2023

Farmer adoption of water practices across four counties in California

Hannah Dekker
University of Vermont

Meredith Niles
University of Vermont

Recommended Citation

Dekker, Hannah and Niles, Meredith, "Farmer adoption of water practices across four counties in California" (2023). *UVM Honors College Senior Theses*. 539.
https://scholarworks.uvm.edu/hcoltheses/539

Farmer adoption of water practices across four counties in California

Hannah Dekker[1], Meredith T. Niles[1, 2]
[1] **Department of Nutrition and Food Sciences, University of Vermont, Burlington VT**
[2] **Gund Institute for Environment, University of Vermont, Burlington VT**

Abstract

Climate change is deeply impacting agriculture, including water availability, which is affecting farmers' ability to have enough water to continue growing crops. In California, a large agricultural producer where drought frequency and intensity has increased in recent years, the state recently enacted the Sustainable Groundwater Management Act (SGMA). This study explores what influences farmers to adopt future water management practices, specifically water intensive practices, water reduction practices and water technology practices. Six hundred and ninety farmers across four California counties responded to a mail survey asking them about their perceptions on SGMA, farm characteristics, and on-farm practices in 2017 and 2019. The hypothesis of this study is that farmers who grow very water intensive crops, such as almonds and walnuts, will be the most likely to intend to implement water intensive practices and less likely to intend to implement water conservation or water technologies in the future versus farmers of crop types whose crops are less water intensive. A multivariable linear regression assessed whether farm and farmer characteristics such as age, income, acres managed, succession plan status, county location (Yolo, San Luis Obispo, Madera, and Fresno), education, and awareness of voluntary programs to see if these factors influenced farmer adoption. Unlike hypothesized, there is no effect of crop type on farmer adoption of any water practices, though other farm and farmer characteristics are significantly correlated. Furthermore, farmers are most likely to implement water technology practices overall, with less preference for water extraction and practices that use less water. These results suggest that farmers are more willing to use their water more efficiently, rather than accessing more water or using less water.

Keywords: SGMA, water management practices, succession plan, drought, groundwater, surface water

Introduction

Water is a critical resource in agricultural production as crops require water to thrive. Agriculture is the largest user of water worldwide, compared to any other industry, accounting for nearly 70% of total freshwater withdrawals (United Nations, 2017). However, climate change is making it harder for farmers to have enough water to continue growing their crops (United States Environmental Protection Agency, n.d.). Climate change can also contribute to decreased crop yields, through multiple mechanisms. Droughts cause the soil to become drier, minimizing available water for crop growth, while increased, more erratic and intense precipitation can also cause decreased crop yields through water logging (McDonald, 2021). Increasingly, irrigation is being recommended in many regions as technological fixes for addressing water shortages, “irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification,” (The World Bank, 2022). However, as water availability remains questionable in many regions as a result of climate change, irrigation may also be increasingly unreliable.

California has the largest agriculture sector in the United States, employing over 420,000 people and generating more than $50 billion in annual revenue (Escriva-Bou et al., 2022). California’s agriculture includes more than 400 commodities. California grows over a third of the vegetables and three-quarters of the fruits and nuts grown in the country (California Department of Food and Agriculture, 2022). California’s top 10 agricultural commodities in

2021 were dairy products, which are valued at $7.57 billion, grapes at $5.23 billion, almonds at $5.03 billion, cattle and calves at $3.11 billion, strawberries at $3.02 billion, pistachios at $2.91 billion, lettuce at $2.03 billion, tomatoes at $1.18 billion, walnuts at $1.02 billion, and rice at $1 billion (California Department of Food and Agriculture, 2022).

Despite being an agricultural powerhouse, California is also prone to droughts, and during droughts, groundwater provides up to 60% of the water supply in the state (Langridge & Van Schmidt, 2020). There is increasing demand for water for both people and environmental purposes (Wagner & Niles, 2017). Forty to eighty percent of total water supplies are used through irrigated agriculture in California (Johnson & Cody, 2015). “The 2020 and 2021 water years constituted the second-driest two-year period since records began in 1895, and the driest since the 1976–77 drought,” (Escriva-Bou et al., 2022). In 2021, there were very warm temperatures, almost 3.5F above the 20th century average. These unusually warm temperatures caused an 8% increase in crop demands for water (Escriva-Bou et al., 2022). These recent events highlight that changes need to be made to account for the decreasing water in the state, as well as changing conditions (Dennis et al., 2020).

In response to the growing prevalence of drought and dwindling supply of water, in 2014, the Sustainable Groundwater Act (SGMA) was passed by the California legislature. The components of SGMA include the formation of Groundwater Sustainability Agencies (GSAs), which are formed by local agencies in the areas with water basins that are designated as high and medium priority (Dennis et al., 2020). California categorized their 515 groundwater basins into four categories: high, medium, low or very low-priority, based on the groundwater supplies of the region and how much they rely on these sources, as well as, economic development, population, and indicators of groundwater resource conditions (Dennis et al., 2020). High and medium priority basins are a subset of basins that have been identified as “critical overdraft”, meaning that these basins had been identified as showing substantial degradation from excessive use.

The role of the GSAs is to develop Groundwater Sustainability Plans (GSPs), which determine how the groundwater basins will achieve sustainability by avoiding the six undesirable results and reduce overdraft of the basins by 2040 (California Department of Water Resources, n.d.). Achieving sustainability is defined as, “avoiding six undesirable results: chronic lowering of groundwater levels, reduction in groundwater storage, seawater intrusion, degraded water quality, land subsidence and depletions in interconnected surface water” (California Department of Water Resources, n.d.). The groundwater sustainability plans must be reviewed and approved by the state. If a local agency doesn’t meet the law’s requirements, the State Water Resources Control Board can take over the basin and implement its own plan (Dennis et al., 2020).

The Sustainable Groundwater Management Act is a new way of performing environmental governance of water ecosystems and allocation in California, which has historically relied on voluntary organizations to manage groundwater. Instead, SGMA is utilizing government agencies and a variety of local entities to oversee the implementation process through a common pool resource governance structure. Groundwater is a common pool resource and when groundwater levels are low it can impact entire communities if wells start to go dry and there is a potential for infrastructure damage (Lubell et al., 2020). SGMA has led to innovations in supply management to help manage lowering groundwater (Lubell et al., 2020). The development of common-pool resource governance structures has become a dominant environmental governance approach worldwide (Méndez-Barrientos et al., 2020). A drought in California from 2011-2016 resulted in reduced surface water, which led to adaptations to farmer practices, including increased groundwater pumping. During this drought, the reliance on groundwater in California increased 20% (Méndez-Barrientos et al., 2020). Prior to SGMA being passed, groundwater pumping was mostly unregulated; only 14% of water agencies had developed voluntary groundwater management plans before the passing of SGMA (Méndez-Barrientos et al., 2020).

Farmer perspectives on SGMA and water management have been previously studied through focus groups in Yolo County, CA (Wagner & Niles, 2017). The farmers in the focus group (n=20) felt that there were issues with water allocation by the state, as the water may not be allocated in a way to benefit them (Wagner & Niles, 2017). Water use in Yolo County is used for both agricultural and non-agricultural reasons, and farmers reported that new drivers are changing the landscape, including an increase in permanent crops, urbanization and new agricultural development of previously uncultivated areas (Wagner & Niles, 2017). Droughts in recent years have led to an increase in the use of groundwater for irrigation. They also expressed that there are quality issues with the irrigation water, as it contains salts and boron (Wagner & Niles, 2017). The farmers also reported impacts of water changes, such as, access to water and economic challenges (Wagner & Niles, 2017). Access to water has changed as surface water availability has become inconsistent (Wagner & Niles, 2017). Economic challenges include extra costs for pumping groundwater and farms investing in water infrastructure (Wagner & Niles, 2017). Farmers in the focus group discussed some ways they have had to adapt to the lack of water including buying crop insurance, fallowing land, changing crops, purchasing water, monitoring wells and digging new wells (Wagner & Niles, 2017). These focus groups also asked farmers explicitly about SGMA, and farmers expressed seeing common sense design, which means that SGMA would need to have implementable long-term sustainable solutions for water use in agriculture (Wagner & Niles, 2017). Other perspectives early on in the SGMA process included desires for “bottom-up processes”, a perception that farmers weren’t included in the SGMA processes to date, and a desire for inclusion because farmers have knowledge surrounding their local water supply and their knowledge should be valued to create a unique plan that pertains to their geographic area (Wagner & Niles, 2017).

Given the implementation of the SGMA policy, as well as the high reliance of agriculture on water, farmers are a critical stakeholder. It is likely that farmers will need to implement new management practices and technologies to respond to changing conditions, both ecologically and politically. Therefore, it is important to understand what factors may influence farmers to adopt water management practices in the future, to help California agriculture manage droughts and water allocation, as well as under extreme events and new policy systems. However, previous research demonstrates there are many barriers for farmers to adopt sustainable management practices. These barriers may include economic factors, with income playing a role, if a farmer lacks the financial resources to make a change, then they are unable to make the change even if they are willing to implement these changes (Mills et al., 2016). Sustainable management practices on farms can be expensive to implement, which may also be a barrier for adoption; however, some practices may have a reduced input cost or could lead to fuel and labor savings in the future which may motivate adoption of that practice (Ranjan et al., 2019). Some other barriers that contribute to adoption of these management strategies includes profitability, market conditions, labor availability or government regulations (Lane et al., 2018). Financial incentives in the form of cost-share programs may overcome some of these issues and positively influence the adoption of conservation practices (Pradhananga & Davenport, 2019). Attitudes, behavior, environmental awareness, farm characteristics, information (seeking or using information), economic factors and operator characteristics, including education and age of the farmer (Adusumilli & Wang, 2018), are all factors that can influence the adoption of conservation practices (Prokopy et al., 2019).

In California, implementation of new practices may be especially challenging for some crop types and regions, as California grows many water intensive crops. The dilemma with California growing water intensive crops is that these farms are suffering from droughts and frequently have limited access to water, while also now needing to respond to SGMA changes. Four major California crops – almonds, walnuts, alfalfa, and rice – accounted for 41% of total sales but 73% of California's total water footprint in 2014. Almonds alone are estimated to be 25% of total sales, but 42% of the total water footprint (Fulton et al., 2019). California grows about 80% of the world's almonds (Fulton et al., 2019). Wine grapes, table grapes, strawberries, pistachios, and oranges accounted for more sales than almonds at 35%, but these crops are less water intensive only accounting for 13% of the total water footprint (Fulton et al., 2019).

Given the differences in water intensity and needs of varying crops, this research explores the role of crop types and other farm and farmer demographics on the intended future adoption of a suite of different water management practices, including water intensive, water reduction, and water saving technology approaches. I hypothesize that farmers who grow very water intensive crops, such as almonds and walnuts, will be the most likely to intend to implement water intensive practices and less likely to intend to implement water conservation or water technologies in the future versus farmers of crop types whose crops are less water intensive.

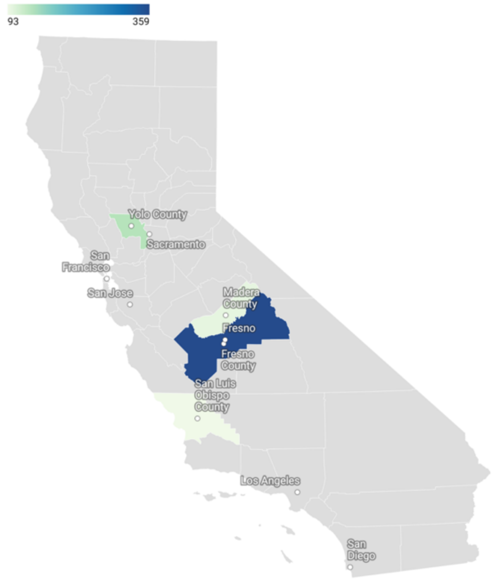
Methods

Data Collection

A survey was developed to assess farmer perceptions of groundwater issues, on-farm practices, farm characteristics, and SGMA perceptions and participation. The survey was originally developed and deployed in Yolo County, California in 2017, which was informed by focus groups with farmers in the areas (Wagner & Niles, 2017). In 2019, the survey was refined slightly for updated SGMA conditions and deployed in three additional counties in the Central Valley and Central Coast including Fresno, Madera, and San Luis Obispo. In all four counties, collaborations with the county Farm Bureaus were established and the Farm Bureaus promoted the survey to their members. In Fresno, Madera, and San Luis Obispo, this also included letters from the Farm Bureau, which accompanied the mail survey.

This survey utilized the Dillman method to increase response rate, which first sent a postcard to farmers to announce the survey (Dillman et al., 2014). Then, a mail survey was distributed to all farmers in the County, which were identified through public records of Pesticide Use Reports, as well as through Organic certification records. Duplicate farms/farmers were removed. Farmers that did not respond were sent a postcard reminder two weeks after the first mailing. A second survey was mailed to farmers approximately one month after the first if they still did not respond.

There was a total of 690 farmer responses: 359 responses from Fresno County, 101 from Madera, 93 from San Luis Obispo and 137 from Yolo County (Figure 1). Response rates across the surveys varied between 15 and 25% across the four counties. Given the farmer populations of these regions, these response rates correspond to a margin of error +/- 3%.



Yolo County-137 responses Madera- 101 responses Fresno- 359 responses San Luis Obispo-93 responses
Created with Datawrapper

Figure 1: California counties where the survey was implemented.

Variables and Analysis

This analysis uses several different variables, to account for different explanations of why farmers might be intending to adopt these water practices in the future. Demographic and farm characteristics include education, income, age, whether the farmer had a succession plan, the amount of acreage that the farmer owned or managed, as well as the type of crops that were grown on this land. Other variables included farmers' involvement in voluntary programs and their familiarity with the programs was assessed. Future intended use of water practices was another variable identified to assess whether farmers will use conservation, technological, or water intensive practices in the future. All variables are further explained in Table 1.

Table 1: Variables used in this study, including the survey question and scale.

Variable	Questions	Scale
Education	What is the highest level of formal education you completed?	1=Some high school 2=High school diploma 3=Trade school, apprenticeship or on job training 4=College education-no degree 5=College education-associate degree 6= College education-bachelor's degree 7=Graduate education-master's degree 8=Graduate education-doctorate degree
Income	What is your approximate yearly household gross income, including all on farm and off-farm incomes?	1=Less than $40,000 2=40-60k 3=60-80k 4=80-100k 5=100-150k 6=150-200k 7=200-500k 8= More than 500k 9= Prefer not to answer
Age	In which year were you born?	
Crop Type Binary	In a typical year, how much of the following crops, animals or land do you manage/own (acres)?	1= any acreage of a given crop type 0= no acreage of a given crop type Crop Types: fruit crops, nut trees, row crops, seed crops, vegetables, rice, grain, table grapes, vineyard grapes, hay
Succession Plan	Do you have a farm succession plan for after you retire?	-yes/no/partial 0=no 1=partial 2=yes
Acreage	How many total acres do you manage (all land owned, leased or managed)	

Involvement in Programs	Does your farm participate in any of the following voluntary programs?	-Agricultural Conservation Easement Program, California Agricultural Water Enhancement and Efficiency Program, California Landowner Incentive Program, California State Water Enhancement and Efficiency Program, Conservation Reserve Program, Environmental Quality Incentives Program, Organic/biodynamic certification If there was a yes response to any of the voluntary programs it was coded as a 1, if there wasn't a response it was coded as a 0
Future use of water practices	Please indicate, in response to water scarcity, if you currently use the following practices and your likelihood to use the following practices in the future.	Future use levels: 1= very likely 2= Unlikely 3= Somewhat unlikely 4= Somewhat likely 5= Likely 6= Very Likely -Drill more wells, restore existing wells, make existing wells deeper, pump more groundwater than previous years, drip irrigation, water monitoring technology, fallow fields, soil moisture sensors, change to a less water intensive crop, reduce livestock stocking rates, leaf sampling to measure plant-water status, purchase additional water, purchase crop insurance
Future water use intensive	Drill wells, restore wells, deepen wells, more groundwater, purchase water, crop insurance	Continuous variable, with increments between one (very unlikely) and 6 (very likely)
Future water use technology	Drip irrigation, monitoring, soil sensors, leaf sampling	
Future water use less	Fallow, less water, reduce stocking rates	

Since crop type is identified by farmers indicating the amount of acreage, they grew of a given crop, these variables were transformed to create binary variables that identified whether a farmer grew any amount of a given crop. Binary variables were generated for all the crop types including fruit trees, nut trees, row crops, seed crops, vegetables, rice, grain, table grapes, vineyard grapes, and grapes (which combined table grapes and vineyard grapes into one variable) and hay. In addition, future water practice intention variables were transformed from Likert variables to binary (any intention to adopt in the future or not). Finally, the voluntary program variable was converted to a binary variable to assess whether or not farmers were aware of any of a suite of voluntary programs (Agricultural Conservation Easement Program, California Agricultural Water Enhancement and Efficiency Program, California Landowner Incentive Program, California State Water Enhancement and Efficiency Program, Conservation Reserve Program, Conservation Stewardship Program, Environmental Quality Incentives Program and Organic/biodynamic certification).

Factor analyses were utilized to aggregate variables into similar groups. A factor analysis for the dependent variable, future water practices, determined that three clusters of practices emerged: practices that were 1) water intensive (i.e. drill more wells, restore existing wells, make existing wells deeper, pump more groundwater than previous years, purchase additional water and purchase crop insurance); 2) practices that use less water (i.e. fallow fields, reduce livestock stocking rates and change to a less water intensive crop); and 3) practices related to water technology (i.e. drip irrigation, water monitoring technology, soil moisture sensors and leaf sampling to measure plant water status) (Table 2). Using best practices to determine if these groups fit together, the eigenvalue had to be greater than 1, factor loadings had to be greater than

0.4 (Costello and Osborne 2005) and the Cronbach's alpha greater than 0.7 (Peterson 1994), which was true for all three grouped water intention variables.

Table 2: Factor analysis results for three future water intension practices.

Variable	Eigenvalue	Factor Loading	Alpha
Future Intensive Water (futurewaterints)	2.735		0.729
Drill Wells		0.675	
Restore Wells		0.758	
Deepen Wells		0.705	
More Groundwater		0.705	
Purchase Water		0.628	
Crop Insurance		0.562	
Future Less Water (futurewaterless)	1.97		0.716
Fallow		0.811	
Less Water		0.829	
Reduce Stocking Rates		0.791	
Future Water Technologies (futurewatertech)	2.882		0.88
Drip Irrigation		0.756	
Monitoring		0.9	
Soil Sensors		0.894	
Leaf Sampling		0.838	

An additional factor analysis for the binary crop type variables organized crop types into three categories: nut trees, fruit trees and a third crop category including mixed crops and vegetables; hay, grain, rice, vegetables, seed crops, and row crops (Table 3). The expected outcome is that crop type 1, which is predominantly nut trees, will be correlated with less adoption of water conservation and technology practices and more correlated with water intensive practices. Finally, a series of multivariable linear regression models predicted likely intended future adoption of the three suites of water practices. Stata 17.0 was utilized for all analyses.

Table 3: Factor analysis results for crop types.

Variables	Factor 1	Factor 2	Factor 3	Uniqueness
Fruit Trees	-0.147	**2.153**	0.62	-4.041
Nut Trees	**3.375**	0.122	-0.055	-10.411
Hay	0.009	-0.379	**0.706**	0.358
Grain	0.097	-0.31	**0.848**	0.176
Rice	0.095	-0.361	**0.797**	0.225
Grapes	-0.086	-0.134	-0.156	0.95
Vegetables	0.025	-0.212	**0.598**	0.597
Seed Crops	0.049	-0.314	**0.756**	0.328
Row Crops	0.073	-0.263	**0.639**	0.517

Results

Farmer demographics:

On average, farmer respondents were 66 years old with a range from 27 to 96. The total number of acres the farmers managed was 863 acres with a minimum of 0 acres and a maximum of 38,500 acres. The median education level of farmer respondents was a bachelor's degree (median=6). Farmer income on average ranged between $100,000-150,000 and $150,000-$200,000 ($100,000-200,000). Farmers were asked if they had a succession plan and thirty five percent responded that they did not. Farmers were also asked if they were aware of voluntary programs and seventy eight percent of farmers were aware of at least one program. The most prominent crop types were nut trees which about 47% of the farmers grew, then grapes which 37% grew, and 25% grew fruit trees (Figure 2).

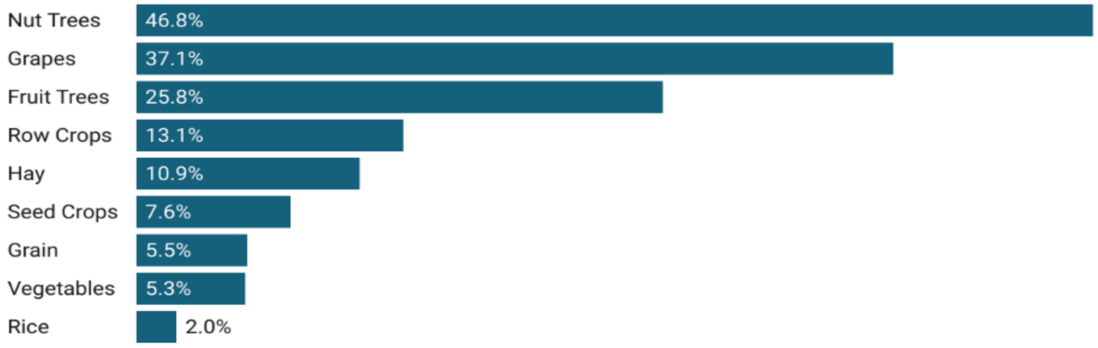


Figure 2: Percentage of Crop Types Farmers Grow

Farmers indicated a variety of intention to adopt the three types of water management practices (Figures 3,4,5). For water intensive practices, crop insurance (which can enable farmers to continue to grow water intensive crops) was most likely to be adopted in the future (47%), while restoring wells (46%) and drilling new wells (41%) were the second and third most likely future behaviors. Water management practices that could reduce overall water use were less common overall among respondents. Twenty-seven percent of farmers indicated they would fallow fields, 19% use less water and 12% reducing livestock stocking rates. Finally, farmers had the highest likelihood of adopting water technology practices in the future with 74% saying they would adopt drip irrigation, 69% using water monitoring technology and 67% adopting soil sensors.

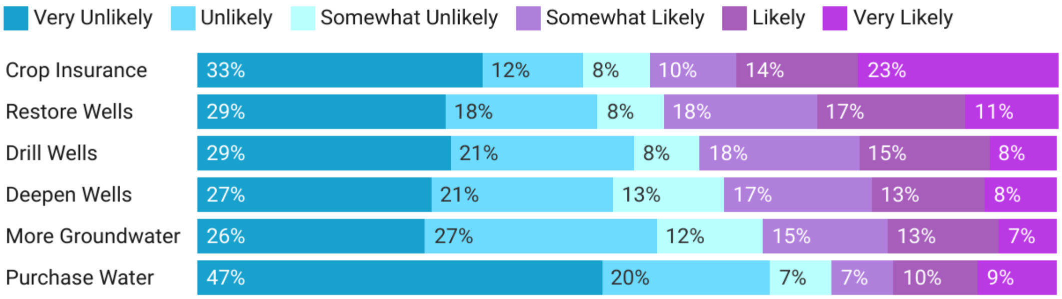


Figure 3: Farmers' Likelihood of Adopting Water Intensive Practices in the Future

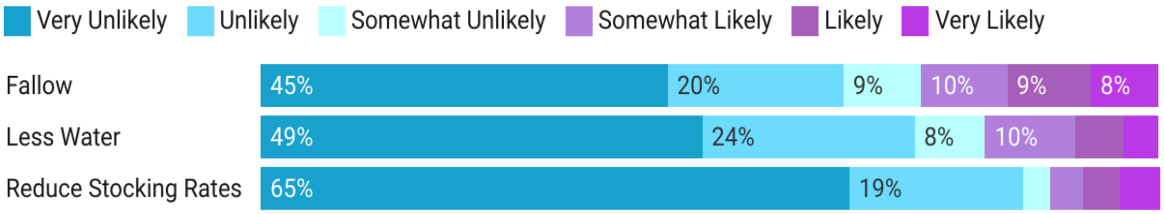


Figure 4: Farmers' Likelihood of Adopting Water Reduction Practices in the Future

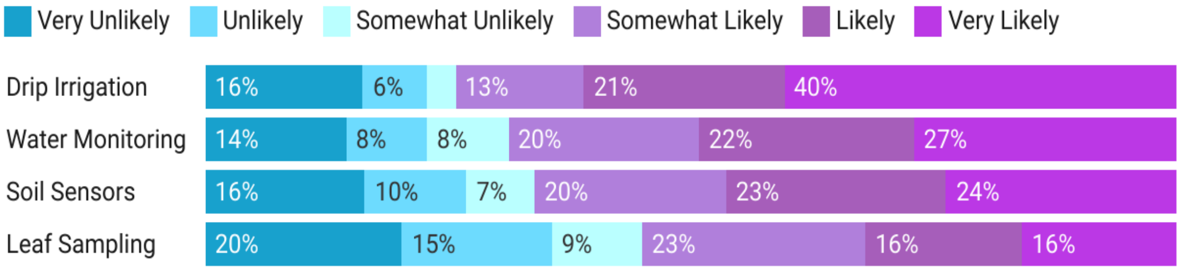


Figure 5: Farmers' Likelihood of Adopting Water Technology Practices in the Future

Statistical analyses

Three multivariable regression models analyzed the factors that correlate with intention to adopt future water management practices, including those related to using less water, using more water, and water technologies. Significant correlates (p<0.10) are presented below. Farmers' intention to adopt water management practices that use less water were correlated with several other variables (Table 4). Farmers with higher income will be less likely to adopt these practices (b=-0.137, p=0.063). Farmers who were aware of voluntary programs will be more likely to adopt these practices (b=.303, p=.059).

Table 4: Model results from factors associated with intention to adopt water management practices that use less water in the future. Statistically significant (p<0.10) results are bolded for emphasis.

Variables	Coefficient	Std. err.	P value	95% confidence interval	
Education	-0.061	0.069	0.374	-0.197	0.074
Income	**-0.137**	**0.074**	**0.063**	**-0.282**	**0.007**
Total Acres Managed	0.134	0.083	0.106	-0.029	0.298
Succession Plan	-0.062	0.071	0.384	-0.200	0.077
Year Born	-0.015	0.067	0.826	-0.146	0.116
Awareness	**0.303**	**0.160**	**0.059**	**-0.011**	**0.617**
San Luis Obispo	-0.330	0.245	0.179	-0.811	0.152
Fresno	-0.265	0.19	0.165	-0.639	0.109
Yolo	-0.286	0.233	0.220	-0.744	0.172

Nut Trees	0.320	0.601	0.595	-0.862	1.502
Fruit Trees	-1.185	1.168	0.311	-3.482	1.112
Mixed Crops and Vegetables	1.047	0.641	0.103	-0.213	2.306
_cons	2.148	0.210	0.000	1.735	2.561

Farmers' intention to adopt water management practices that use more water were correlated with a number of other variables (Table 5). Farmers with more land will be more likely to use water intensive practices in the future (b=.152, p=.012). Farmers in San Luis Obispo (b=-.788, p=.001) and Yolo (b=-.547, p=.013) counties are less likely than Madera to implement water intensive practices.

Table 5: Model results from factors associated with intention to adopt water management practices that use more water in the future. Statistically significant (p<0.10) results are bolded for emphasis.

Future Water Intensive	Coefficient	Std. err.	P Value	95% confidence interval	
Education	0.028	0.062	0.653	-0.094	0.15
Income	-0.004	0.067	0.947	-0.135	0.127
Total Acres Managed	**0.152**	**0.060**	**0.012**	**0.034**	**0.27**
Succession Plan	0.049	0.064	0.442	-0.077	0.176
Year Born	0.066	0.061	0.281	-0.054	0.185
Awareness	0.098	0.146	0.502	-0.189	0.386
San Luis Obispo	**-0.788**	**0.227**	**0.001**	**-1.234**	**-0.342**
Fresno	-0.215	0.178	0.229	-0.566	0.136
Yolo	**-0.547**	**0.219**	**0.013**	**-0.978**	**-0.116**
Nut Trees	-0.876	0.546	0.109	-1.948	0.196
Fruit Trees	1.35	1.068	0.207	-0.748	3.449
Mixed Crops and Vegetables	-0.451	0.593	0.447	-1.617	0.715
_cons	3.272	0.193	0	2.893	3.650

Farmers' intention to adopt water technology practices in the future were correlated with several other variables (Table 6). The variable total acres managed (b=.184, p=.009) is associated with greater likelihood to use water technology in the future (i.e. larger farms more likely). Farmers with a succession plan (b=.218, p=.005) are more likely to use water technology in the future. The year a farmer was born (and thus their age) is correlated with a farmer using water technology in the future, (b=.280, p=0), such that younger farmers are more likely to intend to adopt. Finally, farmers aware of voluntary programs (b=.570, p=.002) are more likely to use water technology in the future.

Table 6: *Model results from factors associated with intention to adopt water technology management practices in the future. Statistically significant (p<0.10) results are bolded for emphasis.*

Variables	Coefficient	Std. err.	P Value	95% confidence interval	
Education	0.107	0.074	0.147	-0.038	0.253
Income	-0.019	0.080	0.814	-0.175	0.138
Total Acres Managed	**0.184**	**0.070**	**0.009**	**0.047**	**0.321**
Succession Plan	**0.219**	**0.078**	**0.005**	**0.065**	**0.372**
Year Born	**0.281**	**0.074**	**0.000**	**0.135**	**0.426**
Awareness	**0.570**	**0.179**	**0.002**	**0.218**	**0.923**
San Luis Obispo	-0.231	0.289	0.423	-0.799	0.336
Fresno	0.306	0.227	0.179	-0.140	0.752
Yolo	0.388	0.267	0.147	-0.137	0.913
Nut Trees	-0.259	0.664	0.697	-1.564	1.047
Fruit Trees	0.847	1.297	0.514	-1.703	3.398
Mixed Crops and Vegetables	-0.401	0.718	0.577	-1.813	1.011
_cons	3.338	0.249	0.000	2.849	3.827

DISCUSSION

This study explores the relationship of crop type and other farm and farmer characteristics to intended future adoption of water management practices among farmers in four California counties. Unlike I expected, crop type is not significantly correlated with farmer intention to adopt water management practices while controlling for other farm and farmer characteristics. Specifically, there is no evidence that nut tree agriculture is associated with greater likelihood to adopt water intensive practices or less likelihood to adopt water conservation or technology practices. Other factors such as farm size and resource access appear to be more important for water use than crop type. Farm size and awareness of other conservation-oriented programs were associated with adoption in two out of three practice types, and income, age, and presence of a farm succession plan were correlated with intended adoption of at least one type of water management practice types. Furthermore, among all water management practice types, implementation of water technologies is the most popular among farmer respondents.

Interestingly, large farms are more likely to adopt water intensive strategies, but also more likely to adopt water technologies that may reduce water use or use water more efficiently. This finding might reflect that large farms require a large amount of water, compared to small and medium sized farms, but large farms simultaneously may want to employ that water in an efficient manner. It may also suggest that large farms have more resources to afford the adoption of technological water practices (Liu et al., 2018). Large farms also often use a small portion of their land to test out a new conservation practice before adopting this practice across their entire farm (Lu et al., 2022), so their intention or ability to try new things may be more feasible than small farms. This finding may also suggest that farmers think about more than just requiring a certain amount of water, but also using their water in a more efficient way. Farmers might utilize many different strategies for water management, and to the extent that they employ the intensive ones, these results suggest that outreach and extension to large farms about water technologies may be fruitful and well received.

Small and medium farms were less likely to implement water technology practices, which may be related to concerns of the cost of implementation. Small farms may need more incentives to invest in new management practices because they lack the resources to do so on their own (Liu et al., 2018). There were some similar findings with previous literature, such as income and the cost of implementation of sustainable management practices play a role in adoption (Mills et al. 2016; Ranjan et al., 2019). Ranjan et al., found that the cost to implement a conservation practice could either hinder or motivate adoption. For example, if the cost was very high to implement a particular practice, it hindered farmers from adoption, but if a conservation practice was associated with reduced input costs, such as fuel and labor savings, it motivated farmers to adopt the practice (Ranjan et al., 2019). It may be important to target small and medium farms with programs that can help them to afford these water technologies. Farm size may also be a factor in adopt of these technologies if they are less relevant for smaller operations or designed in a way that they are harder to implement on small farms.

Several farm and farmer specific factors were also associated with adoption. Farmer awareness of other conservation programs and policies was significantly correlated with intention to adopt water technologies and use less water. Other studies have found that farmers being aware of conservation programs can influence adoption of management practices (Prokopy et al., 2019). We identify that younger farmers are more likely to want to adopt water technologies, similar to other previous literature evaluated water quality protection and water conservation/efficiency practices (Adusumilli & Wang, 2018). Finally, having a farm succession plan was positively associated with intention to adopt future water technologies, suggesting that those farms have a future plan for their farm and may be more willing to invest in the costs associated with new technologies. Prokopy et al., found that succession plans have a positive association with adoption of practices (2019).

Overall, this study also highlights that farmers are most interested in using water efficiently, rather than reducing water use altogether. The University of Massachusetts Extension Vegetable Program found that by switching to drip irrigation as much as 80% of the water that a farmer normally uses through other irrigation systems could be saved (University of Massachusetts Extension Vegetable Program, 2013). As a result, water technology practices could have an economic benefit as it can help the farmers use their water more efficiently. On the other hand, adopting water reduction practices may be less popular among farmers because it does not have a direct economic benefit, and in many cases could reduce the economic viability of a farm by fallowing fields for example. As a result, this research suggests that water savings in agriculture may be best realized through the promotion of water technologies, that maintain economic benefits but minimize water use, rather than strategies that reduce agricultural production.

Limitations

A limitation for this project, is that the Sustainable Groundwater Management Act hasn't been fully implemented as sustainability doesn't need to be achieved until 2040, so farmers perceptions and practices could change over the next 17 years. Another limitation was that only four counties in California were surveyed and they were similar geographically and climate wise. It could be interesting to get input from other counties throughout California and maybe even some states that also suffer from droughts, such as, New Mexico, Arizona, Nevada, Utah, and Texas.

Future Research

Some areas that could be researched in the future would be about specifically targeting large farms to adopt conservation practices to efficiently use water. It was confirmed through this project and previous studies that larger farms to be more likely to implement some kinds of conservation practices (water efficient technologies in this case), but that they are also more likely to implement intensive practices. Thus, it suggests that there is more nuance to the adoption of practices, not just one or the other. It suggests that there could be dual approaches, since large farms that require a lot of water also seem to be interested in using that water efficiently, rather than not using water at all or scaling back. At the same time, these practices are expensive, so larger farms have the greatest capacity to adopt them. Programs and outreach aimed at smaller and medium sized farms is important to educate and help with the implementation of water technologies available and make sure they are appropriate for the scale of their farm.

Another area of future research could revolve around how to involve more farmers in voluntary programs. Farmers who are aware of and potentially participate in voluntary programs are more receptive to shifting to conservation practices. Involvement in a voluntary program could advertise to farmers opportunities for conservation programs or technologies.

One last area for future research could be to survey farmers at different time points. The first time point could be throughout the implementation of SGMA. The second time point could be to survey farmers after different weather events occur, this might be important to influence their perceptions of the need to adopt different kinds of practices. This could be interesting to evaluate after heavy rains and flooding such as the ones experienced in California during the winter of 2023.

Conclusion

This study gives some insight about what changes farmers are willing to make to their water management practices in California during increasing water stress. Farmers are most willing to implement water technology versus changing the actual quantity of water that they use, both for more and less water use. Farmers who have more land are likely to implement water technologies but are also likely to use water intensive practices. This research highlights that crop type regardless of water intensity did not play a role in influencing farmers likelihood to adopt water practices, which demonstrates the relevance of water management practices across all crop types. Instead, farm and farmer characteristics, such as income, awareness of voluntary programs, a succession plan, the amount of acreage the farmer managed, and the farmers age had the most influence in adoption. Future research can explore these perceptions over time, as climate change continues in the region, and further examine the cost and implementation barriers of water technologies for small and medium farms.

Acknowledgements

The survey was funded by the USDA Water for Agriculture Program and the Water Foundation. I thank my advisor, Meredith Niles and my review committee, Andrea Etter and Terence Bradshaw, as well as Zachary Goldstein for his assistance with statistical training and data analysis.

References

Adusumilli, N., & Wang, H. (2018). Analysis of soil management and water conservation practices adoption among crop and pasture farmers in humid-south of the United States. International Soil and Water Conservation Research, 6(2), 79-86. https://doi.org/10.1016/j.iswcr.2017.12.005

The United States Environmental Protection Agency. Climate Impacts on Agriculture and Food Supply. https://climatechange.chicago.gov/climate-impacts/climate-impacts-agriculture-and-food-supply

California Department of Food and Agriculture. (2022). California Agricultural Production Statistics https://www.cdfa.ca.gov/Statistics/

The World Bank. (2022). Water in Agriculture. The World Bank. https://www.worldbank.org/en/topic/water-in-agriculture#1

Costello, A. B., and J. W. Osborne. 2005. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Practical Assessment, Research and Evaluation 10(7).

Dennis, E. M., Blomquist, W., Milman, A., & Moran, T. (2020). Path Dependence, Evolution of a Mandate and the Road to Statewide Sustainable Groundwater Management. Society & Natural Resources, 33(12), 1542-1554. https://doi.org/10.1080/08941920.2020.1772926

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method. Wiley. https://books.google.com/books?id=W5I_BAAAQBAJ

Escriva-Bou, A., Medellín-Azuara, J., Hanak, E., Abatzoglou, J., & Viers, J. (2022). Policy Brief: Drought and California's Agriculture.

Fulton, J., Norton, M., & Shilling, F. (2019). Water-indexed benefits and impacts of California almonds. Ecological Indicators, 96, 711-717. https://doi.org/10.1016/j.ecolind.2017.12.063

Johnson, R., & Cody, B. A. (2015). California Agricultural Production and Irrigated Water Use.

Lane, D., Chatrchyan, A., Tobin, D., Thorn, K., Allred, S., & Radhakrishna, R. (2018). Climate change and agriculture in New York and Pennsylvania: risk perceptions, vulnerability and adaptation among farmers. Renewable Agriculture and Food Systems, 33(3), 197-205. https://doi.org/10.1017/s1742170517000710

Langridge, R., & Van Schmidt, N. D. (2020). Groundwater and Drought Resilience in the SGMA Era. Society & Natural Resources, 33(12), 1530-1541. https://doi.org/10.1080/08941920.2020.1801923

Liu, T., Bruins, R. J. F., & Heberling, M. T. (2018). Factors Influencing Farmers' Adoption of Best Management Practices: A Review and Synthesis. *Sustainability*, *10*(2), 432. https://doi.org/10.3390/su10020432

Lu, J., Ranjan, P., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., Gramig, B. M., Singh, A. S., & Prokopy, L. S. (2022). A meta-analysis of agricultural conservation intentions, behaviors, and practices: Insights from 35 years of quantitative literature in the United States. *Journal of environmental management*, *323*, 116240. https://doi.org/10.1016/j.jenvman.2022.116240

Lubell, M., Blomquist, W., & Beutler, L. (2020). Sustainable Groundwater Management in California: A Grand Experiment in Environmental Governance. Society & Natural Resources, 33(12), 1447-1467. https://doi.org/10.1080/08941920.2020.1833617

McDonald, G. (2021). Waterlogging-the science. https://www.agric.wa.gov.au/waterlogging/waterlogging-%E2%80%93-science

Méndez-Barrientos, L. E., DeVincentis, A., Rudnick, J., Dahlquist-Willard, R., Lowry, B., & Gould, K. (2020). Farmer Participation and Institutional Capture in Common-Pool Resource Governance Reforms. The Case of Groundwater Management in California. Society & Natural Resources, 33(12), 1486-1507. https://doi.org/10.1080/08941920.2020.1756548

Mills, J., Gaskell, P., Ingram, J., Dwyer, J., Reed, M., & Short, C. (2016). Engaging farmers in environmental management through a better understanding of behaviour. Agriculture and Human Values, 34(2), 283-299. https://doi.org/10.1007/s10460-016-9705-4

Food and Agriculture Organization of the United Nations. (2017). Water for Sustainable Food and Agriculture

Pradhananga, A. K., & Davenport, M. A. (2019). Predicting Farmer Adoption of Water Conservation Practices Using a Norm-based Moral Obligation Model. Environ Manage, 64(4), 483-496. https://doi.org/10.1007/s00267-019-01186-3

Peterson, R. A. 1994. A Meta-Analysis of Cronbach's Coefficient Alpha. Journal of Consumer Research 21(2):381–391.

Program, U. E. V. (2013). Irrigation, Drip. https://ag.umass.edu/vegetable/fact-sheets/irrigation-drip#:~:text=A%20properly%20installed%20drip%20system,subsurface%2C%20near%20the%20root%20zone.

Prokopy, L. S., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., Gramig, B. M., Ranjan, P., & Singh, A. S. (2019). Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature. Journal of Soil and Water Conservation, 74(5), 520-534. https://doi.org/10.2489/jswc.74.5.520

Ranjan, P., Church, S. P., Floress, K., & Prokopy, L. S. (2019). Synthesizing Conservation Motivations and Barriers: What Have We Learned from Qualitative Studies of Farmers' Behaviors in the United States? Society & Natural Resources, 32(11), 1171-1199. https://doi.org/10.1080/08941920.2019.1648710

Resources, C. D. o. W. Sustainable Groundwater Management Act (SGMA). https://water.ca.gov/programs/groundwater-management/sgma-groundwater-management

Wagner, C. H., & Niles, M. T. (2017). Farmers share their perspectives on California water management and the Sustainable Groundwater Management Act. California Agriculture, 72(1), 1-6. https://doi.org/10.3733/ca.2017a0040