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Groundwater Governance and Agricultural Sustainability: Examining Farmer Interactions with California's Sustainable Groundwater Management Act

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GROUNDWATER GOVERNANCE AND AGRICULTURAL SUSTAINABILITY: EXAMINING FARMER INTERACTIONS WITH CALIFORNIA'S SUSTAINABLE GROUNDWATER MANAGEMENT ACT

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ABSTRACT

Climate change has exacerbated groundwater depletion globally, and policymakers have struggled to effectively manage groundwater resources. California enacted the Sustainable Groundwater Management Act (SGMA) in 2014 to restore groundwater to sustainable levels.

The first paper of this thesis examines the drivers associated with uptake of groundwater conservation practices in agriculture. While a rich body of research has explored farmers' conservation practice adoption, understanding of groundwater conservation practices is more limited. This study explores how information sources influence the actual and intended adoption of groundwater management practices in California. Using survey data from farmers (n = 553) in three largely agricultural counties of California, we examine the extent to which farmers' preferred and actual sources for information related to SGMA are associated with adoption of groundwater conservation practices while controlling for farm and farmer attributes. We find that farmer trust in groundwater policy information from informal sources such as other farmers, social media, and popular media is negatively associated with both current adoption and intended future adoption of groundwater conservation practices. These findings suggest that policymakers and extension agents seeking to spread conservation information could tap into peer-to-peer networks and partner with a diverse range of organizations to ensure that they send trusted information to farmers.

The second paper of this thesis assesses local variation in SGMA implementation. The legislation is implemented by local Groundwater Sustainability Agencies (or "Agencies"), which can be formed from different kinds of public institutions. Some types of Agencies, such as irrigation and reclamation districts, primarily represent the water interests of farmers, whereas others such as county and municipal governments represent a broader array of interests. We hypothesize that farmers in Agencies governed by farmer-oriented entities are on average more likely to participate in SGMA implementation and have more favorable perceptions of SGMA implementation and dispute resolution options via Agencies. We use mail survey data (n = 424) in three California counties and publicly available geospatial data from the US Department of Agriculture Cropland Data Layer to control for the prevalence of agriculture in an Agency or county. We run three ordered logistic regressions and find that Agency type is not significantly associated with farmer participation in SGMA implementation or perceptions of SGMA implementation or dispute resolution via Agencies. However, whether the farmer is a member of their local Farm Bureau does appear to be a significant positive predictor of participation in and favorable perceptions of SGMA implementation. This suggests that better-connected farmers may be more likely to participate in and benefit from SGMA implementation. Thus, policymakers should consider inequities in political capital both across and within stakeholder groups.

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1.1. Introduction

As climate change has exacerbated the frequency and intensity of droughts globally, water-scarce regions have struggled to manage groundwater resources [1]. Few places embody the challenges of agriculture and groundwater management more than California, which has faced continual worsening episodes of drought for several decades, culminating in the summer of 2021 as the most severe recorded drought conditions in California's history [2]. But California is far from alone, as many regions are facing worsening drought conditions and are struggling to address water resource depletion [3]. Thus, addressing and managing the impacts of severe drought is an urgent global problem. Similar to other large agricultural regions that rely heavily on groundwater, without widespread adoption of conservation strategies, California could see a sharp reduction in suitable agricultural land during the next century [4]. California instituted a locally-driven regulatory policy in 2014 to develop and implement groundwater policies relevant to specific groundwater basins and regions. California's Sustainable Groundwater Management Act (SGMA) is a landmark piece of legislation that tasks local

Groundwater Sustainability Agencies (GSAs) with crafting plans for water conservation [5].

However, SGMA is also incredibly complex, involving hundreds of GSAs, an extensive engagement process with potential users, and a complex network of information dissemination stemming from many different sources into the information ecosystem. SGMA provides a ripe opportunity to examine farmer networks due to the complexity and difficulty of policy communication under the legislation [6]. Information sources, as well as trust in information sources among farmers, are documented to influence adoption of conservation practices and policy support for conservation programs [7–12]. However, insufficient attention has been paid to the differences between formal and informal information sources in their potential influence on conservation practice diffusion [13,14]. Such oversight may be especially important in an active policy arena, where a variety of policy engagement opportunities exist amidst a suite of information sources. Here we use survey data from a sample of California farmers to examine the extent to which formal versus informal information networks are associated with adoption of groundwater conservation practices.

1.1.1. Characteristics of Conservation Adopters

Researchers have extensively studied the factors that influence whether farmers adopt new conservation practices on their farms [15]. Variables often found to be positively associated with conservation practice adoption include pro-environmental attitudes such as a farmer's belief in climate change [16–19], information access and intake [8,10–12,20], larger farm size [12,21,22], economic concerns and income level

[10,23], a greater amount of formal education [24,25], and participation in conservation incentive programs [26]. One challenge in this literature is that the traits of adopters and non-adopters could differ by region and local climate [23,27]. Indeed, several systematic reviews of farmer adoption of conservation practices observe conflicting results across studies [13–15], indicating room for further research. Prokopy et al. [14] note that more research is needed on social and systems-level factors that could influence conservation behavior, such as information networks.

For policy efforts seeking to promote agricultural conservation, it is also important to understand the factors that influence farmers' intentions to adopt conservation practices in the future. As Fishbein & Ajzen [28] note in their theory of planned behavior, intention is closely linked to behavior but is not a perfect predictor, since perceived and actual barriers restrict behavior. Prior studies have found that social dimensions such as norms can influence farmers' intentions to adopt conservation practices [29] and that a range of farm and farmer characteristics such as farm size and education are positively associated with intention to adopt conservation practices [30]. The factors associated with intended adoption of conservation practices are not always identical to those associated with actual adoption. Niles et al. [31] find that among a sample of New Zealand farmers, certain climate change attitudes appear to be associated with intended but not actual conservation adoption. Thus, further research into both actual and intended adoption would prove fruitful.

1.1.2. Information Sources and Conservation Adoption

A farmer's decision to engage in a conservation practice does not exist in a vacuum, but rather is a social process [32]. Under the diffusion of innovations theory, information networks can influence whether an individual actor such as a farmer adopts an innovative practice, as well as how such practices spread through a population [33]. Moreover, Elinor Ostrom's social-ecological systems (SES) model emphasizes that individual resource users such as farmers are embedded in social, policy, and biophysical systems that impact their decisions in complex and intertwined ways [34]. It is thus crucial to understand whether and how the flow of information from policymakers to farmers, as well as among farmers, is associated with conservation practice adoption. Owen [35] notes that collaboration and information-sharing seem to be key contributors to the success of adaptation strategies, and other researchers have similarly noted that information dissemination from policymakers and scientists is likely to play a substantial role in future efforts to adapt agriculture to climate change [4,27,36]. Prior research has repeatedly found a positive association between increased information access and adoption of conservation practices [8,10,12], as well as between farmer network involvement and conservation adoption [20,37].

Beyond the relationship of information and conservation behavior, the political science literature has further emphasized the importance of information *sources* in citizens' civic behavior. Researchers have observed that among the general public, the venues and sources from which people receive information — not just whether and how much information they receive — seem to be associated with attitudinal and behavioral shifts [38,39]. In particular, social media and informal information sources have been found to be important contributors to citizens' civic beliefs. Swigger [40] finds that frequent use of social media is associated with a higher degree of support for civil liberties. Relatedly, Anspach and Carlson [41] observe that reliance on information from social media can result in people having misinformed beliefs about key political issues.

These findings from political science suggest that information sources could similarly affect the behavior of farmers. However, Prokopy et al. [14] indicate a need for further research to better understand how farmer networks might impact conservation behavior. While some kinds of informational and organizational affiliations may be positively associated with conservation behavior, others might be negatively associated with such behavior or have no effect. The kinds of information farmers receive is diverse, and the effects of this information might likewise be varied. Indeed, there have been some attempts to analyze the complexities of farmer information networks in prior literature. McBride and Daberkow [11] draw on a survey of US farmers (n = 3,193) and note that the relationship between interpersonal information and adoption of conservation practices is stronger than the relationship between mass media information and adoption. More recently, Arbuckle et al. [7] assess climate attitudes among a sample of Iowa farmers (n = 1,276), finding that farmers who trust environmental interest groups are more likely to indicate that they favor climate adaptation in agriculture, while farmers who trust agricultural interest groups are less likely to indicate that they favor climate adaptation. The authors thus suggest that farmers who trust industry actors might differ in their climate-related beliefs and actions from farmers who trust environmental interest groups or other groups. Further, Garbach and Morgan [9] examine the role of social versus technical learning in influencing farmers' adoption of novel pollinator management practices. Using a quantitative network analysis of a survey of Michigan growers (n = 367), the researchers find that network connections with government agencies, technical service providers, and neighbors have different relationships with practice adoption. Still, prior literature has underemphasized how formal sources of information, such as government entities and extension agents, might differ in their effects on conservation adoption from informal sources, such as interpersonal communication among farmers, social media, and popular media.

1.1.3. Exploring Farmer Networks in the California Context

In California, as in many other regions, groundwater overuse — much of which is caused by agricultural irrigation — has contributed to depleting aquifer levels and reduced water quality [42]. Farmers often turn to aquifers when other water sources such as reservoirs and streams are unavailable, particularly during droughts [43]. California's Sustainable Groundwater Management Act (SGMA), enacted in 2014, aims to promote groundwater conservation in part through the creation of local Groundwater Sustainability Agencies (GSAs). GSAs are tasked with instituting local plans for managing groundwater, which are intended to bring about sustainable groundwater levels prior to the 2040s [42]. The legislation is still in the process of being implemented [44].

Implementation of SGMA provides an opportunity to study the complexities of farmer networks due to the multitude and diversity of actors involved. The implementation process relies heavily on cooperation across multiple levels of government. The act involves 264 individual groundwater agencies communicating with farmers in the development of local plans, as well as involvement from a host of different actors including extension agents, the California Department of Water Resources, the State Water Resources Control Board, city governments, county governments, irrigation districts, and water districts [6,44–46]. Additionally, the legislation requires GSAs to communicate with a range of "interested parties," such as farmers and others who use groundwater, nongovernmental entities, environmental justice organizations, and disadvantaged groups [6]. Relationships among farmers are also an important consideration for groundwater management plans. For instance, tension can arise between farmers who drill their own water from wells and those who rely on water from their local irrigation or water district [43]. Relatedly, farmers who retrieve groundwater independently rather than through a local irrigation or water district may be less integrated into farmer social and institutional networks [47]. Accordingly, analyzing networks both among farmers and between farmers and institutions is important for researchers seeking to understand SGMA implementation. One important part of analyzing these networks is assessing how information about groundwater is communicated by local, regional, and state public institutions [45].

Researchers have explored the factors contributing to local management plan adoption [48], farmer sentiments towards SGMA implementation [49], the role of social networks in SGMA implementation [45], and the relationship between science and policy in SGMA implementation [50]. Méndez-Barrientos et al. [47] examine how opposition to government intervention appears to motivate farmers to get more involved in the SGMA implementation process. However, the role of information dissemination in groundwater management is an underexplored topic. Given the centrality of local governance within SGMA, the legislation presents a unique opportunity to examine the relationship between farmer information networks and conservation behavior.

To that end, this study assesses the factors contributing to adoption of groundwater conservation practices among farmers in California. Specifically, we ask the following: (1) Which sources do farmers use and trust for information related to SGMA? (2) To what extent is trust in and use of information from formal or institutional sources associated with current and intended future adoption of groundwater conservation practices? (3) To what extent is trust in and use of information from informal sources, such as other farmers, popular media, and social media, associated with current and intended future adoption of groundwater conservation practices? We hypothesize that farmers who trust and receive information from formal SGMA information sources will be more likely to engage in groundwater conservation behavior, while farmers who trust and receive information from informal SGMA information sources will be less likely to engage in groundwater conservation behavior.

1.2. Materials and Methods

1.2.1. Data Collection Methods

In 2017, a mail survey on groundwater management was piloted for 137 farmers in Yolo County, California based on the results of 20 farmer focus groups [49]. The survey was then reworked for three additional counties: San Luis Obispo County, Madera County, and Fresno County. These three counties represent a range of crops grown, irrigation needs, and GSA formation processes. Farmer mailing lists were obtained through county-level pesticide reporting lists and the USDA Organic INTEGRITY database. The research team conducted meetings with County Farm Bureaus and water agencies to understand local groundwater needs and organizational interests while developing the survey. In partnership with the County Farm Bureaus, mail surveys were co-branded with the County Farm Bureau logo and accompanied by a letter from each County Farm Bureau president. In accordance with the survey methods outlined by Dillman et al. [51], farmers were sent an initial postcard advertising the survey, after which they were send the mail survey. Farmers who did not fill out the initial survey were sent a reminder postcard and a second mail survey. Participants were recruited during the winter of 2019. Although the mail surveys that were collected contained farmer mailing addresses, mail survey data was deidentified after data collection and before data analysis, as per institutional review board specifications

The goal of the 2019 survey was to learn about groundwater management in California, with a particular emphasis on the implementation of SGMA and farmers' perceptions of the implementation process. The survey also contained a range of additional questions on topics including groundwater management practices used by farmers, climate beliefs and attitudes, and farm and farmer demographics. Additionally, the survey included some open-ended questions. In total, there were 553 respondents between the three counties. The majority of the responses were from Fresno County. (n = 359, 65%), with smaller samples in San Luis Obispo County (n = 101, 18%) and Madera

County (n = 93, 17%). Data analysis for this paper was conducted in StataSE Version 17 [52].

1.2.2. Variables and Transformations

The outcome variable for our statistical models is farmer use of groundwater conservation practices. The survey asked farmers to indicate from a list which groundwater practices they currently use and which they are likely to use in the future. For each practice, farmers are grouped into one of three nominal categories related to their current adoption: uses the practice; does not use the practice; or not applicable. For intended future adoption, farmers are grouped into one of seven categories: a six-point Likert scale ranging from very unlikely to very likely; and not applicable. Our analysis does not cover all practices listed on the survey. Instead, we only include the following practices that we consider to constitute conservation practices: drip irrigation; water monitoring technology; fallow fields; soil moisture sensors; change to a less water intensive crop; and leaf sampling to measure plant-water status. We do not include the following practices: drill more wells; restore existing wells; make existing wells deeper; pump more groundwater than previous years; purchase additional water; purchase crop insurance; and reduce livestock stocking rates. While these practices could be helpful from an individual farmer's perspective, they are not included within the category of groundwater conservation practices as they are not specifically strategies to reduce groundwater use and meet local GSA goals. Although "reduce livestock stocking rate" could reduce groundwater use, we exclude this variable as it might further complicate interpretability given that it only applies to livestock farms.

We include a range of farm and farmer predictor variables in our models. The first set of variables relate to farmers' network embeddedness and information interactions. The first independent variable corresponds to whether the farmer indicated that they participated in SGMA implementation events. Four of the independent variables in the models pertain to the information that farmers trust and receive related to SGMA. The survey included a list of sources for SGMA information, ranging from formal or institutional sources such as University of California Cooperative Extension and local irrigation or water districts, to informal sources such as other farmers, social media, and popular media. The survey asked each farmer to select both which sources they trust for SGMA information and which sources of information they actually receive. These information sources present different conceptions of how novel practices could spread through a population. As Arbuckle et al. [7] suggest, farmers who place trust in different kinds of sources for climate-related information could have different conservation attitudes or behaviors, and this might also be true of SGMA information sources [44]. We also include an independent variable indicating the number of sources from which the farmer received SMGA information, to control for the possibility that observed relationships could be due to the amount of information farmers receive rather than which sources they receive.

Our models also contain a range of farm and farmer demographic controls, including: total acres managed; whether a farm grows crops and/or livestock; farmer participation in voluntary agricultural programs; education; and having some land in "white areas" that are not part of irrigation districts (Table 1). We include this final variable to control for the fact that farmers not integrated into irrigation districts and who may thus rely on groundwater could have different irrigation needs, information networks, and perceptions of the SGMA implementation process. We do not include farm income as a control variable to preserve sample size in our models, since there were 128 missing values for income and income was correlated with education in the sample.

Table 1

Descriptions of Variables, Scales, and Transformations for the Multiple Linear Regressions

Variable name	Measurement scale	Question and/or content	Transformation (if applicable)
Model 1 outcome variable: degree of current adoption of groundwater practices	Continuous	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 Practices included in analysis: drip irrigation; water monitoring technology; fallow fields; soil moisture sensors; change to a less water intensive crop; leaf sampling to measure plant-water status	Performed multiple correspondence analysis on three-level variable (adopted; not adopted; not applicable) and used predicted coordinate as outcome in model 1
Model 2 outcome variable: likelihood of intended future adoption of groundwater practices	Continuous	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 Practices included in analysis are identical to those in model 1	Grouped somewhat to very likely together and somewhat to very unlikely together to create three-level variable (intends to adopt; does not intend to adopt; not applicable); performed multiple correspondence analysis on three-level variable and used predicted coordinate as outcome in model 2

Participation in SGMA events	Binary	If you have personally participated in SGMA related events, which of the following have you done and when? Events listed: attended a SGMA meeting; served on a board related to SGMA; testified on a SGMA issue; voted on GSA agency formation. Fill-in responses for SGMA event participation are not included.	Transformed to binary variable indicating whether farmer participated in any of the listed events
Trust in SGMA information	Continuous	Would you trust information on SGMA from this source? List of sources: Commodity organization/grower cooperative; County Agricultural Commissioner; Department of Water Resources; GSA-Eligible Entities meetings/working groups; Local Irrigation or Water District; Other farmers; Popular Media (e.g., newspapers, radio, television); Social Media (e.g., Facebook, Twitter); State/Regional Water Resources Control Board; University of California Cooperative Extension. Only information sources listed on all three county versions of the survey are included in our analysis.	Performed principal component analysis on the set of binary variables indicating whether farmers trust each source for SGMA information; used predicted coordinates for two dimensions with eigenvalues > 1 as independent variables in the multiple linear regressions
Use of SGMA information	Continuous	Have you received information on SGMA from this source? List of sources is identical to those for trust in SGMA information	Performed principal component analysis on the set of binary variables indicating whether farmers use each source for SGMA information; used predicted coordinates for two dimensions with eigenvalues > 1 as independent variables in the multiple linear regressions
Total acres managed	Continuous	How many total acres do you manage - all land owned, leased or managed?	
Crop	Binary	In a typical year, how much of the following crops, animals or land do	Transformed to binary variable indicating whether

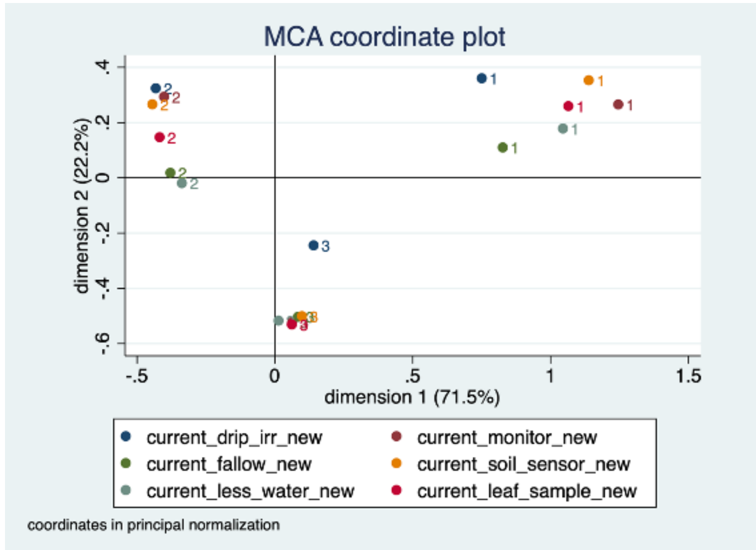
		you manage/own? [Followed by extensive list of crops and livestock, along with an “other” option]	farmer said they have any crops on their operation
Livestock farm	Binary	In a typical year, how much of the following crops, animals or land do you manage/own? [Followed by extensive list of crops and livestock, along with an “other” option]	Transformed to binary variable indicating whether farmer said they have any livestock on their operation
Participation in voluntary programs	Binary	Does your farm participate in any of the following voluntary programs? List of programs: Agricultural Conservation Easement Program; State Agricultural Water Enhancement and Efficiency Program; State Landowner Incentive Program; State Water Enhancement Program; Conservation Reserve Program; Conservation Stewardship Program; Environmental Quality Incentives Program; Organic/biodynamic certification	Transformed to binary variable indicating whether farmer uses any of the listed programs
Education	Ordinal	What is the highest level of formal education you completed? Education levels: some high school; high school diploma; trade school, apprenticeship or on job training; college education, no degree; college education, associate’s degree; college education, bachelor’s degree; graduate education, master’s degree; graduate education, doctorate degree	
Presence of some land in an uncovered “white area”	Binary	Farmers were shown a map of Groundwater Sustainability Agency districts in their county and asked which districts, if any, their parcels are located in	Transformed to binary variable indicating whether any of their parcels fall within “white areas” not covered by irrigation districts

We perform factor analysis techniques on several variables to group farmers into categories based on their conservation practice use and SGMA information preferences. First, regarding the outcome variables of conservation practice use, we transform intended future adoption into a three-category nominal variable by grouping somewhat to very likely together and grouping somewhat to very unlikely together. The goal of this is to simplify interpretability of the models. We preserve the "not applicable" responses rather than dropping them to maximize sample size, meaning that both current and intended future adoption are three-category nominal variables. Then, on both current and intended future adoption, we run a multiple correspondence analysis (MCA), a technique used to determine underlying structure in datasets of categorical non-binary variables with identical categories [53].

The MCAs suggest that in both datasets, the data can be grouped in two-dimensional space with one of the two dimensions corresponding to farmers' likelihood to adopt the conservation practices (Figure 1; Figure 2). We use the results of the MCA to predict the coordinates for each individual farmer, and we in turn use these predicted coordinates as the outcome variables for our regression models. For both current and intended future adoption, we use the second dimension as a proxy for a farmers' willingness to adopt groundwater conservation practices, since this dimension appeared to sort farmers by their willingness to adopt. Moreover, we negate this dimension for ease of interpretability, such that more positive values correspond to a greater current or intended future likelihood to adopt the practices.

Figure 1

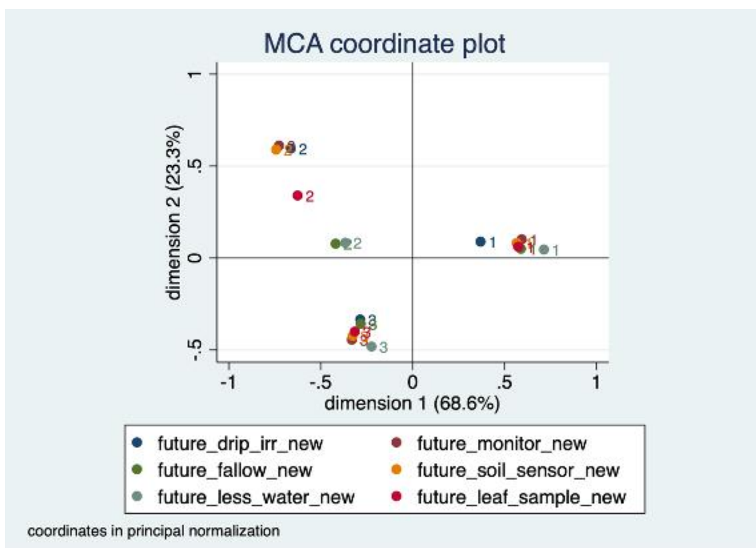
Multiple Correspondence Analysis of Adoption of Groundwater Conservation Practices



Note. 1 = Not applicable; 2 = Has not adopted practice; 3 = Has adopted practice.

Figure 2

Multiple Correspondence Analysis of Intended Future Adoption of Groundwater Conservation Practices



Note. 1 = Not applicable; 2 = Somewhat to very unlikely to adopt practice in the future; 3 = Somewhat to very likely to adopt practice in the future.

We also perform a transformation on the variables related to farmers' trust in and use of SGMA information to group farmers by their information intake preferences. A principal component analysis (PCA) is a statistical technique used to reduce dimensionality in a set of binary variables, and the dimension coordinates for each data row can be used as predictor variables in a multiple linear regression [54]. In our case, the goal of the two PCAs we conduct is to better understand whether the information sources represent distinct information pathways for farmers. We carry out a PCA on the binary variables indicating whether the farmer trusts each source for SGMA information, as well as a second PCA on the binary variables indicating whether the farmer receives each source for SGMA information (Table 2). Farmer responses for trust in information sources and actual receipt of information are both used since they may have different relationships with farmer behavior. Trust levels could be indicative of the networks to which farmers feel most connected, while the information sources they actually receive could indicate how receiving certain kinds of information shapes behavior.

The PCA on the trust in SGMA information sources reveals two components with eigenvalues > 1. The first component is composed largely of trust in formal or institutional information sources, such as public entities and University of California Cooperative Extension, with other farmers and popular media being the weakest aspects of this component. The second component is composed largely of trust in more informal or interpersonal sources, particularly social media and popular media, although the component is also composed to a slightly lesser extent of trust in certain institutional information sources such as the State/Regional Water Resources Control Board. The PCA for information received reveals two similar components: the first is composed more of farmers who trust SGMA information from institutional or formal sources, whereas the second is composed more of farmers who trust SGMA information from informal sources such as social media, popular media, and other farmers. This suggests that there is some basis for thinking that there are different groups of farmers who are more trusting of formal versus informal or interpersonal SGMA information. We then predict the coordinates for each individual farmer and use their coordinates for the first and second components in each PCA as independent variables in the model.

Table 2

Principal Component Analysis of Trust in and Receipt of SGMA Information Sources

	PCA for trust in SGMA information sources		PCA for SGMA information sources received	
SGMA information source	Component 1 eigenvectors	Component 2 eigenvectors	Component 1 eigenvectors	Component 2 eigenvectors
Commodity organization/grower cooperative	0.305	-0.292	0.317	-0.195
County Agricultural Commissioner	0.311	-0.364	0.320	-0.139
Department of Water Resources	0.362	0.060	0.371	-0.026
GSA-Eligible Entities meetings/working groups	0.326	-0.155	0.348	-0.330
Local Irrigation or Water District	0.302	-0.289	0.295	-0.291
Other farmers	0.229	0.087	0.325	0.117
Popular Media (e.g., newspapers, radio, television)	0.289	0.556	0.256	0.535

Social Media (e.g., Facebook, Twitter)	0.307	0.559	0.224	0.665
State/Regional Water Resources Control Board	0.375	0.079	0.371	0.042
University of California Cooperative Extension	0.334	-0.189	0.304	-0.076

Note. Components are preserved if their eigenvalue is greater than 1.0.

1.2.3. Statistical Models

We run two ordinary least squares (OLS) multiple linear regression models, as the outcome variable is a continuous variable corresponding to each farmer's predicted coordinates from the MCA results. Model 1 corresponds to degree of current adoption of groundwater conservation practices, and model 2 corresponds to likelihood of future adoption of groundwater conservation practices. Both regression models include controls for fixed effects by county to account for geographic variability or variability across the three survey versions.

The OLS regression models are as follows:

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \lambda + \alpha$$

$$Y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \lambda + \alpha$$

Where Y_1 = Likelihood of current adoption of groundwater conservation practices, or dimension 2 of the MCA; Y_2 = Likelihood of intended future adoption of groundwater conservation practices, or dimension 2 of the MCA; β_0 = constant or baseline; X_1 = Participation in at least one SGMA event; X_2 = Trust in formal SGMA information, or component 1 of the SGMA information trust PCA; X_3 = Trust in informal SGMA information, or component 2 of the SGMA information trust PCA; X_4 = Receiving formal SGMA information, or component 1 of the SGMA information receipt PCA; X_5 =

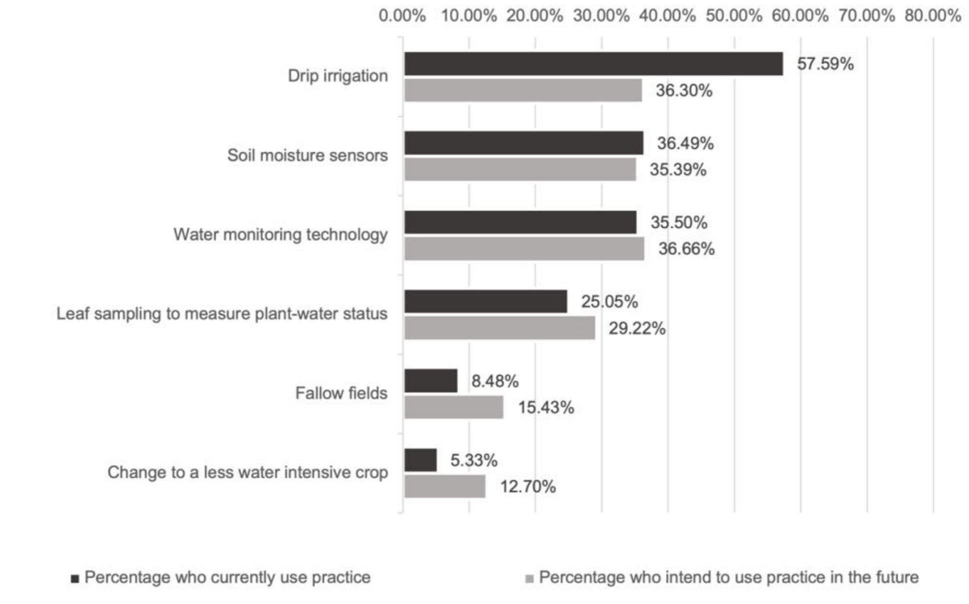
Receiving informal SGMA information, or component 2 of the SGMA information receipt PCA; λ = Farm and farmer characteristic controls; and α = County fixed effects. An alpha level of 0.05 is used for statistical tests. All variables are standardized for these statistical tests so that variable coefficients can be compared.

1.3. Results

There is a wide range in the degree of farmer adoption of conservation practices (Figure 3; Table 3). The top practice in terms of current adoption is drip irrigation (57.59%), and the lowest is shifting to less water intensive crops (5.33%). There is a similarly large range in the percentage of farmers intending to adopt each conservation practice in the future. 45.74% of farmers participated in at least one event related to the implementation of SGMA. The majority of farmer respondents grow at least some crops (90.74%), with a much smaller percentage having at least some livestock (15.06%). Only 28.28% participate in at least one voluntary agricultural program. The median number of sources received for SGMA information is 1. 4.31% of farmer respondents have some land in a “white area” not covered by an irrigation district.

Figure 3

Percentage of Respondents Who Use or Intend to Use Each Groundwater Management Practice



Note. Values indicate the percentage of respondents who stated that they currently use or intend to use each practice among valid responses to each question. For intended future use, answers for somewhat likely, likely, and very likely are grouped together.

Table 3

Summary Statistics for Dependent, Independent, and Control Variables

Variable	Number of valid responses	Percentage of respondents (unless otherwise indicated)
Participated in at least one in SGMA event	551	45.74%
Total acres managed	520	Mean = 747 Std. dev. = 2,419
Crop farm	551	90.74%
Livestock farm	551	15.06%
Participation in voluntary programs	488	28.28%
Education	538	

No college education		12.64%
College education, no degree		13.94%
College education, associate's degree		8.36%
College education, bachelor's degree		44.98%
Graduate degree		20.08%
Number of sources received for SGMA information	487	Median = 1
Presence of some land in an uncovered "white area"	511	4.31%
County	551	
San Luis Obispo County		64.79%
Madera County		18.33%
Fresno County		16.88%

The two OLS regressions suggest that several independent variables are significant ($p<0.05$) predictors of current and intended future adoption of groundwater conservation practices (Table 4). In assessing whether farmers had currently adopted groundwater conservation practices, trust in informal sources of information, such as social media, popular media, and other farmers, is negatively associated with adoption of groundwater conservation practices ($p=0.019$). Likewise, for the future adoption model, trust in informal SGMA information sources is also negatively associated with likelihood of intending to adopt groundwater conservation practices in the future ($p=0.039$). Participating in SGMA events, receiving information from formal or informal sources, and the number of sources received for SGMA information are not significantly associated with current or future adoption of groundwater conservation practices.

A number of farm and farmer characteristics are positively associated with adoption across both models. In the current adoption model, total acres managed (p=0.039), participation in voluntary conservation programs (p=0.002), and higher formal education level (p=0.002) are positively associated with adoption of groundwater conservation practices. On the other hand, farms with livestock (p=0.001) are less likely to adopt these practices on average. For the intended future adoption model, total acres managed (p=0.036), participation in voluntary agricultural programs (p=0.002), and having crops on the farm (p=0.014) are all positively associated with intention to adopt groundwater conservation practices in the future.

Table 4

Multiple Linear Regressions of Current and Likely Future Adoption of Conservation Practices

	Model 1 outcome variable = Degree of current adoption of groundwater conservation practices		Model 2 outcome variable = Likelihood of intended future adoption of groundwater conservation practices	
Predictor variable	Coeff.	Standard error	Coeff.	Standard error
Constant	-0.0004038	0.0143172	0.0054823	0.0141231
Participation in SGMA events	0.018019	0.0153048	0.0223187	0.0150965
Trust in formal SGMA information (component 1)	0.0063448	0.0142232	0.0128318	0.0141658
Trust in informal SGMA information (component 2)	-0.0331658*	0.0140629	-0.029169*	0.0141047
Receipt of formal SGMA information (component 1)	-0.0719765	0.1454701	0.0162852	0.1451436
Receipt of informal SGMA information (component 2)	-0.0127375	0.0137472	0.0010571	0.0136678

Total acres managed	0.0298743*	0.0144224	0.0306743*	0.014578
Crop farm	0.0306672	0.0192317	0.0461826*	0.0186702
Livestock farm	-0.0490019**	0.0143937	0.0107511	0.0143984
Participation in voluntary programs	0.043883**	0.0141742	0.0441584**	0.0141916
Education	0.0494057**	0.0157749	0.0198002	0.0156153
Number of sources received for SGMA information	0.1160643	0.1467198	0.0064802	0.1463477
Presence of some land in an uncovered "white area"	0.0097681	0.0147752	0.0092545	0.0149157
San Luis Obispo County (compared to baseline of Fresno)	0.020312	0.0150269	-0.0273826	0.0150088
Madera County (compared to baseline of Fresno)	0.0282226	0.0151345	-0.0006158	0.0148885

Note. * indicates $p < 0.05$ and ** indicates $p < 0.01$ for a two-tailed significance test. Number of valid observations is 398 for model 1 and 368 for model 2.

1.4. Discussion and Conclusion

Our analysis attempts to discern the differences between current adopters, likely future adopters, and non-adopters of groundwater conservation practices among California farmers. We find that trust in informal sources for SGMA-related information, such as social media, popular media, and other farmers, is significantly negatively associated with current and intended future adoption of groundwater conservation practices. As Prokopy et al. [14] indicate, different information sources may have disparate effects on farmer behavior. Indeed, we find that trust in and receipt of formal sources for SGMA information is not significantly associated with either current or intended future adoption of groundwater conservation practices. Our results suggest that not all kinds of information and organizational participation are associated with agricultural conservation behavior. Farmer networks are not all the same, so researchers should not assume that network involvement will necessarily be associated with an increase in a farmer's likelihood to engage in conservation behavior.

Several observed relationships in our models are consistent with findings from prior research. For example, we find that participation in voluntary agricultural programs is significantly positively associated with current and intended future adoption of conservation practices, consistent with Lambert et al. [26]. Additionally, we find that a higher level of formal education is significantly positively associated with current adoption of conservation practices, consistent with Barbercheck et al. [24] and McCann et al. [25]. However, education is not significantly associated with intended future adoption of conservation practices. This suggests that, as Niles et al. [31] note, the characteristics of current adopters of conservation practices versus intended future adopters of conservation practices might be different.

This study also shows some inconsistencies with prior research. We do not find a significant relationship between farmer participation in SGMA events and current or intended future adoption of groundwater conservation practices. By contrast, prior research indicates that organizational participation and network involvement may be associated with farmer adoption of conservation practices [20,37]. However, given that the implementation of SGMA was still ongoing in 2019 when the survey was distributed, and events including meetings and votes on GSA formation were not completed, these findings may reflect an early aspect of the policy process. Moreover, we find that the number of information sources a farmer receives related to SGMA is not significantly associated with adoption of conservation practices, inconsistent with some prior studies that find a positive relationship between information access and conservation behavior [8,10].

Our findings suggest that a farmer's quantity and sources of information are less important in predicting groundwater conservation behavior than which information the farmer trusts. This relates to a broader cultural phenomenon of tribalism that extends beyond farmers. Researchers have observed that trust is a key factor in information networks [55]. Individuals tend to have higher levels of trust in their own social groups when those groups are small, homogenous, or closed-off [56], which may be the case among farmers. Farmers may trust their own social circles over regulators or government entities, since other farmers can better understand their lived experiences and values. Moreover, social media has altered the way that people consume and trust information. On the one hand, social media has facilitated peer-to-peer information-sharing networks. However, these platforms can also foster echo chambers in which people filter out unwanted information. This can lead to homogenous thought, misinformation, and "fake news" [57,58]. Relatedly, which information people trust on social media is largely about *who* is sharing the information, rather than just the content of the information [59]. In that sense, farmers may trust information on social media since this mode of communication shows them people they agree with and information that aligns with their worldview.

Therefore, policymakers seeking to promote sustainable management of groundwater should consider not only whether their information is reaching farmers, but also whether farmers trust that information. Farmers who trust peer-to-peer networks over formal sources of information may have less faith in institutions and may be doubtful of policy efforts to encourage groundwater conservation. Public institutions such as state agencies, extension agents, and local irrigation and water districts should seek to send trusted information to farmers, perhaps by tapping into peer-to-peer networks and by engaging with a diverse range of organizations to convey information that will be trusted across different farmer groups [44,45]. Formal and informal information sources present disparate ways of spreading knowledge about groundwater practices. While information from public sources is highly curated and controlled, information from social media, popular media, and other farmers is unregulated and self-selecting. Formal sources provide the sort of technical guidelines that are helpful for implementing new management strategies on a farm, while informal information provides a way of sharing what farmers have found in their own experience works well in managing water resources [9]. Policymakers may thus need to adjust their modes and methods of communication to better reach farmers who trust informal communication networks.

There are several limitations in this analysis. For one, the total number of valid responses in each of the OLS regression models was limited by nonresponses to survey questions. Further, survey data is retrieved from three counties in California, so the findings may not apply to farmers in other geographic areas in California or beyond. Likewise, the politically contentious nature of groundwater issues in California [43], as well as the uniqueness of SGMA as a strategy for conserving groundwater [6], could limit the ability to generalize these results to other US states. Additionally, assessing likely future adoption on a survey is an imperfect measure of farmers' intentions to adopt conservation practices in the future, since farmer answers could be influenced by desirability bias. Nevertheless, this study can help researchers, policymakers, and extension agents better understand how farmer information networks relate to adoption of groundwater conservation practices in California.

Future research should continue to explore other kinds of information and organizational participation to further understand the complexities in the relationship between farmer networks and adoption of conservation practices. We explore only information related to SGMA, meaning that researchers could continue to examine the extent to which other kinds of information are associated with conservation practice adoption. Relatedly, grouping all of the conservation practices into one MCA dimension does not provide the potential to explore which exact practices are underlying these relationships. Future studies could thus examine which specific groundwater conservation practices are behind the relationships observed in these models. Studies could also analyze the communication strategies of different sources for SGMA information to explore how their information dissemination methods vary and how this might relate to farmer groundwater conservation practices. Finally, future studies could examine farmer information flows using a social network model to provide a richer understanding of how farmers may receive information from multiple sources simultaneously.

This study uses survey data from California farmers to examine the extent to which farmers' preferred and actual information sources for groundwater policy are associated with current and intended future adoption of groundwater conservation practices. We find that farmer trust in information from informal sources such as social media, popular media, and other farmers is significantly negatively associated with current and intended future adoption of conservation practices, but that other information network variables included in the regression models do not have significant associations. Our analysis highlights that policymakers or extension agents aiming to effectively or efficiently disseminate information about conservation practices should consider not only whether their information reaches farmers, but also whether farmers trust that information. Policymakers may find that turning to informal and peer-to-peer avenues of communication could help them tap into the networks that some farmers trust for staying informed on groundwater policy.

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CHAPTER 2: GROUNDWATER GOVERNANCE AND FARMER POLICY INTERACTIONS: ASSESSING THE CONTRIBUTIONS TO FARMER PARTICIPATION IN AND PERCEPTIONS OF THE CALIFORNIA SUSTAINABLE GROUNDWATER MANAGEMENT ACT

2.1. Introduction

A key global challenge in addressing climate change will be determining how to govern the extraction of water resources, including groundwater (Pathak et al., 2018). Groundwater is difficult to govern in part since in many areas it is a common-pool resource, meaning that actions landowners take via extracting groundwater on their own land will impact groundwater resources for neighbors and the broader groundwater basin. Similarly to other natural resource systems, governance of groundwater requires addressing various biophysical and social factors, including climate change, competition among water users, property rights, inequality in access to water, and market factors. Researchers have identified a need to consider ways in which groundwater is influenced by interconnected social and biophysical systems, as well as a need for mixed methods and interdisciplinary research to better understand the complexities of groundwater systems (Huggins et al., 2023).

It is helpful to consider groundwater governance using Elinor Ostrom's social-ecological systems (SES) framework, according to which social, political, and biophysical systems interact in complex and deeply intertwined ways (Ostrom, 2009). Indeed, community regulation of water resources in California was one of the key cases that Ostrom used in the development of the SES framework (Ostrom, 1990). Ostrom describes various factors that could relate to sustainability outcomes, including resource systems, resource units, governance systems, resource users, and the interactions among these factors. Though groundwater depletion is in one sense an environmental problem, finding an effective long-term solution requires an understanding of social and political dynamics, including how and why stakeholders participate in the policy process. Additionally, Ostrom theorized that certain governance design principles guide the success or failure of natural resource management schemes, including congruence of management rules to local conditions and the ability of users to participate in collective-choice processes to modify rules (Cox et al., 2010). Therefore, in this paper we explore the dynamics of local groundwater governance by examining the governance factors and farmer characteristics that shape farmer participation in and perceptions of California's Sustainable Groundwater Management Act (SGMA), with particular interest in the role of local government entities in shaping SGMA implementation.

2.1.1. SGMA and California Groundwater Depletion

For decades, water users in California have over-extracted groundwater to an unsustainable degree, part of a broader global trend of heightening water scarcity in the context of climate change (Pathak et al., 2018). California has experienced increasingly severe droughts in recent decades, a trend that will continue with climate change (Mann & Gleick, 2015). The agricultural sector is the largest groundwater user in California (Kiparsky et al., 2017). Agricultural producers contribute to water depletion in California both through the use of surface water sources for irrigation and through farmers drilling for underground water on their land. When farmers experience drought conditions and lack available surface water, they often turn to aquifers for irrigation, potentially creating a positive feedback loop in aquifer depletion (Escriva-Bou et al., 2022). Additionally, the uncertainty of groundwater resources in California renders farmers and other groundwater users vulnerable to shifting political, economic, and climate conditions (Fairbairn et al., 2021).

The path to enacting SGMA consisted of decades of policy evolution, in which local-level communities and organizations began to manage groundwater resources, eventually paving the way for state-level policy efforts (Blomquist, 1992; Dennis et al., 2020; Ostrom, 1990). There were some early state-level attempts in California to regulate groundwater through voluntary plans. In 1992, the California Legislature enacted the Groundwater Management Act, which allowed counties to adopt voluntary plans to manage groundwater. Other state-level legislation incentivized local governance through funding opportunities (Macleod & Méndez-Barrientos, 2019). However, prior to 2014, no state-level laws existed to comprehensively curb groundwater extraction through mandates. This reflected an artificial legal boundary between surface water and groundwater. While some state-level policies in California addressed the issue of water access broadly, state policies under-emphasized the importance of groundwater and treated groundwater and surface water as separate policy realms. Moreover, the prospect of groundwater regulation was further complicated by preexisting property rights regimes that limited possible local actions (Owen et al., 2019). Historic drought levels beginning in 2011 eventually prompted action by the California Legislature (Cagle, 2020). In 2014, the Legislature enacted SGMA with the goal of restoring groundwater to sustainable levels before 2040 (Sustainable Groundwater Management Act, 2014).

SGMA has a three-part goal of halting over-extraction of groundwater, restoring groundwater levels, and achieving long-term sustainability of groundwater resources by 2040. Local Groundwater Sustainability Agencies (GSAs, or "Agencies" for short), which can be formed from one of several different kinds of existing entities that have land- and water-use jurisdiction, including county governments, municipal governments, public irrigation districts, reclamation districts, water utility districts, conservation districts, or a combination of the above, implement SGMA. An entity can form a standalone Agency or coordinate with other entities to form a multi-entity Agency. For designated high- and medium-priority basins, Agencies are required to create Groundwater Sustainability Plans (GSPs, or "Plans" for short), which dictate processes for restoring groundwater to sustainable levels. Agencies can create these Plans either on their own or in conjunction with other Agencies. In the event that multiple Agencies exist within one water sub-basin, the various Agencies coordinate on a Plan to achieve sustainable groundwater levels for the sub-basin. During the Plan development process, Agencies are required to consult with stakeholders, including farmers, disadvantaged communities, environmental water users, and tribal communities (Lubell et al., 2020; Macleod & Méndez-Barrientos, 2019; Perrone et al., 2023).

Although SGMA relies on collaborative and local governance, the legislation also includes some state-level checks on Agencies. Local institutions are allowed to form Agencies, but if no local entity opts to form an Agency, then the state can step in to regulate groundwater levels in a particular sub-basin. Moreover, local Plans must be approved by the state Department of Water Resources. In the event that a Plan is not approved for a particular sub-basin, the State Water Resources Control Board is responsible for governing groundwater in the area. Some priority water sub-basins were required to submit Plans by 2020, while for other sub-basins Plans are still in development (Cagle, 2020). Many of the Plans that were submitted for the 2020 deadline were considered "incomplete," meaning Agencies are required to reformulate the Plans for those sub-basins (Cahill, 2022). Thus, SGMA is still actively being implemented, providing a real-time opportunity to examine the implementation of cornerstone environmental legislation.

2.1.2. SGMA and Local-Level Governance

SGMA presents a unique case to study policy implementation, given the high degree of local discretion in how the legislation is implemented. Under common-pool resource theory, local variation in the policy actor arena can affect policy outcomes for stakeholders (Ostrom, 2009). Given SGMA's reliance on local implementation and collaborative governance to protect groundwater resources, there could be a wide range in how different kinds of entities implement SGMA at the local level (Conrad et al., 2018). Kiparsky et al. (2017) develop nine criteria for assessing the success of local implementation under SGMA. Four of these criteria are efficacy-based: scale and scope of Agencies; Agencies' institutional capacities; funding levels; degree of authority and legal powers; and Agency independence. The authors also describe four criteria for evaluating fairness under SGMA implementation: participation of stakeholders; representation of stakeholders in decision-making processes; accountability of Agencies;

and transparency of decision-making. These criteria are useful in considering how to evaluate disparities in local implementation across Agencies.

Several prior studies have analyzed local variability in the implementation of SGMA. Dobbin et al. (2022) assess how different measures of collaborative governance under SGMA, such as stakeholder participation in Plan formation, relate to the degree of equity in Plans. The authors measure equity by whether environmental justice concerns in drinking water are adequately included in Plans. The authors find that collaborative governance has only a slight or negligible association with equity outcomes. Thus, other factors outside of collaborative governance may be more critical for Plan success. Milman et al. (2018) qualitatively examine the factors that affect local decisions about whether to form a single-entity Agency or a multi-entity collaborative Agency. The authors find that much of the decision revolves around jurisdictional disputes, since the decision not to form an Agency means that some other entity will likely form the Agency. Thus, political entities may seek to protect their turf by forming Agencies. Perrone et al. (2023) examine the relationship between stakeholder integration into the Plans and protection for those stakeholders' access to groundwater, finding that greater integration is associated with greater protection for stakeholders. Interestingly, this finding held for domestic and environmental stakeholders, but not agriculture, suggesting that agricultural users, with the ability to have their interests represented by irrigation and reclamation districts, may have more decision-making power in the process than other stakeholders.

A key underexplored research topic related to SGMA implementation, building on the work of Perrone et al. (2023), is the role of the *kind* of entity that forms an

Agency. Different kinds of local entities are able to form Agencies, ranging from county or municipal governments to local irrigation or reclamation districts. The kind of entity that forms an Agency in theory might play a role in what the implementation process looks like. For example, irrigation and reclamation districts primarily represent the water interests of farmers, while counties also represent the interests of other groups such as drinking water users and thus have more of a generalized policy aim (Méndez-Barrientos et al., 2020). Irrigation and reclamation districts have a policy mandate to maintain and distribute water resources, meaning that these districts may be more likely to prioritize agricultural irrigation needs in Plan development. By contrast, local government entities such as county or municipal governments have a broader set of policy goals. These differences in Agency goals could also affect how Agencies prioritize different stakeholders in the development of Plans, as well as the extent to which they include various stakeholders in the implementation process. Researchers have described this difference in Agency priorities as "single-interest" entities such as irrigation and reclamation districts, versus "general-interest" entities such as county and municipal governments (An & Tang, 2023). Another way of conceptualizing this, drawing on political science literature, is that irrigation and reclamation districts represent the "concentrated" (i.e., focused and highly motivated) irrigation interests of farmers, while county and municipal governments represent the "diffuse" (i.e., spread across the population and generalized) interests of the entire population (Overdevest, 2000).

Some prior research has explored how Agency entity type relates to policy processes and outcomes. MacLeod & Méndez-Barrientos (2019) assess adoption of voluntary Groundwater Management Plans (GMPs) prior to the enactment of SGMA in 2014. GMPs were similar to GSPs, except that GMPs were voluntarily adopted by local public institutions prior to the groundwater governance mandates under SGMA. The authors find that GMPs were most commonly adopted by irrigation and reclamation districts, with county and municipal governments having substantially lower rates of adoption. Based on these results, the researchers suggest that institutional capacity is a key factor in California groundwater management, since local government entities such as county governments have other policy interests that may prevent them from prioritizing groundwater governance. Local variation in institutional capacity of Agencies under SGMA could likewise vary by entity type. Additionally, An & Tang (2023) analyze how Agency entity type relates to bureaucratic disputes and institutional cooperation in the implementation of SGMA. Since multiple Agencies can form within one water basin, an important aspect of SGMA implementation is cooperation among Agencies. The authors argue that the economic interests of Agencies could influence the extent to which they are willing to cooperate with each other. The researchers divide Agencies into single-interest and general-interest entities. Their definition is more expansive than the distinction described above; in addition to irrigation and reclamation districts, their single-interest category also includes water districts that are focused on water management but not specifically farmer irrigation needs. The authors find that single-interest Agencies are on average less likely than general-interest Agencies such as county governments to participate in collaborative governance processes, possibly due to water-focused entities aiming to protect their political territory. However, one aspect of

SGMA implementation that has been underemphasized in prior literature is whether Agency entity type might influence stakeholder experiences with the SGMA implementation process.

2.1.3. Policy Participation and SGMA Implementation

Prior research has examined inequities in the extent to which different stakeholder groups have access to political representation during the SGMA implementation process (Dobbin et al., 2022; Lubell et al., 2020; Macleod & Méndez-Barrientos, 2019; Perrone et al., 2023). However, while studies have focused mainly on inequities in access to political representation *across* stakeholder groups in SGMA implementation, there has been less focus on variation *within* stakeholder groups, such as inequities in political capital and groundwater access among California farmers. For example, farmers of color and lower-income farmers face barriers to policy participation and thus might be disadvantaged in the development of Plans (Macnamara Morton et al., 2022; Marshall-Chalmers, 2022). Relatedly, smaller farms may be disadvantaged in SGMA implementation, as larger farms have more resource flexibility and are thus better able to adjust to regulatory changes (Rudnick et al., 2016). In "white areas," a term used to refer to areas that are not covered by a surface water provider such as an irrigation or reclamation district, farmers are generally more reliant upon groundwater since they do not have access to other sources of irrigation water (Conrad et al., 2018). White-area farmers may have less political capital and tend to be less politically organized than farmers who have access to representation and political gathering spaces under the jurisdiction of irrigation or reclamation districts. Moreover, since these white-area farmers are not represented by Agencies formed from farmer-interest entities, they may be less likely to have their interests considered in the development of Plans. This could mean that Agency representation serves to reinforce existing inequities, as the farmers in white areas who have less stable access to irrigation resources are also less likely to have their interests represented under farmer-interest Agencies (Méndez-Barrientos et al., 2020). Thus, it is important to assess variation in policy interactions *within* stakeholder groups, such as inequities between various categories of farmers, in addition to variation and equity considerations across stakeholder groups.

However, representation through Agencies is only one way that stakeholders may interact with the SGMA implementation process. Farmers can attend Agency events, serve on boards, and testify at meetings, all of which can occur regardless of which kind of Agency represents their area. Indeed, SGMA requires Agencies to consult directly with groundwater stakeholders while developing Plans (Lubell et al., 2020). Thus, it is important to consider the factors that influence farmer participation in SGMA implementation, as well as how participation varies across farmer groups. Farmers are divided in whether they support regulatory processes under SGMA, as well as whether they have participated in the implementation process (Niles & Hammond Wagner, 2019). Another method by which stakeholders may interact with the SGMA implementation process is through dispute resolution. When multi-entity Agencies are formed, the Memorandums of Understanding or Joint Powers Authorities Agreements outlining their formation often include clauses about how to handle any disputes that might arise. The dispute resolution process might look very different depending on the kind of Agency facilitating the process, since different institutions will have different dispute resolution priorities (Moran et al., 2019). If the local irrigation or reclamation district Agency is involved in a dispute resolution, the process may be more favorable to farmers given the priorities of the Agency.

2.1.4. Research Aims

This paper explores the factors that contribute to farmer engagement in the SGMA implementation process, with particular focus on the role of local government entities in shaping the implementation process. Just as An & Tang (2023) find that single- versus general-interest Agencies are associated with differences in the degree of collaboration in SGMA implementation, the kind of entity that forms an Agency may also relate to farmer participation in and perceptions of SGMA implementation. Irrigation and reclamation districts specifically represent farmer interests and could in theory craft Plans to favor farmers or include farmers in implementation to a greater extent than other Agencies. However, prior research has underemphasized this aspect of SGMA implementation. An & Tang (2023) point to a need for additional research examining the representation of stakeholders in the SGMA implementation process and how different kinds of Agency entities may impact SGMA implementation. Moreover, drawing on common-pool resource theory, we examine the relative importance of governance system factors, resource unit factors, resource system factors, and resource user factors in policy interactions under SGMA. Relatedly, by measuring the factors that are associated with farmer participation in SGMA implementation, we can assess which kinds of governance arrangements might be more likely to align with design principles associated with successful management.

Our overarching research question is: which governance-level, resource-level, and user-level factors are associated with farmer participation in and positive perceptions of SGMA implementation? We are particularly interested in the relationship between the kind of entity that forms an Agency and farmers' participation in and perceptions of SGMA implementation. Specifically, do farmer policy interactions under SGMA differ between Agencies formed by farmer-interest entities such as irrigation and reclamation districts, versus general-interest entities such as county governments, municipal governments, and water and conservation districts? We divide our overarching research question into the following sub-questions:

- How does Agency entity type relate to farmer participation in the SGMA implementation process?
- How does Agency entity type relate to farmer perceptions of the SGMA implementation process?
- How does Agency entity type relate to farmer perceptions of dispute resolution by Agencies?
- How do other farmer characteristics, including Farm Bureau membership, farm size, education, gender, and farmers' succession plans, relate to farmer participation in and perceptions of SGMA implementation and dispute resolution?

Our hypotheses are as follows:

- H1: Famers with parcels in irrigation and reclamation districts will be more likely on average to participate in the SGMA implementation process.
- H2: Farmers with parcels in irrigation and reclamation districts will on average have more favorable perceptions of the SGMA implementation process.
- H3: Farmers with parcels in irrigation and reclamation districts will on average have more favorable perceptions of SGMA dispute resolution via Agencies.

2.2. Materials and Methods

Our analysis uses farmer-level survey data from a 2019 survey of California farmers in three key agricultural-producing counties. We also use geospatial data from the US Department of Agriculture (USDA) Cropland Data Layer, mapped onto shapefiles of Agencies and counties, to determine the percentage of each Agency or county that is cultivated. We conduct our data analysis in StataSE Version 17 (StataSE, 2021). We also use Google Earth Engine to download and process public geospatial data (Gorelick et al., 2017). We run three ordered logistic regressions with the same set of predictor variables and different outcome variables corresponding to different dimensions of farmer interactions with SGMA implementation.

2.2.1. Survey Methods

The farmer survey was informed in its first iteration by a series of focus groups with California farmers (Hammond Wagner & Niles, 2018). Niles & Hammond Wagner (2019) then implemented a mail survey on SGMA with 137 farmers in Yolo County, California. Following the results and early understanding of farmer perspectives in the

SGMA implementation process, the survey was adjusted for additional locations and sent in 2019 to three further counties in California's Central Valley: San Luis Obispo County, Madera County, and Fresno County. This version of the survey had additional questions on SGMA implementation utilized in these analyses. Farmer mailing addresses were obtained from the USDA Organic INTEGRITY database and pesticide use reporting lists, required by law in California and publicly available. The researchers also conducted meetings with County Farm Bureaus and water agencies to better understand local groundwater contexts and test survey questions. The mailings of the farmer survey were co-branded with the local County Farm Bureaus and accompanied by a letter describing the survey, which was jointly signed by the Principal Investigator and the County Farm Bureau president. Following Dillman et al. (2014), farmers were sent an initial postcard followed by the mail survey, and any farmers who did not fill out the initial survey copy were mailed a reminder post-card and second copy of the survey.

The goal of the survey was to learn about groundwater management in California and farmers' interactions with the SGMA implementation process. The survey asked farmers about how they manage groundwater on their farms, which Agency(ies) their parcel(s) are located in, whether and how the farmers interacted with the implementation of SGMA, the farmers' perceptions of SGMA implementation and dispute resolution, and farm and farmer demographics, among other questions. The survey also included some open-ended qualitative questions. There were 553 respondents across the three counties, with Fresno County (n = 359, 65%) accounting for the majority of respondents, followed by San Luis Obispo County (n = 101, 18%) and Madera County (n = 93, 17%), reflecting the agricultural composition of each county.

2.2.2 Variables and Transformations

We run three ordered logistic regression models in total, each of which has a different outcome variable but the same set of independent and control variables (Table 5). In model 1, the outcome variable is a score based on the degree of farmers' participation in the SGMA implementation process. In model 2, we assess farmer perceptions of the SGMA implementation process, measured on a 24-point ordinal scale aggregated from farmers' 6-point agree-disagree Likert responses to four statements related to SGMA implementation. Finally, the model 3 outcome variable measures farmer perceptions related to SGMA dispute resolution via Agencies. We are particularly interested in farmer perceptions of dispute resolution via Agencies, as farmers in irrigation or reclamation district Agencies may be more likely to support dispute resolution via their local Agency than farmers in more general-interest Agencies.

Table 5

Variables Used in Ordered Logistic Regression Models

Variable name	Measurement scale	Question or variable content	Transformations or variable coding
Model 1 outcome: Participation in SGMA events	Ordinal	If you have personally participated in SGMA related events, which of the following have you done and when? Events listed: attended a SGMA meeting; served on a board related	0-4 scale created, aggregated from how many types of SGMA events farmers have participated in at any point in the past. The survey also included an open-ended question for other types of SGMA events farmers may have participated in, but these

		to SGMA; testified on a SGMA issue; voted on Agency formation.	fill-in responses are not included in the aggregated scale.
Model 2 outcome: Perceptions of SGMA implementation	Ordinal	Farmers were asked for their level of agreement with the following statements related to SGMA implementation on a 6-point Likert scale (strongly to somewhat agree and disagree): The SGMA process is being managed at the local County level; Farmers have been involved in the SGMA process; I feel the process for engaging farmers in the SGMA process has been fair; I know how to participate in the SGMA policy process and have my opinions heard.	Aggregated 6-point Likert responses to an ordinal scale (1-24).
Model 3 outcome: Perceptions of Agency dispute resolution	Ordinal	What is your preferred means of reconciliation, should disputes arise over SGMA implementation? Answer choices are a 6-point Likert scale from strongly to somewhat preferred and not preferred. Question was asked for the following means of reconciliation: State Water Resources Control Board; Agencies; County Board of Supervisors; Superior Court System; Arbitration	Used farmers' 6-point Likert scale answer for whether they prefer Agencies as a dispute resolution mechanism.
Agency entity type	Binary	Whether the farmer's parcel is in an Agency that is an irrigation or reclamation district (group 1) or any other kind of Agency entity type, including white areas (group 2).	Coded via assistance from USDA Food Systems Research Unit (Perrone et al., 2023).
Percent cultivated land in Agency	Continuous	Percent of Agency (or county, in the event that a farmer is in an uncovered area) that is cultivated land.	Used publicly available data from the US Department of Agriculture Cropland Data Layer on whether a particular unit of land is cultivated or non-cultivated land, mapped onto shapefiles of Agency

			and county boundaries obtained via the California Open Data Portal.
Farm Bureau membership	Binary	Are you a member of [relevant county's] Farm Bureau? Options: Yes; No	
Education	Ordinal	What is the highest level of formal education you completed? Eight levels: some high school; high school diploma; trade school, apprenticeship or on job training; college education, no degree; college education, associate's degree; college education, bachelor's degree; graduate education, master's degree; graduate education, doctorate degree.	
Total acres	Continuous	How many total acres do you manage - all land owned, leased or managed?	
Gender	Binary	Are you (check one): Options: Male; Female; Prefer not to answer	Gender is included as a binary since survey only included two options for gender plus "prefer not to answer," which is dropped for ease of interpretation.
Age	Continuous	In which year were you born? (fill-in)	Converted to age by subtracting from 2019, the year that the survey was conducted.
Succession plan	Categorical	Do you have a farm succession plan for after you retire? Options: Yes; No; Partial	

The independent variables in our models are chosen to mirror different facets under common-pool resource theory that relate to policy interactions (Figure 4). The central independent variable of interest is a binary variable indicating whether the farmer's land is in a farmer-interest or general-interest Agency, which is coded via a question about which Agency(ies) the respondent has parcel(s) in (Figure 5). To perform this coding into a binary variable, we drop any farmers ($n = 127$) whose land is located in more than one Agency, or who did not indicate an Agency on the map. Another reason that we needed to drop farmers in two or more Agencies from the analysis is that, as described below, we control for the percent of cultivated land in an Agency or county, which would not be possible for farmers with parcels in multiple Agencies. Most (84.21%) of the farmers surveyed have parcels in only one Agency. We drop 15.79% of farmers and are left with a final sample size of $n = 424$. The mean of total acreage for farmers dropped from the analysis is statistically significantly larger than the mean for farmers with only one Agency representation, $t(518) = -7.1506$, $p < 0.001$, which makes sense given that larger farms would be more likely to extend into multiple Agencies. Additionally, dropped farmers are on average better educated than farmers in the final model, X^2 (7, N=5538) = 23.4154, $p = 0.001$ (Appendix A). For all of the Agencies that appear on the survey, we sort them by whether they are irrigation or reclamation districts (group 1) or any other kind of entity (group 2). This allows us to distinguish between Agencies whose primary concern is agricultural interests versus other general-interest Agencies (Perrone et al., 2023).

Figure 4

Mapping Model Variables onto the Social-Ecological Systems Framework

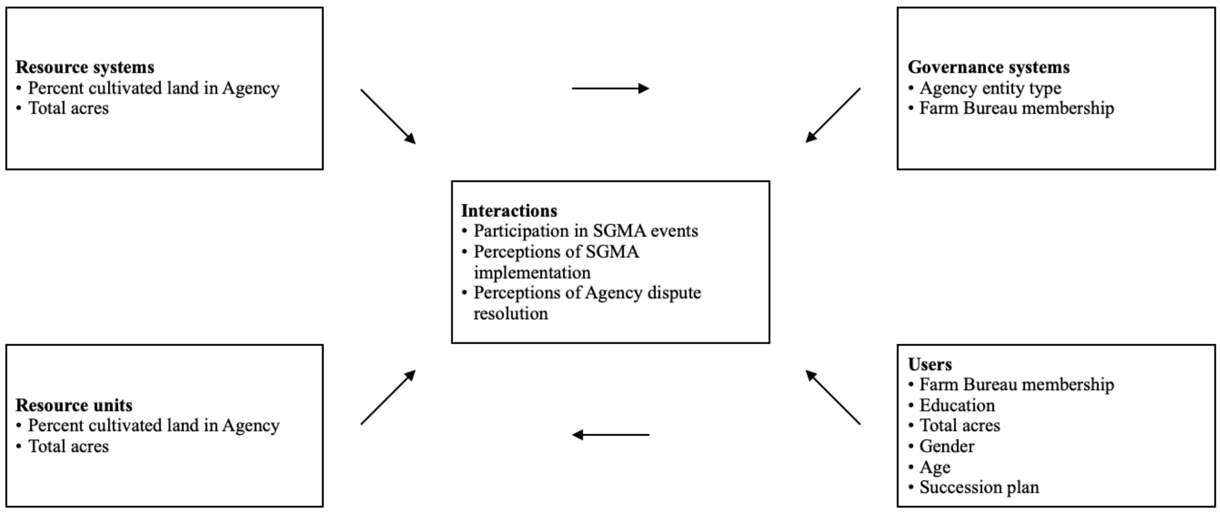
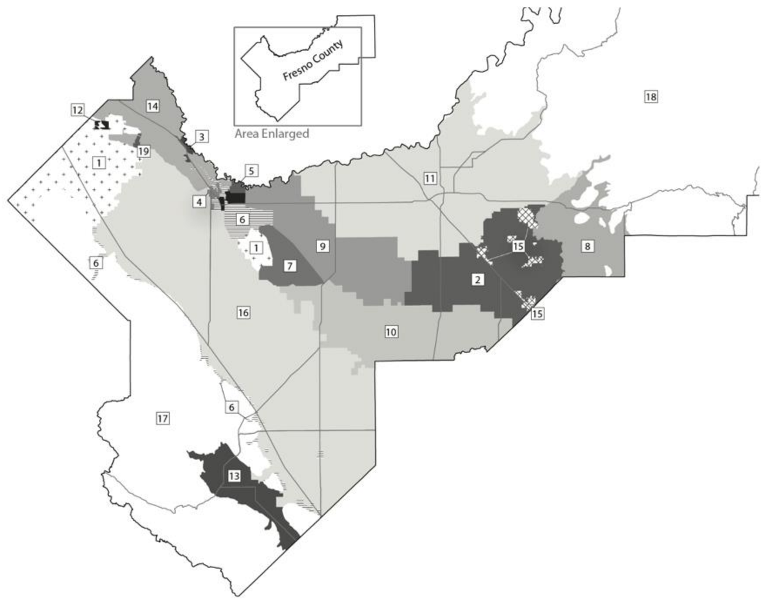


Figure 5

Example of Agency Survey Question, from Fresno County Version of 2019 Survey



7. Above is a map of the Fresno County Groundwater Sustainablity Agencies (GSAs). Please indicate below in which districts you have land parcels. Check all that apply.

__ 1 Central Delta - Mendota Region Multi-Agency
__ 2 Central Kings
__ 3 City of Firebaugh
__ 4 City of Mendota
__ 5 Farmers Water District
__ 6 Fresno County
__ 7 James Irrigation District
__ 8 Kings River East
__ 9 McMullin Area
__ 10 North Fork Kings
__ 11 North Kings
__ 12 Ora Loma Water District
__ 13 Pleasant Valley
__ 14 San Joaquin River Exchange Contractors Water Authority
__ 15 South Kings
__ 16 Westlands Water District
__ 17 White Area 1
__ 18 White Area 2
__ 19 Wildren Water District

We also include a range of control variables to address potential alternative causal explanations and to examine which other factors are associated with farmer SGMA engagement. The first control variable is the percent of land in the Agency that is cultivated land. We include this as a control variable to address the possibility that the amount of agricultural production in an Agency could be a confounding variable. Farmer-interest Agencies may be more likely to be located in agriculture-dominated regions, and farmers in these agricultural areas may have more economic and political capital than farmers in other areas. To code this variable, we use publicly available data from the USDA Cropland Data Layer on land use. This dataset includes information about whether a particular unit of land is cultivated or non-cultivated land. We do not include the Cropland Data Layer's variable for pastureland, since this would be too inclusive as it would count grassland that is not used strictly for agricultural purposes. We obtain shapefiles for Agencies and counties from the California Open Data Portal (CA Geographic Boundaries, 2019; I03 Groundwater Sustainability MapService, 2023). We then use Google Earth Engine to map the geospatial data from the Cropland Data Layer onto shapefiles of each Agency and county (Gorelick et al., 2017). For farmers with parcels in an Agency, we use the Agency shapefile. However, for farmers in a white area or an area in which the county acts as the Agency, we use the percent of the county that is cultivated land, since county governments would be the relevant political entity in these cases. Additionally, municipal government shapefiles would be less readily available. This allows us to avoid dropping these white-area farmers, as dropping these farmers would force us to exclude from our analysis this underserved group of farmers who often have less access to water resources. Thus, we end up with a continuous variable in our dataset corresponding to the percent of land in each Agency or county that is cultivated according to the Cropland Data Layer coding.

Policy interactions can be shaped by resource user characteristics in addition to governance system entity characteristics (Ostrom, 2009). Thus, we also include a set of farm and farmer demographic controls to account for other potential confounding variables that could influence farmer interactions with SGMA implementation. The first control is Farm Bureau membership, coded as a binary variable, indicating whether the farmer respondent is a member of their local Farm Bureau. We include this control since farmers who are members of Farm Bureaus may have more political capital and might be more socially connected, which could facilitate their participation in SGMA implementation and might mean that they fare better in the face of groundwater policy changes. Other farm and farmer demographic controls in our models include education, total acres, gender, age, and whether the farmer has a succession plan, all of which may influence SGMA participation and perceptions. We also include county fixed effects in the models to control for survey versions and county variation.

2.2.3. Statistical Methods

We run three ordered logistic regression models, each of which has a different outcome variable but the same set of independent and control variables. We standardize all independent and control variables to allow for comparison of coefficients. The outcome variables in all cases are ordinal but not continuous, which allows us to run an ordered logistic regression but not a multiple linear regression. The scale for model 2 has 24 values and is normally distributed; thus, we ran the model both as a multiple linear regression model with the assumption of normality and an ordered logistic regression. These two models yielded similar coefficient results, so we maintained the ordered logistic regression model for all three cases. We use a confidence value of 95% in our analysis. We also run variance inflation factor (VIF) analyses on our models to test for multicollinearity. The VIF analyses reveal a moderate degree of multicollinearity for several variables, but not rising to an extent that would necessitate exclusion of any of the independent variables (Appendix B).

2.3. Results

We first run summary statistics on our outcome, independent, and control variables for all farmers in the final models, meaning after farmers in zero or two or more Agencies are dropped (Table 6). Among the survey respondents included in our models, 41.51% indicated that they have participated in at least one of the four listed categories of SGMA events at some point in the past (Figure 6). The percent of respondents indicating that they agree with prompts related to perceptions of the SGMA implementation process ranged from 43.84% to 65.84% (Figure 7). Further, 61.49% of respondents indicated that they prefer the Agency to be the entity responsible for managing dispute resolutions, and 36.79% of farmer respondents in the final dataset are located in an Agency that we consider to be a farmer-interest Agency. The mean value of the percent of a farmer's Agency or county that is cultivated is 37.79%. Additionally, 54.22% of farmers are members of their local Farm Bureau, 70.81% of farmer respondents indicated that they received an associate's degree or above, 62.87% have at least a partial farm succession plan, and 91.40% of respondents are men. The mean age of respondents is 67.20, and the mean number of total acres is 360.97.

Table 6

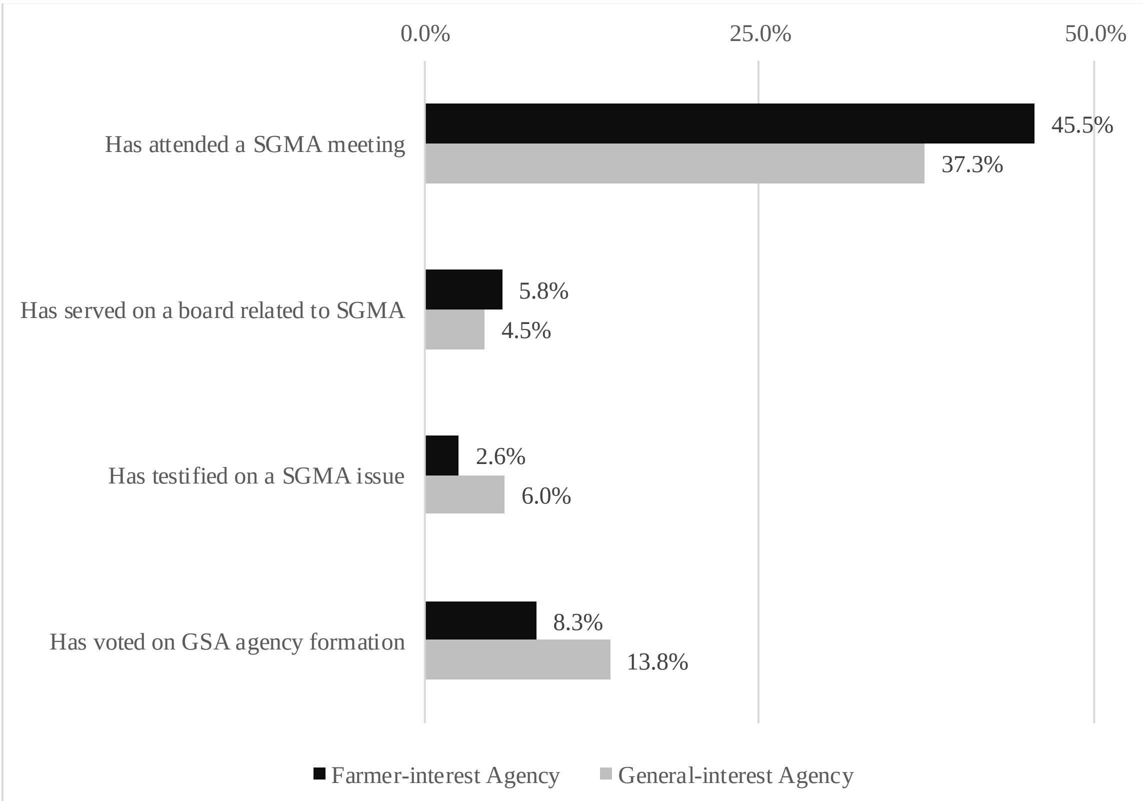
Summary Statistics for Dependent, Independent, and Control Variables

Variable	Measurement scale	Number of valid responses	Percent of respondents (unless otherwise indicated)

Located in a farmer-interest Agency (i.e., irrigation or reclamation district)	Categorical	424	36.79%
Percent of farmer's Agency that is cultivated	Continuous	424	Mean = 37.79%
Member of Farm Bureau	Categorical	415	54.22%
Education	Categorical	411	
No college education			12.90%
College education, no degree			16.30%
College education, associate's degree			9.98%
College education, bachelor's degree			41.36%
Graduate degree			19.47%
Age	Continuous	406	Mean = 67.20
Gender	Binary	407	
Man			91.40%
Woman			8.60%
Farm succession plan	Categorical	404	
Full			40.84%
Partial			22.03%
None			37.13%
Total acres	Continuous	405	Mean = 360.97
County	Categorical	424	
San Luis Obispo County			16.75%
Madera County			17.22%
Fresno County			66.04%

Figure 6

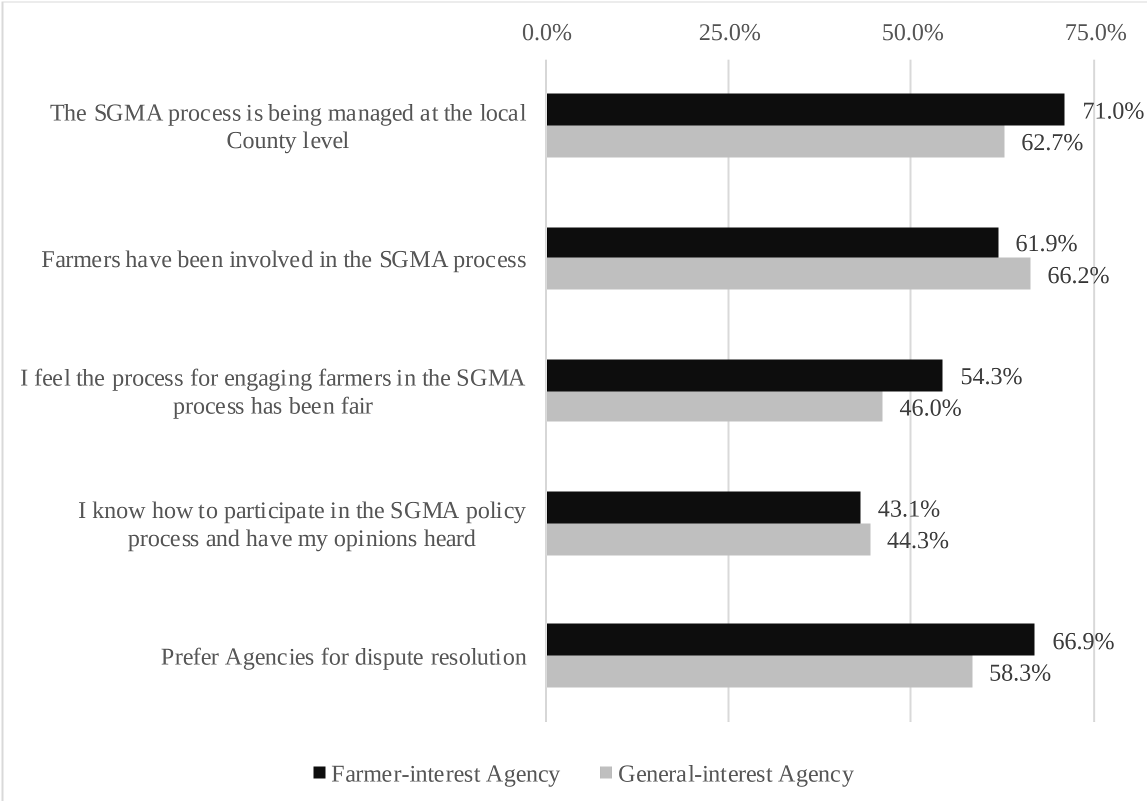
Percent of Respondents Who Participated in SGMA Events



Note. All prior participation is grouped together for the purposes of this chart. Percentages are for farmer respondents used in the final statistical models.

Figure 7

Percent of Respondents Answering "Agree" for SGMA Perception Prompts



Note. Responses for somewhat agree, agree, and strongly agree are grouped together for the purposes of this chart. Likewise, responses for somewhat preferred, preferred, and strongly preferred are grouped together. Percentages are for farmer respondents used in the final statistical models.

2.3.1. Statistical Models

In all three ordered logistic regression models, a farmer's Agency entity type is not significantly associated with farmer policy interactions or perceptions of the SGMA implementation or dispute resolution processes (Table 7). Multiple controls were statistically significant. In model 1, Farm Bureau membership is a significant positive predictor of farmer participation in SGMA implementation events ($p<0.001$). Additionally, in model 1, the percent of land cultivated in an Agency or county is significantly positively associated with participation in SGMA implementation (p=0.010), In model 2, Farm Bureau membership is a significant positive predictor of favorable farmer perceptions of the SGMA implementation process (p=0.010).

Table 7

Ordered Logistic Regressions of Farmer Participation in and Perceptions of SGMA Implementation

	Model 1 = Participation in SGMA events		Model 2 = Perceptions of SGMA implementation		Model 3 = Perceptions of Agency for dispute resolution	
Predictor variable	Odds ratio	Standard error	Odds ratio	Standard error	Odds ratio	Standard error
Agency entity type	1.001672	0.1254086	0.8845097	0.122272	1.030108	0.1196402
Percent Agency land cultivated	1.633236*	0.19034	1.381356	0.1918425	1.264503	0.1800945
Farm Bureau membership	1.565236**	0.1151508	1.31355*	0.1052949	1.115618	0.106801
Education	1.129549	0.1151351	0.93026	0.1094483	0.9811268	0.1106145
Age	0.8648342	0.114837	0.9981154	0.1093575	0.9493884	0.1068132
Gender	0.9855401	0.1109458	0.8907977	0.1141213	0.9085407	0.1126596
Farm succession plan	1.227739	0.1115613	1.041905	0.1033442	1.011161	0.1064758
Total acres	1.175576	0.1029305	1.045197	0.1054836	1.02838	0.1027727
San Luis Obispo County	1.558247**	0.1600395	1.150194	0.1466947	1.002114	0.1490839
Madera County	1.207339	0.1673175	1.195897	0.1619421	1.078179	0.1528236

Note. * indicates $p < 0.05$ and ** indicates $p < 0.01$ for a two-tailed significance test.

2.4. Discussion

Our analysis suggests that whether a farmer's land is located in a farmer-interest Agency, which we define as irrigation or reclamation districts, does not appear to be a significant predictor of farmer participation in SGMA events, perceptions of the SGMA implementation process, or perceptions of dispute resolution via Agencies. Thus, we do not find evidence for our hypothesis that farmers in farmer-interest Agencies will on average be more likely to participate in SGMA implementation and have more favorable perceptions of SGMA implementation and Agency dispute resolution. By contrast, farmers who are members of their local Farm Bureaus are on average more likely to participate in SGMA implementation events and have more favorable perceptions of SGMA implementation. The percent of cultivated land in an Agency or county is significantly associated with farmer participation in SGMA implementation, but not the other two outcome variables, meaning that farmers in Agencies with more agricultural production are on average more likely to participate in the implementation process. Taken together, these results suggest that Agency entity type is not associated with greater or more favorable farmer experiences with SGMA. Instead, it is important to consider the full range of factors that may affect a farmer's interactions with policy processes, including their membership in their local Farm Bureau, which our analysis indicates is a positive predictor of both participation and positive perceptions of the SGMA governance process.

Prior studies have found an association between Agency entity type and Plan adoption rates (Macleod & Méndez-Barrientos, 2019) and Agency entity type and the degree of bureaucratic cooperation among Agencies (An & Tang, 2023). We do not observe a relationship between Agency entity type and farmer policy interactions. It is possible that this disparity may be the result of our specific sampling frame, since we survey farmers in three highly agricultural Central Valley counties. The implementation process may favor farmers in general in these three counties given the prevalence of agricultural production, so we may not observe nuances in farmer participation across Agencies. Alternatively, this disparity between our null result and prior findings could be explained by the specific outcome variables that we measure. In other words, it is possible that Agency type does relate to certain aspects of SGMA implementation, but not to the degree of farmer participation.

Nonetheless, our results suggest that variation among political actors does not explain stakeholders' policy interactions in our sample. Under common-pool resource theory, governance system actors are one of many social, political, and biophysical factors that could shape policy outcomes in natural resource management (Ostrom, 2009). In our models, governance system entities do not correlate with SGMA participation and perceptions. Indeed, other governance-level and user-level characteristics such as Farm Bureau membership, as well as resource system- and resource unit-level characteristics such as the amount of cultivated land in an Agency or county, are also important for understanding farmers' SGMA engagement and perceptions. In that sense, whether a management system aligns with Ostrom's design principles, including congruent rules and collective-choice participation, depends not only upon the relevant governance actors, but also the characteristics of the resource system, units, and users. Additionally, our results suggest that in addition to examining inequities in engagement across stakeholder groups, it is also important to consider differences within a stakeholder group. Thus, regardless of the kind of Agency farmers are located in, certain sub-groups of farmers — particularly those who are less integrated into some types of farmer networks — may face barriers in policy participation. As per Kiparsky et al.'s (2017) criteria for evaluating fairness in the SGMA implementation process, the fact that Farm Bureau membership is significantly associated with farmer SGMA engagement suggests that policy participation and representation in decision-making processes may not be equitable across all sub-groups of farmers.

These results have several implications for stakeholder engagement and representation efforts. Prior research has suggested that farmers may be privileged over disadvantaged communities or environmental actors in SGMA implementation (Dobbin et al., 2022; Lubell et al., 2020; Macleod & Méndez-Barrientos, 2019), in part due to different levels of political capital among stakeholder groups. However, this research points to potential inequities between different farmer sub-groups related to SGMA implementation. Some farmers, particularly those who are part of established networks such as Farm Bureaus, may be more socially connected, and thus have greater engagement and participation in the policy process. To the extent that participation favors those farmers participating, this could in turn mean that locally implemented environmental policies such as SGMA run the risk of exacerbating existing inequities among resource users by favoring those who are already better-connected. This suggests that it is critical to integrate farmers who are not part of Farm Bureau networks in future implementation efforts. That said, we only measure farmers' engagement via Farm Bureaus, so it is possible that farmers are engaged through other kinds of formal or informal farmer networks. Moreover, even if particular kinds of Agencies represent the interests of farmers, this does not guarantee that such Agencies will represent all farmers equally, since farmers can participate in SGMA indirectly through Agencies or directly by attending meetings and other events. Representation through Agencies alone may not be enough to ensure stakeholder inclusion, suggesting that other types of representation may be critical to full stakeholder inclusion (Perrone et al., 2023). Farmers have different degrees of financial, social, and political resources, and these inequities can lead to institutional capture by more politically powerful sub-groups of farmers (Rudnick et al., 2016). Thus, even if farmers are part of the same Agency, they may face different levels of policy access. In that sense, representation via Agencies may not be a complete solution for stakeholder representation.

There are several potential limitations in our analysis. For one, our sample is restricted to three counties with substantial agricultural production in the California Central Valley, meaning that our results may not generalize across all counties in California. Relatedly, the fact that survey outreach was conducted in partnership with County Farm Bureaus could have resulted in variation in response rates between farmers who are and are not members of their local Farm Bureaus. Additionally, for the variable corresponding to the percent of an Agency that is cultivated, farmers in white areas do not have a corresponding Agency. Thus, for such farmers we use county government shapefiles as the proxy for Agencies, potentially presenting an issue in the interpretation of this variable. Moreover, we drop farmers in zero or two or more Agencies, since for these farmers we would not be able to map their perceptions onto a specific Agency. The group of dropped farmers are on average better educated and have a larger amount of acreage than the farmers in our final models (Appendix A). Another potential limitation is that we code Agencies as falling into a binary of either farmer-interest or general-interest entities. However, many Agencies are multi-entity Agencies. Some multi-entity Agencies have members that are farmer-interest entities but do not solely consist of farmer-interest entities. In that sense, whether an Agency is a farmer-interest Agency could also be conceptualized as a scale rather than a binary. However, we simplify this variable to a binary due to data availability and our specific research aims. Finally, we measure the association between Agency entity type and specific dimensions of farmer participation and perceptions; however, it is possible that Agency entity type is associated with other dimensions of farmer policy participation that are not measured here.

Future research should address how Agency entity type relates to other aspects of farmer policy interactions, such as farmer perceptions of the actual contents of Plans. Relatedly, since the survey data were collected in 2019 when SGMA implementation was still at its early stages, follow-up studies could examine how farmer perceptions may have changed with additional years of SGMA implementation. Additional studies could also assess how farms that stretch into multiple Agencies might differ from those in a single Agency. Researchers could also qualitatively analyze how the process of writing Plans varies by Agency entity type, to more comprehensively consider ways in which the process and outcomes might differ across Agencies. Finally, researchers should further assess inequities *within* stakeholder groups, such as variation in political representation among disadvantaged communities or environmental actors.

2.5. Conclusion

This study analyzes farmer survey data and geospatial data on land use to examine how local variation in environmental governance relates to farmer interactions with groundwater policy in California. We find that the type of entity that forms an Agency does not significantly relate to farmers' participation in or perceptions of SGMA implementation or dispute resolution via Agencies. However, we observe that farmers' membership in their local Farm Bureaus is a significant positive predictor of policy participation and favorable perceptions of SGMA implementation. Thus, even within an Agency, there may be inequities in farmers' propensity to participate in political processes, or be represented in these processes, depending on the networks they participate in. Accordingly, future SGMA engagement efforts should attempt to include underrepresented farmers in groundwater decision-making.

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Appendix A

In the second thesis paper, we drop 127 farmers who either did not fill out the Agency map question on the survey or who have parcels in more than one Agency area. Thus, here we examine whether the farmers that were dropped are different than the farmers in the final models on key agricultural and farmer demographics. The mean of total acres for dropped farmers is significantly larger than the mean for farmers preserved in the final models, $t(518) = -7.1506$, $p < 0.001$. Additionally, chi-square tests indicate that dropped farmers are significantly better educated than the group of farmers in the final model, X^2 (7, N=5538) = 23.4154, $p = 0.001$.

Comparison of Demographics Between Dropped Farmers and Farmers in Final Models

Variable	Percentage of respondents (unless otherwise indicated)		
	Dropped farmers (i.e., farmers in 0 or 2+ Agencies)	Farmers in final model (i.e., farmers in 1 Agency)	Chi-square or t-test results
Education			X^2 (7, N=5538) = 23.4154, p = 0.001
No college education	11.81%	12.90%	
College education, no degree	6.39%	16.30%	
College education, associate's degree	3.15%	9.98%	
College education, bachelor's degree	56.69%	41.36%	
Graduate degree	22.04%	19.47%	

Age	Mean = 65.47	Mean = 67.20	$t(525) = 1.2634$, $p = 0.2070$
Gender			X^2 (1, N=530) = 0.0141, $p = 0.906$
Man	91.06%	91.40%	
Woman	8.94%	8.60%	
Farm succession plan			X^2 (2, N=525) = 2.4146, $p = 0.299$
Full	43.80%	40.84%	
Partial	26.45%	22.03%	
None	29.75%	37.13%	
Total acres	Mean = 2,106.28	Mean = 360.97	$t(518) = -7.1506$, $p < 0.001$

Note. Reported t-tests are for two-tailed significance tests.

Appendix B

Variance Inflation Factor (VIF) Results to Test for Multicollinearity

Predictor variable	Model 1 = Participation in SGMA events	Model 2 = Perceptions of SGMA implementation	Model 3 = Perceptions of Agency for dispute resolution
Percent Agency land cultivated	3.27	3.27	3.28
Madera County	2.39	2.39	2.41
San Luis Obispo County	2.11	2.11	2.14
Agency entity type	1.42	1.42	1.4
Total acres	1.14	1.14	1.13
Age	1.13	1.13	1.12
Education	1.07	1.07	1.08
Farm Bureau membership	1.07	1.07	1.08
Farm succession plan	1.07	1.07	1.07
Gender	1.04	1.04	1.05

Supplementary Material

Full Regression Results for the Three Ordered Logistic Regression Models of Farmer Participation in and Perceptions of SGMA Implementation and Dispute Resolution via Agencies

	Model 1 = Participation in SGMA events			
Predictor variable	Odds ratio	Coeff.	Standard error	p-value
Agency entity type	1.001672	0.0016703	0.1254086	0.989
Percent Agency land cultivated	1.633236*	0.4905633	0.19034	0.010
Farm Bureau membership	1.565236**	0.4480368	0.1151508	0.000
Education	1.129549	0.1218186	0.1151351	0.290
Age	0.8648342	-0.1452175	0.114837	0.206
Gender	0.9855401	-0.0145654	0.1109458	0.896
Farm succession plan	1.227739	0.205174	0.1115613	0.066
Total acres	1.175576	0.1617585	0.1029305	0.116
San Luis Obispo County	1.558247**	0.4435617	0.1600395	0.006
Madera County	1.207339	0.1884184	0.1673175	0.260

	Model 2 = Perceptions of SGMA implementation			
Predictor variable	Odds ratio	Coeff.	Standard error	p-value
Agency entity type	0.8845097	-0.1227217	0.122272	0.316
Percent Agency land cultivated	1.381356	0.3230653	0.1918425	0.092
Farm Bureau membership	1.31355*	0.2727334	0.1052949	0.010

Education	0.93026	-0.0722912	0.1094483	0.509
Age	0.9981154	-0.0018863	0.1093575	0.986
Gender	0.8907977	-0.1156379	0.1141213	0.311
Farm succession plan	1.041905	0.0410509	0.1033442	0.691
Total acres	1.045197	0.0442058	0.1054836	0.675
San Luis Obispo County	1.150194	0.1399305	0.1466947	0.340
Madera County	1.195897	0.1788969	0.1619421	0.269

	Model 3 = Perceptions of Agency for dispute resolution			
Predictor variable	Odds ratio	Coeff.	Standard error	p-value
Agency entity type	1.030108	0.0296641	0.1196402	0.804
Percent Agency land cultivated	1.264503	0.2346788	0.1800945	0.193
Farm Bureau membership	1.115618	0.1094086	0.106801	0.306
Education	0.9811268	-0.0190536	0.1106145	0.863
Age	0.9493884	-0.0519373	0.1068132	0.627
Gender	0.9085407	-0.0959156	0.1126596	0.395
Farm succession plan	1.011161	0.0110995	0.1064758	0.917
Total acres	1.02838	0.0279846	0.1027727	0.785
San Luis Obispo County	1.002114	0.0021118	0.1490839	0.989
Madera County	1.078179	0.0752731	0.1528236	0.622

Note. * indicates $p < 0.05$ and ** indicates $p < 0.01$ for a two-tailed significance test.