in agricultural value (California Agricultural Statistics Report, 2012). Likely holding the distinction of the most agriculturally productive region in the country and perhaps the world, the valley accounts for approximately 37% of the state's production and processing. Over one third of the region's jobs are related to farming, as are nearly the same proportion of goods and services produced in terms of dollar value (Paggi, 2011).

Equally as impressive is California's network of irrigation and water delivery systems that makes agriculture possible. Figures from the US Department of Agriculture estimate that irrigated acreage accounted for approximately 7.3 million acres in the state, receiving about 22.6 million acre-feet of water per year (Paggi, 2011). Integral to the San Joaquin Valley's gargantuan agricultural output is the Sacramento Bay Delta. This vast confluence of streams and estuaries marks the meeting place of the San Joaquin and Sacramento Valleys, both of which form the broader 'Central Valley'. Situated as the centerpiece of a north-to-south water conveyance system, the Delta receives water runoff from 50% of California's stream-flow and from about 40% of California's land area (Ingebritsen et al., 2000). Figure 1 illustrates the Delta's hydrologic and infrastructural importance to California.

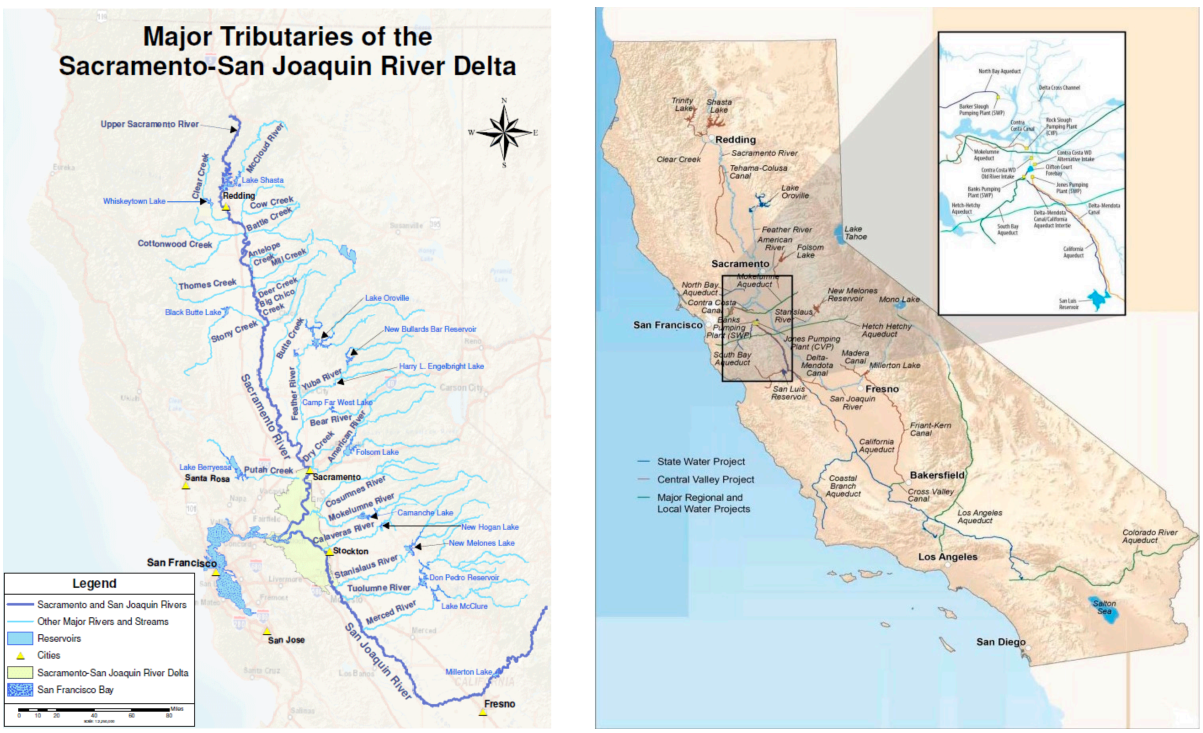


Figure 1. **Left**: Illustration of California's network of rivers and tributaries that feed into the Delta; source: State Water Resources Control Board. **Right**: Delta's pivotal position with regard to water delivery infrastructure; source: deltacouncil.ca.gov

Historically, the Sacramento Bay Delta is no stranger to adverse environmental and ecological effects caused by urban and agricultural withdrawals. Effects include but are not limited to land subsidence due to groundwater pumping (Ingebritsen et al, 2000), adverse water quality from pesticides (Pereira et al, 1996), and threats to species that inhabit the Delta's estuaries. The Delta hosts a number of species that are listed as endangered or threatened under both Federal and State environmental legislation, the most iconic and controversial of which being an endemic fish species known as the Delta Smelt. Following the species' listing in 1993 has been nearly three decades of controversy between agricultural, environmental, and urban stakeholders. The value of the smelt lies in its role as an 'indicator species', serving as a proxy for the overall ecological health of the delta.

Perhaps the most noticeable economic impacts of the Endangered Species Act (ESA) with regard to the Delta have been the periodic curtailment of water exports from the Delta in attempts to salvage the population of the smelt. Compounded with the effects of drought and climate change, these curtailments pose a continual difficulty to the agricultural economic agents of the San Joaquin Valley. In accordance with a 2008 Biological Opinion issued by the US Fish and Wildlife Service, flows are required to be curtailed from January through early summer when certain biological triggers are met. A visualization of yearly water exports from two of the Delta's biggest irrigation conveyance projects is shown in Figure 2. Deliveries from the state water project drop to almost a quarter of the maximum values at the advent of the executive actions in 2008.

Table 1

	State Water Project Exports (Acre-Feet)	Central Valley Project Exports (Acre-Feet)
2000-2014 Average	1,380,887	1,135,712
2008	606,560	925,277
2009	914,613	977,997
2013	929,757	753,855

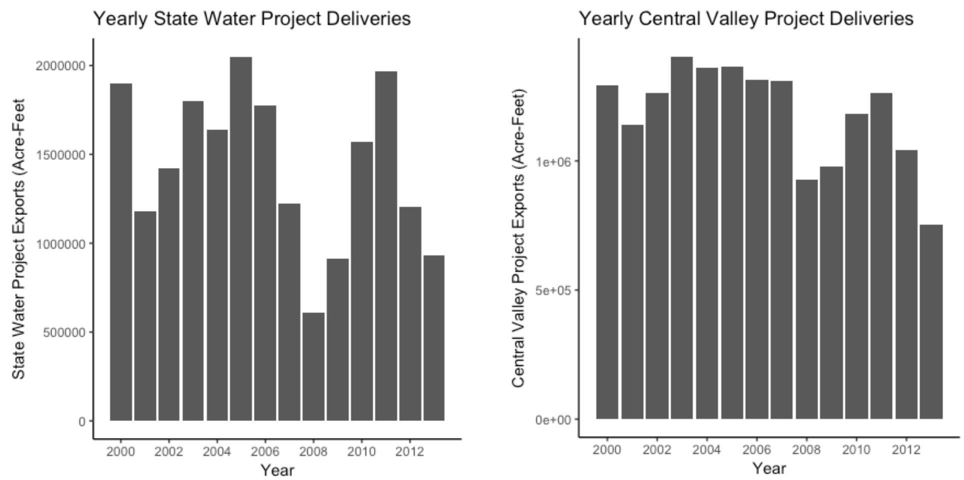


Figure 2. Table of Project exports in Acre-Feet; data source: DWR Dayflow

Economic evaluations of economic impacts due to water limitations can be confounding for a number of reasons. The duration of agricultural employment is highly susceptible to seasonal fluctuations and variations. Deciding on an adequate measure of employment can be contentious. In addition, the use of undocumented labor by agricultural producers adds another dimension of difficulty to measures of employment, one that goes beyond the scope of this paper.

Further complicating matters is the distribution of impacts across the region. California's water rights structure is one of prior appropriations (Gopalakrishnan, 1973), giving senior water rights to those who obtained them at an earlier date. The unequal curtailment of water among junior and senior appropriators is likely to lead to an unequal distribution of losses at the county and the region levels.

Climate change poses yet another obstacle to a quantitative analysis of policy impacts. The impacts of climate change have been such that climate extremes such as drought and heat wave are likely to occur simultaneously. In 2014, California's aridity was worse than any year recorded in more than 100 years of observations (AghaKouchak et al., 2014). The difficulty in disentangling the effects of environmentally-motivated restrictions from drought is self-evident.

The curtailments that this paper chooses to analyze follow a Biological Opinion offered by the US Fish and Wildlife Service in 2008 determining that the uninhibited operations of the State Water Project (SWP) and Central Valley Project (CVP) are detrimental to the smelt's survival. The decision-making structure for the projects' flows is governed by the USFWS Smelt Working Group, typically meeting biweekly during the smelt's spawning season.

The question that this paper seeks to answer is the extent to which curtailments in 2008, 2009 and 2012 have affected the economies of the agricultural counties reliant upon the San Joaquin Bay Delta for irrigation. It contributes to the literature by comparing the economic effects of curtailments across different periods as well as by examining the effects with regard to certain crops. The paper uses a difference in difference framework in order to control for drought and statewide factors that affect agricultural production. I consider agricultural employment and output as dependent variables.

Literature Review

Much like other American environmental legislation, the Endangered Species Act is prohibited from taking into account cost-benefit analysis when considering the protection of species that are listed as endangered. The seminal ESA ruling on cost-benefit analysis derives from the Supreme Court case Tennessee Valley Authority v. Hill (1978). The court's majority ruling enjoined the construction of Tellico Dam, a public works project which would have destroyed critical habitat for an endemic fish species known as the Snail Darter. Cameron and Russel (1981) note that the passage of the ESA and the subsequent ruling in TVA v. Hill is evidence that the death of even one species, anywhere, is a disaster to be avoided at nearly all costs. Put another way, the congressional goal of species preservation is to be pursued regardless of ‘countervailing costs, values, and equities’.

The Endangered Species Act purports to be science-driven law rather than an economically expedient one. Section 4 requires the species and critical habitat listing criteria to be based “solely on the basis of the best scientific and commercial data available”. The controversial section 7 requires all federal agencies to ensure that the actions they carry out, fund, or authorize do not "jeopardize" the continued existence of listed species or result in "adverse modification" of their critical habitat (United States Endangered Species Act, 1973). Sagoff (1981) claims that the United State’s environmental legislative framework beginning in the 1960s fails to make economic ‘common sense’. Weighing the benefits of the existence of the Delta Smelt with the economic losses of the restrictions would make little sense in this respect. For the purposes of this paper then, the intent of the Endangered Species Act is to place an infinite value on the continued preservation of endangered species. As the injunction on water flows is done with purely biological concern and no cost-benefit analysis, we treat the action as purely exogenous to the Central Valley’s aggregate agricultural production function and do not consider the value of the smelt’s preservation.

Geerts and Raes (2009) review the crop water production function (CWP function), which maps the relationship between marketable yield (Y_a) and amount of water consumed by the crop (otherwise known as Relative evapotranspiration, ET_a). A graph of water productivity, measured as the ratio of yield to evapotranspiration exhibits a logistic shape. The authors divide the graph into four sections that might be said to exhibit low, increasing, leveling, and decreasing marginal products of water with regard to crop yield. The first, characterized by low ET_a experiences a low-quality yield with little market value or even total loss of yield (Yazar and Sezen, 2006). While physical yield per unit of water is one important consideration when optimizing crop mix, the Geerts and Raes also contend that the nutritional value of water inefficient crops might make them more desirable in drought-prone areas.

Although the literature is virtually in consensus that reduced water flows are responsible for a downturn in employment, the degrees to which these estimates account for job loss are far from incontrovertible. Howitt et al. (2009) discuss methods used to estimate the impact of restrictions in 2009. One common source of employment data for California agriculture is the state's Employment Development Department (EDD) database. The authors note that using the EDD's employment statistics do not account for the differences in water rights across counties. They use the example of Fresno County, whose east side has stronger water rights relative to its west side. They also note that although agricultural employment is commonly temporary, the EDD statistic reports all jobs as Full Time Equivalent (FTE) jobs. Any deviation in 'baseline' employment can be attributed in large part due to seasonality. Additionally, the authors discuss the particular way in which the data is collected. EDD counts employee who works during the week of the 12^{th} day of the month towards its monthly employment count. Shifts in other industries (the paper gives construction as an example) can lead to a surfeit of laborers willing to work in agriculture. Knowing this, it is important to consider the possibility that more workers might be working, albeit for fewer hours. This information has the potential to bias upwards our estimates. Howitt et al. also consider Michael's (2009) assertion that labor intensity of agriculture has declined as evidenced by an increase on output and a decrease in employment. The authors contend that although there is a slight downturn in the production to output ratio in the early 2000s, the increase in agricultural productivity does not exhibit enough of a constant trend to cause a job shortage in its own right.

Sunding et al. (2011) use Bureau of Economic Analysis data to compare six San Joaquin Valley counties to six counties that do not receive Sacramento Delta water. The authors find that 444 acre-feet of water were associated with one job during 2009. Their estimates pertain to both livestock and crop-harvesting employment. While the paper speculates that the loss in jobs is due to an increase in fallowed acres, it does not examine crop-specific employment or value of output.

Economic Theory

A proof of concept of agricultural behavior can be obtained by an analysis of total acres harvested within particular counties. Data measuring total harvested acres and those of individual crops is available in annual individual county crop reports. I collect data from three of the most prominent San Joaquin area counties: Kings, Kern, and Fresno. I plot total harvested acres of field crops, fruits, nuts, and vegetables in Figure 3.

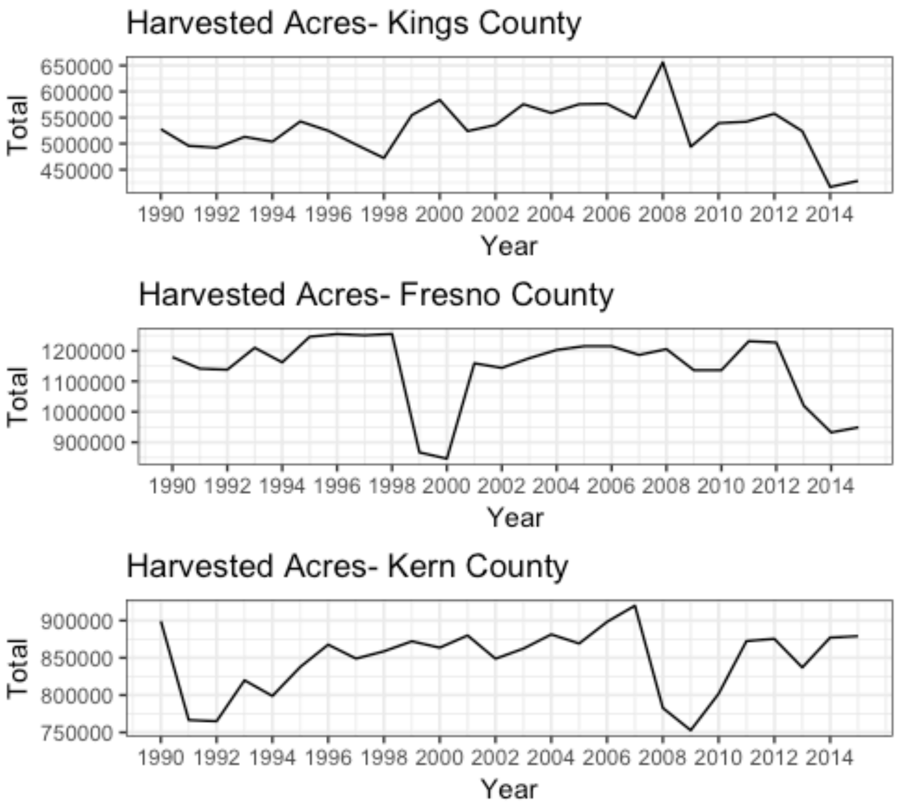


Figure 3. Total Harvested Acres for three of the San Joaquin Valley's top producing counties

While it is apparent that each county observes its own time trends and supply shocks, it should be noted that all counties experience a decline in harvested acres in 2009 and 2013.

The notion that water curtailments have a noticeable impact on agricultural markets necessarily involves an inference about the agricultural production function. We assume that a farmer solves an optimization problem similar to (1).

(1)

$$\textbf{maximize } \text{Value}_{it} = \text{Price}_{it} * \text{Output}_{it}$$

$$\textbf{subject to: } \text{Output}_{it} = f(\text{Water}_{it}, \text{Land}_{it}, \text{Labor}_{it}, \text{Technology}_{it})$$

Similarly, we can assume that demand for agricultural labor by firms is a function of potential agricultural output. Thus we can accept a function along the lines of:

(2) $$\textbf{Employment}_{it} = \textbf{g}(\textbf{PotentialOutput}_{it}, \textbf{Policy}_{it})$$

Barring technological efficiency and groundwater replacement, the elasticity of output with respect to surface water deliveries is highly inelastic. The possibility of groundwater replacement is discussed later. Hypothetically, because water is positively correlated with potential output, as Geerts and Raes discussed, a reduction in this input ought to reduce the output as well as the demand for labor in the agricultural sector. For these reasons, I predict that the periods of restriction will be accompanied by a statistically significant downward shift in employment and value produced.

Data

In order to control for climate, I use data from The University of Nebraska-Lincoln's United States drought monitor. The drought monitor classifies six categories of drought, and uses data from field stations in order to estimate what percentage of a given county is experiencing each category in a given week. The classification of drought ranges from 'None' to 'Exceptional Drought'. Classification of each category is based off of five drought indicators which account for factors such as soil moisture, precipitation, and stream-flow. A table of descriptive statistics is given in Table 2. The drought stage D0 has the highest mean of all indicators, suggesting that the most frequent condition in both the Sacramento and San Joaquin regions is light drought.

Table 2

San Joaquin				
Statistic	Mean	St. Dev.	Pctl(25)	Pctl(75)
None	40.1	47	0	100
D0	59.9	47	0	100
D1	43.2	47.2	0	100.
D2	27.7	42	0	68.7
D3	13.7	33.3	0	0
D4	9.3	28.4	0	0
Sacramento				
Statistic	Mean	St. Dev.	Pctl(25)	Pctl(75)
None	43.4	47.3	0	100
D0	56.6	47.3	0	100
D1	41.3	46.7	0	100
D2	25.3	41.3	0	48.6
D3	13.2	32.8	0	0
D4	5.9	22.4	0	0

Price data is obtained obtained from the United States Department of Agriculture's National Agricultural Statistics Service. I use survey data represented by price indices for fruit, vegetables, and total crops at the national level and anchored to year 2011. One assumption underlying the use of a national price index is that farmers face the same price for outputs around the county. Given that California exported 26% of its agricultural production by volume in 2015 (CDFA 2015), it is not an unreasonable assumption that a national price index affects farmer behavior in California. Figure 4 plots each of the three price indices for which I control. Fruit and nut prices experience the most consistent growth, achieving a level 20% higher than the value to which it is anchored in 2011.

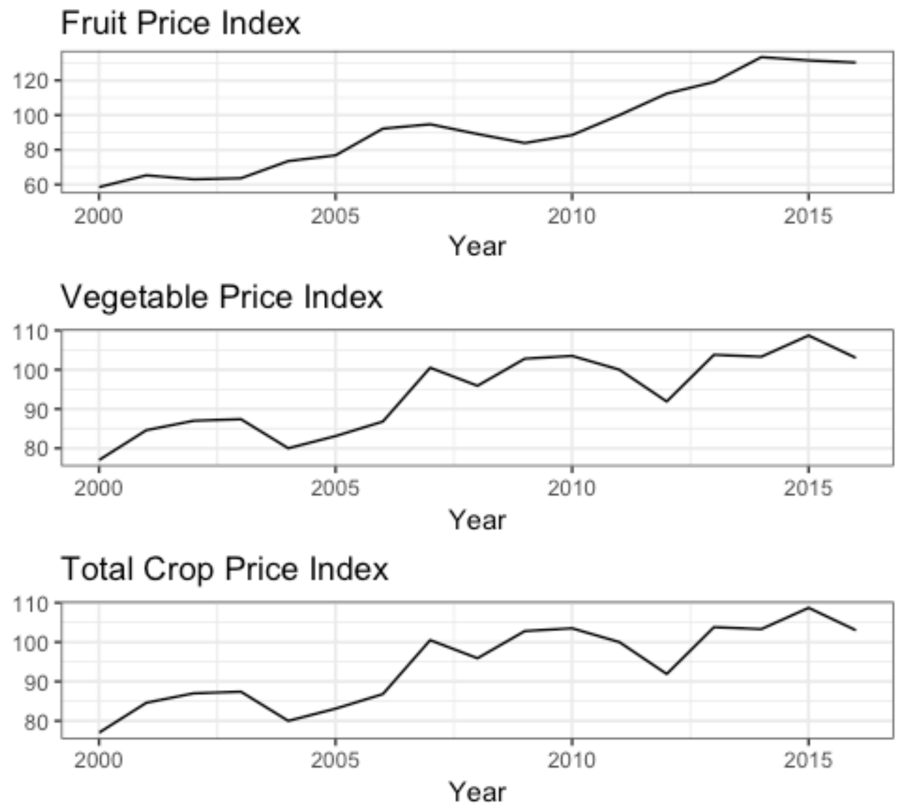


Figure 4. Crop Price Index Graphs

Finally, for my dependent variables I use employment and value of output. Employment estimates come from both the California Employment Development Department (EDD) and the Bureau of Labor Statistics. One advantage of EDD agricultural employment can be divided into sub-industries. The three that I use for the purpose of my analysis are total crop production, fruit and nut employment, and vegetable and melon employment. A major drawback to the EDD model is that monthly data is aggregated at the region rather than the county level, including many areas in the San Joaquin and Sacramento Valleys that have low agricultural output. If we assume that these counties are associated with both low agricultural employment and low fluctuations, then this does not have the potential to bias the results significantly. Figure 5 shows the Sacramento and San Joaquin Valleys as defined by the Employment Development

Department and the US Department of Agriculture. Additionally, the data includes number of employees rather than labor hours.

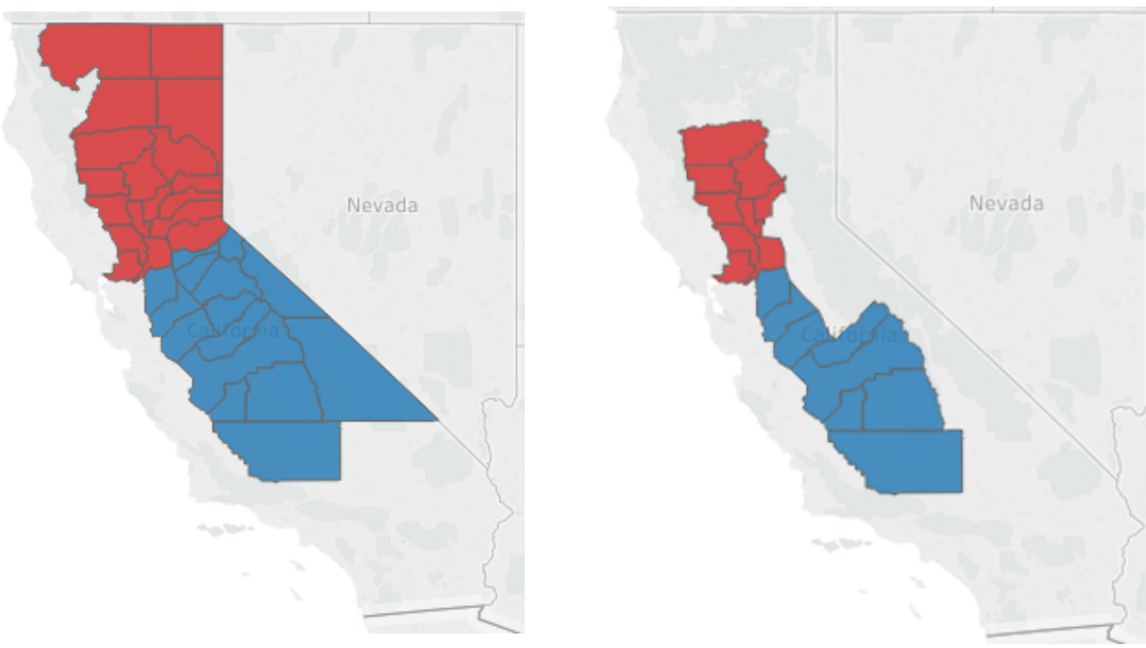


Figure 5. Red counties indicate the Sacramento Valley while blue counties indicate the San Joaquin. The left panel represents The California Employment Development Department's definition of the Sacramento and San Joaquin Valleys while the right illustrates the USDA's regional definitions

The fundamental characteristics of the regions that make them of interest in this paper are their relation to the Sacramento Bay Delta. While the Sacramento receives irrigation from streams which eventually feed into the Delta, the San Joaquin Valley receives a significant portion of its irrigation from the Delta itself (LAO, 2015). The underlying assumptions in the difference-in-difference model run in this paper are twofold. Firstly, this paper assumes that the valleys are similar enough in composition that they respond similarly to conditions that affect their agricultural economies. Secondly, their different relation to the Delta must mean that actions affecting the Delta are likely only to affect the San Joaquin Valley. Because the Sacramento Valley receives little irrigation from the Delta, this assumption is satisfied.

Data concerning agricultural output comes from the California County Agricultural Commissioners' Reports, an annual publication based on annual county crop reports. One caveat when using data from Commissioners' Reports is that it is a compilation of data reported by different methods by individual counties. Different sources for data include grower surveys, regulatory and inspection data, shipment data, etc. In addition, the level of detail reported varies by county.

While employment data is available at the month level, data regarding output is recorded on the year level. As the restrictions do not occur on a whole-year basis, estimates involving agricultural value are far less precise and must be taken in context with the other estimates that this paper makes.

Methodology

The curtailments ordered by the US Fish and Wildlife Service's Smelt working group limit water diversions by ordering that pumping not exceed an average rate over a designated period of time. Therefore, the model includes a dummy variable denoting the period of restrictions of water curtailment. Determinations were given biweekly beginning in early winter and lasting through June. Accordingly, my dummy variable takes on a value of one for the months during which the restrictions are issued. A San Joaquin Valley dummy and San Joaquin/ Restriction interaction term are also included. The coefficient on the San Joaquin/ Restriction interaction variable theoretically captures the effect of the restrictions on the San Joaquin Valley by comparing it to the otherwise similar Sacramento Valley (or, more concisely, to its usual relation to the Sacramento Valley). I run separate regressions for each restrictions period in order to determine whether effects are common to most periods. I experiment with a lagged dependent variable that takes a value of one for the remaining months of the year after the curtailments have abated. The lagged dependent variables are included to measure any changes in farmer behavior when water becomes available again directly after curtailments.

The reasoning for the use of a difference-in-difference model is the existence of a handful of factors that are likely to correlate the coefficient on the Restrictions dummy variable with the error term. I add controls to strengthen the parallel trends assumption. The dependent variables I examine are value of production and employment. The San Joaquin dummy variable represents time invariant fixed effects that are particular to the San Joaquin region. Because the effects of the restrictions period across both regions are controlled for by the restrictions dummy, the restrictions and San Joaquin interaction term is meant to give the 'true' effect of the restrictions on the San Joaquin region. The model is summarized as follows, with Y_i representing either agricultural employment or value of production. Month fixed effects are only used with the employment model, as value of production is measured at the year level.

$$\textbf{(3)}\quad Y_i = \alpha + \beta_1\text{*Trend} + \beta_2\text{*Year Fixed Effects}_t + \beta_3\text{*Month Fixed Effects}_t + \beta_4\text{*Drought Indicators}_{it} + \beta_5\text{*Price Index}_t + \beta_6\text{*San Joaquin}_i + \beta_7\text{*Restrictions}_t + \beta_8\text{*Restrictions}_t\text{*San Joaquin}_i + \varepsilon$$

Factors that might bias the direction and magnitude of the estimation of the effect of the restrictions on the San Joaquin Valley in a standard OLS regression include drought and economic conditions. Figure 6 illustrates drought levels during the first week of 2008, 2009, and 2012. Especially severe in the first two years of restriction that I examine, drought has the potential to bias downward the estimate of the Restrictions dummy in a panel that includes only San Joaquin County. One possible pitfall is that the drought is not evenly distributed across region, as panel 3 of Figure 6 suggest. For this reason, drought controls are included in the difference-in-difference model.

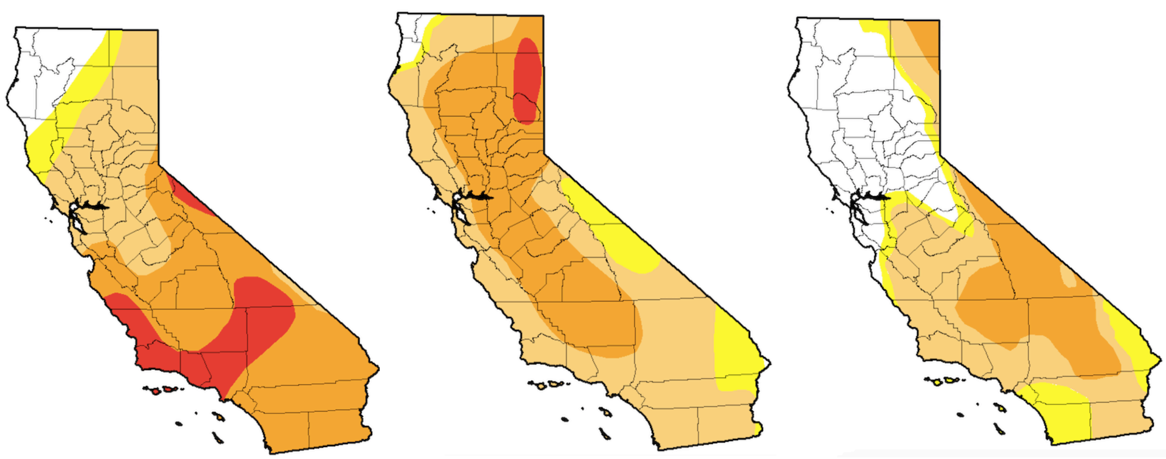
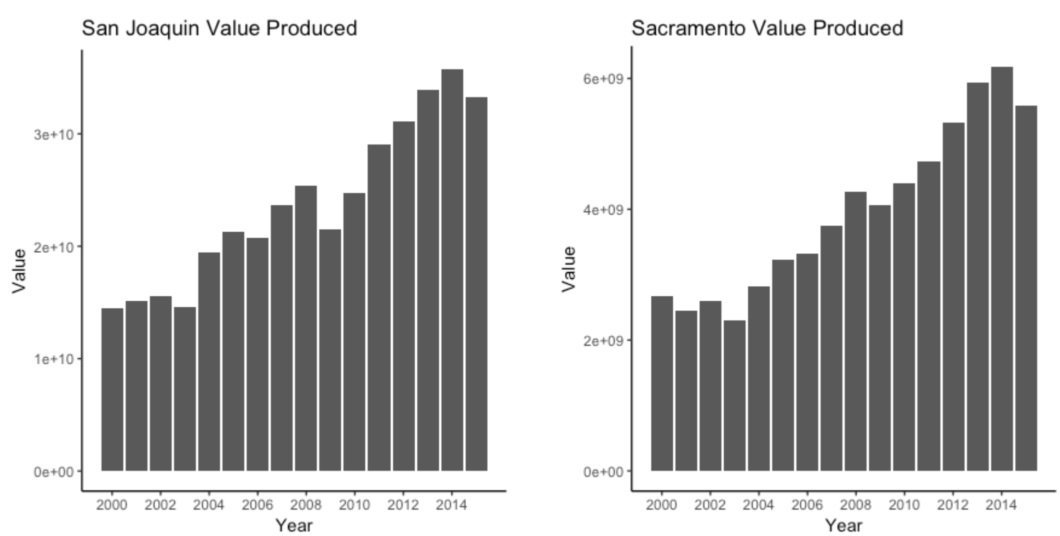


Figure 6. Drought map of California during the first week of January in 2008, 2009, and 2013; source: droughtmonitor.unl.edu

Economic factors might also bias results from standard OLS regression. The first two years of restrictions coincide with the 2008-2009 economic crisis. The possible effects of this are at least two-fold. First, as Michael (2009) notes, the downturn of the construction industry is likely to have flooded the agricultural labor market with temp workers, shifting the agricultural labor supply curve outward and making the effects of restriction appear less severe in my model.

Secondly, consumers may have demanded cheaper crops, biasing the effects of the restrictions on fruits and nuts downwards while biasing the effect on lower value crops upward. Although theoretically this bias should be filtered out by a difference-in-difference equation, I include fruit, vegetable, and total crop price indices as controls.

Counties north of the San Joaquin Bay Delta receive little to no water from the California State Water Project and Central Valley Project, meaning that the advent of restrictions is likely to have little effect on these counties. The parallel-trends assumption in this model holds that the time trend conditions that affect agricultural employment in the San Joaquin and Sacramento Valleys are otherwise similar. Realistically we can surmise that the regions' geographic proximity make this a somewhat reasonable assumption. Figure 7 compares the regions' employment and output trends. Both counties see an increasing trend in agricultural output as well as a relatively stable pattern of yearly employment. The cause of the increase in output is likely multifaceted. As the total crop price index in this paper's data exhibits a statistically significant upward trend, it is likely that both counties respond similarly to market incentives. Additionally, it can be



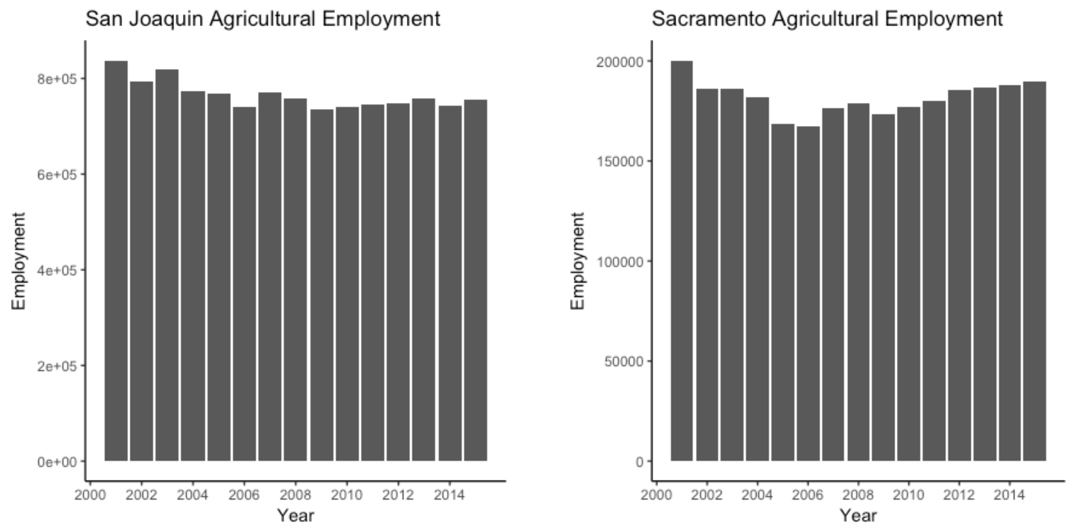


Figure 7. The top two panels plot agricultural value produced while the bottom two plot employment related to crop production. Although the sizes of the two regions differ, the similarity in trends suggests that they are similarly responsive to exogenous factors that affect both counties and that a parallel trends assumption holds.

speculated that both counties adopt similar technologies, as evidenced by the increase in output and stable employment.

Results

This paper's model finds a statistically significant decrease in crop-production related employment during two of the three restrictions in my data set.

The 2009 restrictions are consistent with a reduction in agricultural employment of about 4000 while 2013 saw a loss of about 7500. Although the t-statistic on the 2008 difference-in-difference term is not significantly negative, the reductions in 2009 and 2013 are significant at the 1% level. Coefficients on the restriction dummy, San Joaquin Valley dummy, and interaction term of each difference-in-difference equation is shown in Table 3. The regression tables included in this section omit the coefficient for the most control variables.

Table 3. Differenced Employment

	2008 (1)	2009 (2)	2013 (3)
2008 Restrictions	1,751.625 (2,278.239)		
2009 Restrictions		3,110.358* (1,679.217)	
2013 Restrictions			5,588.082*** (1,868.334)
San Joaquin	48,578.250*** (516.049)	48,774.740*** (536.843)	48,740.710*** (517.473)
2008 Restrictions*San Joaquin	**-2,047.846** **(2,739.796)**		
2009 Restrictions*San Joaquin		**-4,198.199***** **(1,572.499)**	
2013 Restrictions*San Joaquin			**-7,410.736***** **(1,696.108)**
Constant	2,453,545.000*** (792,477.600)	2,314,375.000*** (779,644.200)	2,530,730.000*** (790,567.800)
Notes:	***Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.		

Fruit-and-nut-related employment does not drop in any period of restrictions while vegetable-related employment is associated with a decline of about 600 jobs in the San Joaquin Valley during the 2013 restrictions, suggesting that farmers maintained production on higher-value nut and fruit crops. For the purpose of this analysis, 'fruit' refers to both fruit and nut production.

Table 4. Differenced Crop Employment

	Vegetable 2008 (1)	Vegetable 2009 (2)	Vegetable 2013 (3)	Fruit 2008 (4)	Fruit 2009 (5)	Fruit 2013 (6)
2008 Restrictions	-293.483			1,140.358		
	(309.342)			(1,699.966)		
2009 Restrictions		140.351			1,319.518	
		(372.570)			(1,308.814)	
2013 Restrictions			91.473			1,684.719
			(349.455)			(1,464.522)
San Joaquin	$7{,}033.135^{***}$	$7{,}041.756^{***}$	$7{,}055.751^{***}$	$32{,}200.510^{***}$	$32{,}275.040^{***}$	$32{,}205.850^{***}$
	(120.317)	(123.475)	(121.151)	(391.898)	(410.414)	(399.966)
2008 Restrictions*San Joaquin	**137.528**			**-1,333.705**		
	(248.443)			**(2,440.570)**		
2009 Restrictions*San Joaquin		**-103.695**			**-1,829.929**	
		(344.189)			**(1,309.424)**	
2013 Restrictions*San Joaquin			**-599.833^{**}**			**-1,517.415**
			(269.454)			**(1,404.036)**
Constant	-135,017.200	-142,942.700	-115,326.300	852,073.200	794,002.200	846,977.700
	(170,346.500)	(171,292.800)	(172,733.700)	(600,315.400)	(600,826.000)	(604,585.900)

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Total crop production employment for the remainder of the year following the restrictions does not show a significant change with the exception of 2009, which saw an increase of about 4,000 workers. However, coefficients on almost all lagged difference-in-difference terms see a highly significant increase when analyzing fruit and vegetable employment.

Table 5. Differenced Lagged Crop Employment

	Vegetable 2008	Vegetable 2009	Vegetable 2013	Fruit 2008	Fruit 2009	Fruit 2013
	(1)	(2)	(3)	(4)	(5)	(6)
2008 Restrictions Lagged	-247.657			-2,006.379		
	(409.760)			(1,708.100)		
2009 Restrictions Lagged		-526.126			-1,383.733	
		(352.024)			(1,504.233)	
2013 Restrictions Lagged			-1,392.757**			-4,449.769***
			(624.363)			(1,706.404)
San Joaquin	6,998.250***	6,980.802***	6,938.379***	31,982.980***	32,055.870***	31,911.790***
	(120.235)	(119.884)	(118.488)	(394.357)	(402.458)	(402.516)
2008 Restrictions Lagged*San Joaquin	**904.193****			**4,363.728*****		
	(433.334)			**(1,493.084)**		
2009 Restrictions Lagged*San Joaquin		**1,192.122*****			**2,618.041***	
		(441.304)			**(1,337.003)**	
2013 Restrictions Lagged*San Joaquin			**2,193.329*****			**5,573.921*****
			(466.439)			**(1,265.283)**
Constant	-171,417.400	-147,292.100	-210,719.300	884,017.100	896,157.600	756,704.800
	(134,107.800)	(144,086.300)	(161,061.700)	(605,597.100)	(628,050.400)	(599,648.800)

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Total value of production in the San Joaquin Valley does not show a statistically significant change during any of the three restriction periods. When evaluating the change in value for fruit, vegetable, and field crops individually, all coefficients are also insignificant.

Because production data is available at the county level rather than the region level, it is possible to include the counties that are more agricultural. In particular, I narrow the included counties to those included in the San Joaquin and Sacramento Valleys by the USDA rather than the Employment Development Department (shown in Figure 5). Even with the more selective dataset, value of fruit and nut production is the only coefficient to show a statistically significant change, increasing by $800,000,000, significant at the 5% level.

One shortcoming of this paper's difference in difference model is that the amount of agriculture in the San Joaquin region is much larger. Even though the two regions experience similar trends, a proportional change in San Joaquin employment is likely to be much larger in absolute terms than a change of the same proportion in Sacramento. To explore this, I run the same model again with the dependent variable proportionate to values from years without restrictions. For my employment model, the dependent variable becomes the employment of a given month divided by the average employment for that month in non-restriction years. I find that no employment model has two significant difference-in-difference coefficients for the three periods except for vegetable employment, which shows a reduction of 36% during the restrictions in 2013 and an 11% decrease during the 2009 restrictions. As for production, proportional value, which becomes a ratio of the restriction year's production value to the average value during non-restriction years, shows a 17% decrease in 2013 and a 12% decrease in 2009. One limitation to the proportional models is that the yearly average might be biased upward by unusually high employment or production in some years (making the dependent variable in restriction years proportionally smaller). As shown earlier, both the San Joaquin and Sacramento Valleys exhibit an upward trend in value produced within the paper's dataset, meaning that the dependent variable may not be an accurate measure of actual output to potential output.

Conclusion

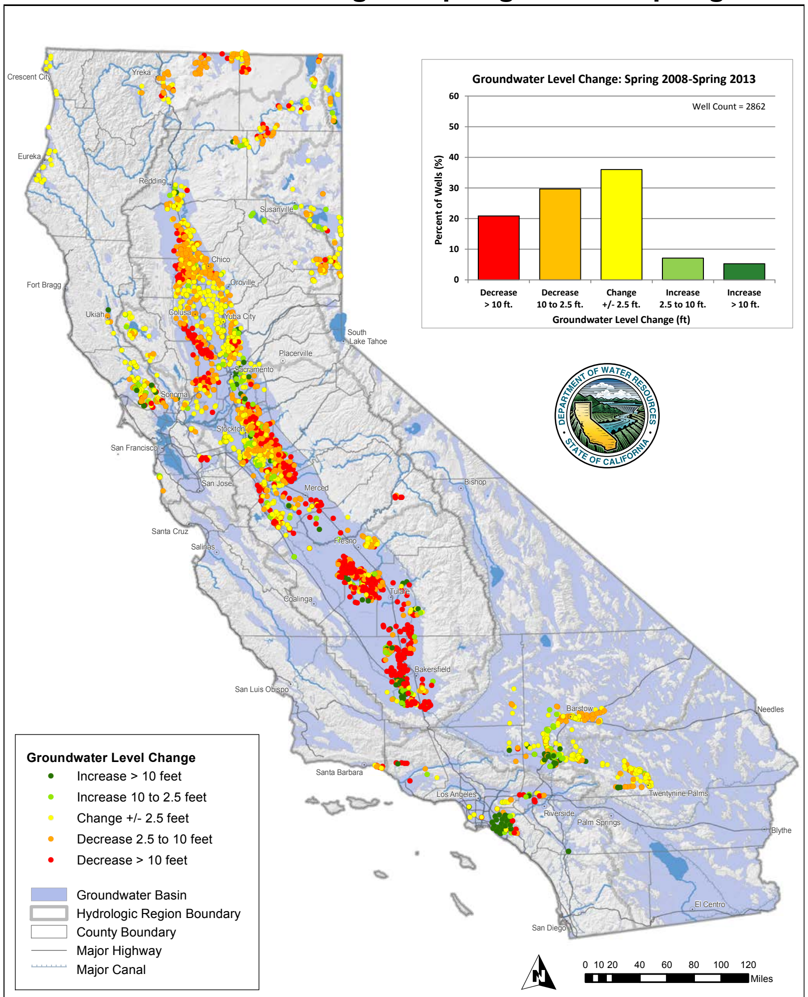
This paper has examined the economic impacts of ESA-driven water curtailments on the San Joaquin Valley. While the finer details of the effects are difficult to discern, some insight can be taken from the analysis.

As I expect in my hypothesis, there exists a notable pattern of reduction in employment during restriction periods. Despite the insignificance of the 2008 difference-in-difference coefficient, the strength of the following two periods' restrictions make this a reasonable interpretation. Reasons for the insignificance could perhaps be the result of the timing associated with the implementation of the restrictions. While the Delta Smelt Working Group's curtailment recommendations began in February for 2009 and December (2012) for 2013, the 2008 curtailments did not gain momentum until early March of that year.

The strongest result that this paper found in its analysis is an increase in San Joaquin fruit and vegetable related employment in the months following the restrictions, with only one coefficient less significant than 1%. One possible explanation for this could be farmers' expectations of future curtailments affecting decisions to produce while irrigation is available. The fact that fruit and nut employment increased significantly while total employment did not is suggestive of the fact that farmers invested in crops that were higher value. In an analogous situation, Howitt et al. (2015) note that California agriculture's resilience in the face of the 2012-2015 drought is due to a shift to higher value crops. Similarly, it is possible that a re-optimization is the reason that no significant loss of agricultural value is seen in this paper's model. With regard to vegetables, farmers may have chosen to plant annuals with shorter growing seasons when water was available in order to fill acres which were fallowed during the restricitions.

Additionally, an increased reliance on groundwater has likely mitigated economic losses due to curtailments, at least in the short run. In normal years groundwater accounts for about 40% of California's water supply, but in some regions can account for nearly 60% in times of water scarcity (DWR 2014). Famiglietti et al. (2011) contend that when farmers face cuts in managed surface water allocations, groundwater use rates are likely to exceed replenishment rates. Over multiple decades slow groundwater recharge, population growth, decreasing snowpack, and continued withdrawal would lead to unsustainable groundwater management practices. Figure 8 illustrates groundwater pumping between 2008 and 2012. The greatest preponderance of pumping appears to occur in the upper and lower ends of the San Joaquin Valley. Insofar as farmers can compensate for reduced irrigation by adopting efficient technology or re-optimizing crops, this paper's results regarding value of production is encouraging. However, if losses to value were mitigated more by slow-replenishing groundwater, the results call into question California agriculture's ability to adapt to curtailments and water scarcity in general.

Groundwater Level Change* - Spring 2008 to Spring 2013



*Groundwater level change determined from water level measurements in wells. Map and chart based on available data from the DWR Water Data Library as of 04/28/2014. Document Name: S2013-S2008_20140428 Updated: 04/28/2014 Data subject to change without notice.

Figure 8. Map of California critical groundwater basins; source: www.water.ca.gov

References

Paggi, Mechel. " California Agriculture's Role in the Economy and Water Use Characteristics ." *Center for Irrigation Technology, Fresno State University, November. http://fresnostate.edu/jcast/cab/documents/pdf/Appendix-1-Economics-12-7-2.pdf* (2011).

AghaKouchak, A., L. Cheng, O. Mazdiyasni, and A. Farahmand (2014), Global warming and changes in risk of concurrent climate extremes: Insights from the 2014 California drought, Geophys. Res. Lett., 41, 8847–8852, doi:10.1002/2014GL062308.

"California Department of Food and Agriculture." *CDFA*. California Department of Food and Agriculture, 2015. Web. 18 Mar. 2017.

Caswell, Margriet, and David Zilberman. "The choices of irrigation technologies in California." *American journal of agricultural economics* 67.2 (1985): 224-234.

Coggins, George Cameron, and Irma S. Russell. "Beyond shooting snail darters in pork barrels: endangered species and land use in America." *Geo. LJ* 70 (1981): 1433.

Department of Water Resources. *Public Update for Drought Response Groundwater Basins with Potential Water Shortages and Gaps in Groundwater Monitoring*. By William Crole, David Gutierrez, Jon Ericson, Manucher Alemi, Dane Mathis, and Mary Scruggs. N.p.: n.p., n.d. Print.

Famiglietti, J. S., et al. "Satellites measure recent rates of groundwater depletion in California's Central Valley." *Geophysical Research Letters* 38.3 (2011).

Geerts, Sam, and Dirk Raes. "Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas." *Agricultural water management* 96.9 (2009): 1275-1284.

Gopalakrishnan, Chennat. "The Doctrine of Prior Appropriation and Its Impact on Water Development: A Critical Survey." *The American Journal of Economics and Sociology*, vol. 32, no. 1, 1973, pp. 61–72., www.jstor.org/stable/3485791.

Howitt, Richard, et al. "Economic analysis of the 2014 drought for California agriculture." *Center for Watershed Sciences, University of California, Davis* (2014).

Howitt, Richard, Josué Medellín-Azuara, and Duncan MacEwan. "Measuring the employment impact of water reductions." *Department of Agricultural and Resource Economics and Center for Watershed Sciences. University of California, Davis, California, available at http://swap. ucdavis. edu* (2009).

Ireland, Richard L., Joseph Fairfield Poland, and Francis Stevenson Riley. *Land subsidence in the San Joaquin Valley, California, as of 1980*. US Government Printing Office, 1984.

Michael, Jeffrey, Shaun Callahan, and Andrew Padovani. "Unemployment in the San Joaquin Valley in 2009: Fish or Foreclosure?." *Eberhardt School of Business: Business Forecasting Center, University of the Pacific* (2009).

Pereira, Wilfred E., et al. "Occurrence and accumulation of pesticides and organic contaminants in river sediment, water and clam tissues from the San Joaquin River and tributaries, California." *Environmental Toxicology and Chemistry* 15.2 (1996): 172-180.

Sagoff, Mark. "Economic theory and environmental law." *Michigan Law Review* 79.7 (1981): 1393-1419.

Sunding, D.L., K.C. Foreman and M. Auffhammer. 2011. "Water and Jobs: The Role of Irrigation Water Deliveries on

Agricultural Employment." *ARE Update* 14(4):9-11. University of California Giannini Foundation of Agricultural Economics.

TVA v. Hill, 437 U.S. 153, 98 S. Ct. 2279, 57 L. Ed. 2d 117 (1978).

United States. Legislative Analyst's Office. *Achieving State Goals for the Sacramento-San Joaquin Delta*. By Anton Favorini-Csorba and Brian Brown. N.p.: n.p., 2015. Print.

United States. United States Geological Survey. *Delta Subsidence in California: The Sinking Heart of the State*. By S. E. Ingebritsen, Marti E. Ikehara, Devin L. Galloway, and David R. Jones. N.p.: U.S. Dept. of the Interior, U.S. Geological Survey, 2000. Print.

United States. US Fish and Wildlife Service. California and Nevada Region. *Formal Endangered Species Act Consultation on the Proposed Operations of the Central Valley Project and State Water Project*. Sacramento: n.p., 2008. Print.

Yazar, Attila, and S. Metin Sezen. "Effects of full and deficit irrigation on yield and water use efficiency of winter wheat in the arid southeast Anatolia region of Turkey." *Proceedings of the 1st International Symposium on Land and Water Management for Sustainable Irrigated Agriculture, CD-rom*. 2006.