The carrot or the stick? Drivers of California farmer support for varying groundwater management policies

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Abstract
Growing demand for groundwater, coupled with the projected threats to groundwater supplies and impacts, has led to an increased focus on policy options for groundwater management. Globally, agriculture is the largest human-use of water, making farmers a critical stakeholder for policy engagement. In California, the Sustainable Groundwater Management Act (SGMA), a comprehensive groundwater policy, was signed into law in 2014. Here we explore farmer perspectives of groundwater availability and groundwater management policy preferences through a mail survey of farmers (n = 137) in Yolo County, California, implemented in 2017. Overall, farmers expressed widespread concern for the five applicable ‘undesirable results’ considered under SGMA and the majority of farmers felt that these conditions were either occurring now or were likely to occur in the next ten years. The majority of farmers were supportive of individual or incentive-based policy options to address groundwater concerns (e.g. voluntary adoption of water management practices). However, a sizable group of farmers were also supportive of regulatory-based policy options (e.g. moratorium on drilling new wells). Multivariate regression models suggest that for both kinds of policies, individual support for SGMA positively predicts groundwater management policy support. However, for regulatory-based policies, subjective norms - a farmers’ belief that the majority of other farmers support SGMA— is also an important predictor of regulatory policy approaches along with a number of other factors. These results suggest that, should regulatory approaches for SGMA implementation be necessary, fostering subjective norms among farmers may be an important mechanism to achieving farmer support.

1. Introduction

Groundwater is the largest source of non-frozen freshwater on the planet (van der Gun 2012). Globally, groundwater extractions support billions of people as drinking water and irrigation water for agricultural production (Alley et al 2002, Siebert et al 2010). In the United States in particular, 60% of irrigation water is from groundwater (Scanlon et al 2012). Growing attention is focused on groundwater as climate change projections estimate greater rainfall variability, drought and desertification conditions in many regions (Jiménez Cisneros et al 2014) amid growing demand and groundwater extractions (Famiglietti 2014). Given these forthcoming challenges, there is growing interest in groundwater monitoring and in regulation of groundwater extractions and prevention of undesirable outcomes in groundwater management.

California is one of the most recent regions to tackle groundwater management, with implementation of the 2014 Sustainable Groundwater Management Act (SGMA) (California State Legislature 2014). By many measures, groundwater management in California is facing serious challenges— between 2002 and 2010,
groundwater pumping supplied between 30 and 46% of the state’s total water supply (California Department of Water Resources 2015) and 85% of Californians use groundwater for some portion of their water supply (Public Policy Institute of California 2017). However, groundwater extractions between 1962 and 2003 have increased four-fold (Faunt 2009). In recent years, groundwater extraction increased as surface water became less available, especially during drought conditions (Scanlon et al 2012). Given that farmers are the largest anthropogenic users of water in California, this paper explores farmer perceptions of groundwater, potential policy strategies to manage groundwater, and the factors that may relate to farmers support of such policy strategies and implementation in California.

In the United States, groundwater policies are distinct from surface water rights (Allin 2008) and largely driven by geography and water access. Two-thirds of groundwater use in the United States occurs in 17 western states and is primarily for agricultural purposes (Reimer 2013). Water allocation in western states, including California, has traditionally occurred through ‘prior appropriation’, which is a first-come, first-served approach (Allin 2008) coupled with the concept of ‘reasonable use’, whereby groundwater resources could be developed if used reasonably (Reimer 2013). In California, water rights are akin to property rights and owners have the legal authority to use water. Groundwater use and ownership is also driven by correlative rights—that ownership of the land above the water provides legal right to the water beneath (California Waterboards 2018a). As a result of these rights and prior appropriation for groundwater management, there have been multiple legal challenges, including difficulties for regulating and monitoring the use of groundwater (Getches 2001, Schlager 2006). With the growing concern over aquifer depletion, groundwater allocation has become increasingly complex (Allin 2008). A recent review of existing groundwater policies across western states confirmed that a variety of allocation approaches are in use, including the traditional prior appropriation approach, as well as new groundwater allocation techniques such as adjudicated pumping quotas and allocation per-irrigated acre (though these are only a small portion in California) (Newman et al 2018).

Beyond allocation approaches, there is also a great diversity of groundwater management policy strategies that can be employed to improve groundwater sustainability. These strategies range from purely voluntary approaches such as farmer incentives for adoption of water saving practices, to mixed market/regulatory strategies such as water trading, to, finally, command and control style policies such as fixed pumping quotas for farms. The choice of groundwater policies to employ in any given sub-basin will depend on the state of the aquifer, as well as the potential sustainability improvements achieved through any suite of policy options. However, the success of policy will depend upon farmers making changes in their use of groundwater, and thus understanding farmer’s potential support of certain policies is an important investigation.

In common pool resource dilemmas like groundwater use, farmer support and preferences matter because of the omnipresent temptation to shirk responsibility and free ride off of the actions of others (Ostrom 1990). Mainstream economic theory would suggest that farmers would prefer incentive-based strategies that allow them to act to maximize personal returns and minimize costs, and therefore, they would resist command and control strategies that limit their management options. This, in turn, would suggest that for critically over-drafted basins, the use of regulatory groundwater management policies will face significant implementation barriers. However, it is also possible in these regions that if perceptions of threats to groundwater resources are significant enough, farmers may support more stringent regulatory measures that protect against free riders. As work by Elinor Ostrom and others has shown with regards to groundwater and other common pool resources, individuals may be willing to incur the costs of setting up new institutions and operating under new rules and regulations to solve the issue of resource overuse (Ostrom 1990, Blomquist 1992, Agrawal 2003). Thus, understanding these farmer preferences and the conditions in which such support may occur is a key focal area of this paper.

Despite this, there has been little exploration of stakeholder perceptions of these policies and preferences for groundwater management strategies, particularly in countries like the United States with often large-scale, high-input agriculture. This is especially true of farmers, who, given irrigation is the largest use of groundwater (Scanlon et al 2012), are arguably one of the most critical stakeholders. Given that under SGMA state intervention is possible if or when Groundwater Sustainability Agencies (GSA) processes or sustainability plans fail (California Waterboards 2018b), understanding how farmers perceive and may respond to changes in groundwater policies can be important for policy design, implementation and overall success of groundwater policies. Such investigations may also be critical for the future of agricultural production altogether—to ensure that farmers remain in agriculture amidst growing challenges. Here we explore farmer perceptions of groundwater management policy options and support of SGMA, the comprehensive groundwater policy signed into law in California in 2014.
2. Methods and data

2.1. California approach

SGMA requires local groundwater basins to form GSAs made up of key stakeholders and groundwater users, and then develop Groundwater Sustainability Plans (GSPs) by 2020 (in critically over-drafted basins) to achieve groundwater sustainability by 2040. Initially, SGMA classified 127 total basins that account for 96% of annual California groundwater pumping as priority basins, including Yolo County, our region of focus, though final prioritization is ongoing with some regions still pending (California Department of Water Resources 2018). Achieving groundwater sustainability under SGMA involves creating programs, policies, infrastructure adjustments or other efforts to avoid the six ‘undesirable results’ set forth in the SGMA legislation. These include:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon.
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

As GSAs were formed by June 30, 2017, efforts now turn towards development of GSPs across California (Conrad et al. 2018). In doing so, GSAs must carefully consider their own local hydrological, geographic, climatic and social context. Engaging with local water users is critically important to the success of the local SGMA process and a statutory requirement of the policy (Mehta et al. 2018). For farmers, who are often part of local GSAs and management approaches, these efforts may have profound implications for the future of groundwater management in California. SGMA explicitly gives jurisdiction to local GSAs to manage and implement sustainability plans, but has mechanisms within the law for state intervention should such efforts not be successful. In these instances, the law explicitly allows for the State Water Resources Control Board to step in and manage local processes. Thus, strict state enforcement is possible and could impact local water management regions should local efforts fail (California Waterboards 2018b).

Our focus is in Yolo County, California, a region in the Northern Central Valley located between San Francisco and Sacramento (figure 1). Yolo County has formed a GSA, and was considered a high priority basin under the SGMA legislation. Yolo County supports diverse agricultural production, including rice, cattle grazed in summer-dry grasslands and savannas, and perennial, vegetable, and row crops (Jackson et al. 2012, Niles and Hammond Wagner 2017). The county had nearly 100 direct export partners, indicating its importance in a global agricultural system (Yolo County Government 2017). Of the 653,454 acres in the county, 532,266 (81%) are agricultural land, including grazing land (California Department of Conservation 2016). Recent participatory modelling by Mehta et al. 2018 in Yolo County found that in the event of severe drought, the county will likely face large trade-offs in groundwater security and financial viability without regulatory intervention.

Here we explore Yolo County farmer perceptions of SGMA at the local and state levels, and assess support for groundwater management policies and strategies. We aim to understand: 1) To what extent are farmers concerned about groundwater management and the undesirable results? 2) To what extent do farmers support SGMA at the local and state level? 3) Do farmers differ in their support for groundwater management policies? 4) What factors are related to support of different groundwater management strategies?

2.2. 2.2 Methods and data

Data for this analysis were obtained through a mail survey implemented in May–July 2017. Focus groups with 20 farmers in October 2016 informed development of the survey (Niles and Wagner 2017). Institutional Review Board approval for the study was obtained through the University of Vermont. The survey was piloted with industry professionals and farmers outside of the target area. Farmer addresses were obtained via the publicly available database of farmers within Yolo County through the Agricultural Commissioner’s office in compliance with Pesticide Use Reporting. Organic farmer addresses were obtained through the United States Department of Agriculture (USDA) Organic INTEGRITY Database (USDA 2017). Instances of obvious non-farmers were removed (e.g. golf courses that use pesticides). Aggregated together, these databases included 653 farmers.
The Dillman method (Dillman and Smyth 2014) was utilized to deploy the survey using a series of postcards and follow-up surveys. A postcard was sent before the first survey, and twice as reminders if a farmer did not return the mail survey. A second and third survey were sent if farmers did not return the first or second survey. An online version of the survey was made available to farmers through a link provided on the paper mail survey (thus, only made available to farmers that had received a mail survey). A total of 142 surveys were returned with four being unusable (e.g. non-farmers or outside focal region). An additional 38 were return to sender. The total response rate was 21.7%, calculated using the American Association of Public Opinion Research standards (American Association for Public Opinion Research 2009). Surveys were entered into excel for analysis. Descriptive statistics reported below in table1 were calculated using Stata 15 (StataCorp 2017).

In addition to the variables presented in table 1, we utilize a number of constructed scale variables. We use confirmatory factor analysis, a multivariate technique to test the degree to which a group of measure variables represents an underlying (non-measured) construct, to create the four scale variables in table 1 (Clark and Watson 1995). All of these scales present factor loadings greater than 0.40, a generally accepted cut-off point for inclusion (Costello and Osborne 2005). Further, these scales all achieve a Cronbach alpha score that represents high-level of internal validity (generally greater than 0.70) (Nunnally 1978, Peterson 1994). Table 2 describes the scale variables and measures of reliability. In addition, we utilized the factoextra package in R (Kassambara and Mundt 2017, R Core Team 2016) to investigate differences in farmer policy support with hierarchical k-means cluster analysis. We classify farmers into groups based on their levels of policy support for the 11 types of groundwater management policies. We then analyze differences in the resulting groups of farmers based on each clusters mean level of support for each of the 11 policy types. Based on the resulting farmer clusters we then divided the 11 management strategies into two categories to create the policy scale variables, Incentive Policy Scale and Regulatory Policy Scale shown in table 1. These variables are aggregate scales of preference for five and six management strategies each. Finally, we run multivariate regression models with the Incentive Policy Scale and Regulatory Policy Scale as dependent variables to examine predictors of support for these two categories of groundwater management strategies. It should be noted that the cluster analysis was conducted only among the subset of farmers (n = 83) that fully responded to all 11 management policy preferences. However, regression models utilized dependent variables that were scales, which enabled a value for a farmer if they responded to any of the 11 management policy preferences.

Our statistical analysis consists of Chi Square tests to examine if there are statistically significant differences between categorical variables, Analysis of Variance (ANOVA) to test if there are statistically significant differences between group means and finally two multivariate linear regression models to examine which factors significantly predict farmer support of Regulatory policies versus Incentive policies (as defined in table 2). These analyses were performed in Stata (StataCorp 2017) and R version 3.5.1 (R Core Team 2016). Most of our questions focus on perceptions at the local scale, therefore, in the regression models we exclude farmer perceptions of groundwater management in California more broadly.

Figure 1. Map of Yolo County within the context of California. (Map credit: Thomas Wentworth).
Table 1. Variables used and descriptive statistics.

| Variable                        | Questions                                                                 | Scale                        | Mean  | Std. Deviation |
|---------------------------------|---------------------------------------------------------------------------|-------------------------------|-------|----------------|
| Ability                         | ‘I feel confident in my ability to manage my own water resources’         | Strongly disagree = 1 to Strongly agree = 6 | 5.10  | 1.04           |
| Achieve Sustainability          | ‘I feel confident that I can achieve groundwater sustainability under SGMA’ | Strongly disagree = 1 to Strongly agree = 6 | 4.01  | 1.29           |
| Affordability                   | ‘SGMA will be affordable to implement’                                   | Strongly disagree = 1 to Strongly agree = 6 | 2.91  | 1.29           |
| Water Use                       | ‘On average, I use less water than other farmers who produce similar products’ | Strongly disagree = 1 to Strongly agree = 6 | 4.24  | 1.02           |
| SGMA Necessary in Yolo          | ‘I believe SGMA is necessary to achieve groundwater sustainability in Yolo County’ | Strongly disagree = 1 to Strongly agree = 6 | 3.86  | 1.54           |
| SGMA Necessary in California    | ‘I believe SGMA is necessary to achieve groundwater sustainability in California’ | Strongly disagree = 1 to Strongly agree = 6 | 4.15  | 1.46           |
| Majority SGMA Necessary in Yolo | ‘The majority of farmers think that SGMA is necessary for achieving groundwater sustainability in Yolo County’ | Strongly disagree = 1 to Strongly agree = 6 | 2.96  | 1.23           |
| Majority SGMA Necessary in California | ‘The majority of farmers think that SGMA is necessary for achieving groundwater sustainability in California’ | Strongly disagree = 1 to Strongly agree = 6 | 3.11  | 1.22           |
| Farm Size                       | How many total acres do you manage (all land owned, leased or managed)?   | 0 to 9 acres = 1; 10–49 acres = 2; 50 to 179 acres = 3; 180 to 499 acres = 4; 500 to 999 acres = 5; >1000 = 6 | 3.75  | 1.67           |
| Succession Plan                 | Do you have a farm succession plan for after you retire?                  | Yes = 1; Partial = 0.5; No = 0 | 0.54  | 0.44           |
| Nut Trees                       | Do you manage/own nut trees?                                             | Yes = 1; No = 0               | 0.53  | 0.5            |
| Groundwater Dependence          | Do you utilize irrigation through groundwater only in dry, normal and/or wet years? | No groundwater only irrigation = 0; In one year of (dry, normal, wet) = 1; In two years of (dry, normal, wet) = 2; In three years of (dry, normal, wet) = 3 | 1.34  | 1.34           |
| Age                             | How old are you?                                                          | continuous                    | 61.54 | 12.51          |
| Years Farming                   | How long have you been farming in Yolo County?                           | continuous                    | 28.59 | 19.56          |
| Income                          | What is your approximate yearly household gross income, including all on farm and off-farm incomes? | Less than $40,000 = 1; $40,000 to $60,000 = 2; $60,000 to $80,000 = 3; $80,000 to $100,000 = 4; $100,000 to $150,000 = 5; $150,000 to $200,000 = 6; More than $200,000 = 7 | 5.01  | 1.77           |
| Sex                             | Are you (check one)?                                                     | Categorical; Male; Female; Prefer not to Answer | Male: 104 (81%) Female: 6 (13%) Prefer not to answer: 8 (6%) |
Table 2. Scales and measures of reliability.

| Variable | Questions | Scale | Eigenvalue | Factor loadings | Alpha |
|----------|-----------|-------|------------|-----------------|-------|
| **Concern** | Level of concern about the following potential conditions related to groundwater management in Yolo County | Likely to NOT occur in the next 20 years = 1; Likely to occur in 20 years = 2; Likely to occur in 10 years = 3; Likely to occur in 5 years = 4; Occurring Now = 5 | 3.633 | 0.902 |
| | Lowering of groundwater levels | | 0.875 | |
| | Reduction in groundwater storage | | 0.912 | |
| | Water quality degradation | | 0.856 | |
| | Local subsidence | | 0.868 | |
| | Depletions of surface water | | 0.742 | |
| **Timeframe** | Likelihood that Yolo County will experience these conditions in the following timeframes without any interventions? | Likely to NOT occur in the next 20 years = 1; Likely to occur in 20 years = 2; Likely to occur in 10 years = 3; Likely to occur in 5 years = 4; Occurring Now = 5 | 3.952 | 0.932 |
| | Lowering of groundwater levels | | 0.942 | |
| | Reduction in groundwater storage | | 0.955 | |
| | Water quality degradation | | 0.836 | |
| | Local subsidence | | 0.832 | |
| | Depletions of surface water | | 0.872 | |
| **Incentive Policy Scale** | Level of preference for these types of management | Strongly against = 1 to Strongly support = 6 | 2.38 | 0.739 |
| | Farmer adoption of water management practices | | 0.711 | |
| | Incentives for water saving practices | | 0.648 | |
| | District investment in conjunctive use infrastructure | | 0.639 | |
| | Public program highlighting Farmers implementing water saving practices | | 0.798 | |
| | Individual recharge credits | | 0.641 | |
| **Regulatory Policy Scale** | Level of preference for these types of management | Strongly against = 1 to Strongly support = 6 | 2.83 | 0.766 |
| | Water trading through markets | | 0.421 | |
| | Groundwater replenishment fees | | 0.822 | |
| | Water metering | | 0.792 | |
| | Moratorium on drilling new wells | | 0.625 | |
| | Permits for drilling new wells | | 0.528 | |
| | Fixed quota for water pumping allocated to each farmer | | 0.826 | |
3. Results and discussion

3.1. Farm and farmer characteristics

Farm demographics in our survey sample are on average representative of agriculture within Yolo County. As shown in Table 3 below, total acres managed ranged from 1 to 20,411 acres with a mean of 1,343 acres. On average, 71% of this land was owned. Farm types were representative of the diversified nature of Central Valley agriculture. The majority of respondents had some acreage in nut trees (53%), while a variety of other agriculture use types were also represented. We find that groundwater is the predominant source of agricultural water use among respondents (Table 4). Among those using irrigation, drip was the most common at 58% of respondents, followed by 37% for furrow, 35% sprinkler, 29% microsprinklers and 1% center pivot.

Farmers were on average 62 years old, had been farming for a mean of 29 years and 13% were female (Table 1). Additionally, 54% of farmers had either a partial or full farm succession plan. Mean yearly income, including farm and off-farm revenue, was in the $100,000 to $150,000 range amongst respondents.

Table 3. Farm land use characteristics.

| Land use        | Percent | Mean acreage |
|-----------------|---------|--------------|
| Total Acres Managed | —       | 1342         |
| Nut Trees       | 53%     | 182          |
| Hay             | 23%     | 79           |
| Row Crops       | 18%     | 177          |
| Grapes          | 17%     | 81           |
| Grain           | 16%     | 58           |
| Fruit Trees     | 15%     | 24           |
| Seed Crops      | 12%     | 70           |
| Cattle Pasture  | 10%     | 91           |
| Rice            | 9%      | 94           |
| Vegetables      | 9%      | 65           |
| Sheep Pasture   | 5%      | 17           |

Note: Percentages sum to more than 100% because respondents were able to report multiple land uses.

Table 4. Irrigation sources during varying climate conditions.

| Irrigation type | Dry year | Normal year | Wet year |
|-----------------|----------|-------------|----------|
| Surface         | 13%      | 27%         | 20%      |
| Ground          | 47%      | 48%         | 40%      |
| Mix             | 28%      | 28%         | 18%      |
| None            | 6%       | 7%          | 9%       |

Note: Percentages do not sum to 100% and each value should be considered individually as percent ‘yes’ for a given combination of irrigation type and year (i.e. question was not multiple choice, but rather check all that apply).

3.2. Farmer concern for groundwater problems

Overall we find widespread concern for the five conditions locally considered for SGMA (we did not ask about saltwater intrusion as this is not a relevant topic in the region). Concern for all conditions ranged from 80% (local subsidence) to 91% (water quality degradation) (Figure 2). There were no significant differences in concern for the five conditions across levels of groundwater dependence (see Supplementary table 1).

The majority of farmers felt that these five conditions were either occurring now or would occur within the next ten years (Figure 3). Lowering of groundwater levels had the highest percent of farmers (65%) who felt the undesirable result was already occurring or would occur within ten years. Conversely, water quality degradation had the smallest percent of farmers (55%) who selected this near-term timeframe. Dependence on groundwater as an irrigation source did not have a statistically significant impact on farmer’s time horizons for these conditions (see Supplementary table 2).

We found a strong, statistically significant relationship between farmers’ concern for undesirable results and perceived timeframe for undesirable results, whereby across all five conditions, those that were more concerned were more likely ($p < 0.05$) to believe it would happen now or in the near future (see Supplementary table 3).
3.3. SGMA policy implementation

A large majority (95%) of farmers feel confident in their ability to manage their own water resources (Ability). The majority (71%) also feel confident that they can achieve groundwater sustainability under SGMA (Achieve Sustainability). In addition, 81% of farmers believe that they use less water on average than other farmers who produce similar products (Water Use). However, less farmers (34%) felt that SGMA would be affordable to implement (Affordability).

We find that 77% of farmers believe that SGMA is necessary to achieve groundwater sustainability in California (SGMA Necessary in California), and 68% believe SGMA is necessary at the county level (SGMA Necessary in Yolo). However, when asked about their perception of other farmer’s support of SGMA, there is a significant shift. Only 47% of farmers agree that other farmers think SGMA is necessary for achieving groundwater sustainability in California (Majority SGMA Necessary in California), and only 38% agree to this at the Yolo County level (Majority SGMA Necessary in Yolo). There were no statistically significant differences of these perceptions by degree of dependence on groundwater for irrigation (see Supplemental table 4).

3.4. Specific SGMA policy options

We find large variation in farmers’ preferences for groundwater management strategies (table 5). For example, the majority of farmers were supportive of farmer’s adoption of water management practices and incentives for water saving practices (both 92%), but only a minority of farmers supported fixed quotes for water pumping allocated to each farmer (26%), and groundwater replenishment fees (13%). We found some instances where farmers who use groundwater exclusively had significantly different preferences on management strategies than farmers using other water sources. Farmers using only groundwater were less supportive of water metering (mean 3.15) compared to those using other water sources (mean = 3.71, \( p = 0.078 \)). Those using only groundwater were also less likely to support fixed quotes (mean = 2.25) compared to others (mean = 2.78, \( p = 0.050 \)).

Support for the 11 management strategies clustered farmers into two distinct groups shown in figure 4. Table 5 reports the mean level of support for each management strategy within the two clusters. Farmers in cluster two show higher levels of support for the 11 management strategies than farmers in cluster one, and in particular, much higher support for a subset of management strategies: groundwater replenishment fees, water trading through markets, water metering, moratorium on drilling new wells, permits for drilling new wells and fixed quotas for water pumping allocated to each farmer. This subset of strategies all have in common that they are partial or full regulatory policies (e.g. water trading is mixed regulatory/market-based strategy as it would
require regulation to structure the market). The farmer clusters produced here provide further justification for creating the two distinct incentive and regulatory policy support scales, which we explore further in regression analyses.

3.5. Predicting policy support
We ran two separate multivariate regression models to explore factors correlated with support of regulatory and incentive policies and we find important differences between the two models. The dependent variable for model 1, shown in table 6, is Incentive Policy Support and the dependent variable for model 2, shown in table 7, is Regulatory Policy Support. In both models we examine the same set of 14 predictor variables to compare predictors of the two types of groundwater management strategies represented by the Incentive Policy Support Scale and the Regulatory Policy Support Scale (see tables 6 and 7 for included variables and tables 1 and 2 for descriptions of each variable). Among 14 variables representing farm and farmer characteristics, we find only two variables significantly correlated with support of incentive-based policies. Individual-level belief that SGMA is necessary at the county level (Beta coefficient ($b = 0.240, p = 0.004$) and agreement that a farmer believes they use less water on average than other farmers that grow similar crops ($b = 0.209, p = 0.014$) are both positively associated with greater support for incentive policies (table 6). Model specifications indicate that 44% of the variance in the dependent variable is predicted by our set of variables ($R^2 = 0.44$).

We use the same set of variables to assess correlation with regulatory policy support. Similar to support for incentive policies, we find that individual agreement that SGMA is necessary at the county level is positively and statistically significant ($b = 0.265, p = 0.013$) (table 7). However, we find a number of other variables are

Table 5. Overall percent support for groundwater management strategies and mean level of support across the two clusters.

| Groundwater management strategies                                      | Percentage of support | Mean cluster 1 | Mean cluster 2 |
|------------------------------------------------------------------------|-----------------------|----------------|----------------|
| Farmer adoption of water management practices                           | 92%                   | 4.38           | 4.93           |
| Incentives for water saving practices                                   | 92%                   | 4.57           | 4.89           |
| District investment in conjunctive use infrastructure (e.g. water storage) | 90%                   | 4.76           | 4.91           |
| Individual recharge credits (e.g. winter flooding)                     | 83%                   | 4.08           | 4.96           |
| Public program highlighting farmers implementing water saving practices | 82%                   | 4.35           | 4.65           |
| Permits for drilling new wells                                         | 72%                   | 3.54           | 4.8            |
| Water metering                                                         | 53%                   | 1.89           | 4.28           |
| Water trading through markets                                          | 45%                   | 2.78           | 3.65           |
| Moratorium on drilling new wells                                       | 31%                   | 2.16           | 3.7            |
| Fixed quota for water pumping allocated to each farmer                 | 26%                   | 1.43           | 3.13           |
| Groundwater replenishment fees                                         | 22%                   | 1.76           | 3.57           |
statistically significant as well. Agreement that the majority of other farmers in the county also think SGMA is necessary \((b = 0.240, p = 0.014)\) as well as confidence in one’s ability to comply with SGMA \((b = 0.187, p = 0.057)\) are positively and significantly correlated with support for regulatory policies. Several farmer and farm characteristics are also correlated with support for regulatory policies including growing nut trees \((b = -0.464, p = 0.018)\), number of years farming \((b = -0.010, p = 0.080)\) and income \((b = 0.132, p = 0.045)\). This suggests that farmers growing nut trees and with more years in farming are less likely to support regulatory policies while farmers with higher income are more likely to support regulatory policies. Model specifications indicate that 53% of the variance in the dependent variable is predicted by our set of variables \((R^2 = 0.53)\).

### 4. Discussion

Here we explore the timely issue of groundwater management in California during an active policy implementation phase of SGMA. Our focus on farmers is critical for understanding potential policy strategies both within Yolo County and in other parts of California. We find that there is widespread concern for groundwater undesirable results, as well as a perception that many of these are already happening. This is somewhat surprising given that other studies of farmer’s concern for other water quality challenges have found less level of concern. For example, while we found that 90% of surveyed farmers expressed some level of concern for water quality degradation, a recent study of farmers in Indiana found that only 49% of English and 12% of Amish farmers had any level of concern for nitrates in water (Ulrich-Schad et al. 2017). Furthermore, our results
suggest that the majority of farmers think that SGMA is necessary both within the region of Yolo County and also in California. Importantly, this does not extend to a perceived general support for SGMA amongst the farming community: the majority of farmers do not believe that other farmers think SGMA is necessary in Yolo County or California. These results have several implications for policy implementation.

First, in line with mainstream economic theory, overall farmers generally support incentive and individual-based policies that are implemented voluntarily. Two factors are correlated with greater support of incentive-based policies: belief that SGMA is necessary and belief they use less water than others. The centrality of the belief that SGMA is necessary for those individuals who support incentive-based policies suggests that this belief may be activating a personal norm, or moral obligation to act to reduce the impact of groundwater issues in the county (Schwartz 1977). According to the Value-Belief-Norm theory for pro-environmental behavior (Stern et al 1999), the ‘ascription of responsibility’ is required for activating a norm in any given situation. In this case, since most farmers are aware of groundwater issues and concerned about them, the belief that a policy is necessary may represent a critical threshold that farmers must pass in their level of concern. As we did not test for the role and salience of particular norms in this study it is possible that this personal norm is not environmental in nature, but rather economic or livelihood-based. That no significant farmer or farm demographics correlate with support of these policies further demonstrates that they are generally accepted policy approaches by many types of farmers.

However, our second key finding is perhaps the most interesting and relevant for understanding the implementation of groundwater policies in California. Though we find that overall regulatory policies are less supported by farmers, we do find in our cluster analysis that there is a sizable portion of the farmer population sampled that do support regulatory policies. Farmers’ personal belief that SGMA is necessary in Yolo County is also a significant predictor of support for regulatory policies. It appears that the same personal norm to reduce groundwater issues may be at play for regulatory and incentive-based policy support. Nut tree farmers may be less likely to support regulatory policy support, namely production of nuts and greater years of farming, while farms with higher income are necessary for achieving SGMA goals, that strategies to help farmers understand how other farmers feel about groundwater concerns and personal beliefs about SGMA may be an important component of the policy process if regulatory policies are under consideration. Much outreach has been done by GSAs and the regional water board to support farmer understanding of SGMA, groundwater management and policy options, which has
most likely supported peer-to-peer learning and contributed to the level of regulatory policy support that we observe. However, our results suggest that farmer-led events that allow farmers to learn from each other that ‘other farmers like you believe that regulation is important’ could further increase farmer acceptance of more stringent regulatory policies.

We note a number of limitations to our study, including the scope and scale of the research and the potential for survey response biases. Our focus is confined to Yolo County, and while our results suggest a number of perceptions that may be important for SGMA implementation across the state of California, the results should not be interpreted as representative of the state. With regard to the survey approach taken in this study, it is also possible that some of the trends and relationships that we report could be influenced by biases in farmers’ responses to the survey instrument. It is possible that since farmers were aware of the groundwater focus of the survey, they desired to appear more ‘groundwater friendly’, along the lines of social desirability bias (Lavrakas 2008). Additionally, self-selection bias amongst survey respondents would also skew our results in the ‘groundwater friendly’ direction, in that those who are more interested and engaged with groundwater management are more likely to respond to the survey. Finally, our total sample size was 138, but because of missing data, some models resulted in fewer numbers of responses.

5. Conclusion

Increasing population, climate change, and the expanding need for water across many sectors are growing challenges for groundwater management. As California explores policy strategies to achieve groundwater sustainability within the coming decades, there is an important need to capture the perspectives and preferences of major water users. Here we’ve explored Yolo County, California farmers’ groundwater concerns and preferences for different policy outcomes. Our results suggest farmers are widely concerned about groundwater extraction, and that they believe such impacts are already occurring or will shortly. Further, farmers widely support incentive-based policies for groundwater management. While, more regulatory approaches are sometimes unsupported by farmers, there is a sizable sub-group of farmers that do support regulation. Importantly, perception that others think the policy is necessary that is an important predictor for regulatory policy support. Thus, subjective norms demonstrate an important relationship to groundwater regulatory approaches in California.

These results suggest that fostering opportunities for farmers to share their perspectives with each other on groundwater management could potentially influence their subjective norms about SGMA. Should regulatory approaches be necessary to achieve SGMA implementation, these subjective norms could play a critical role in driving potential policy support. Nevertheless, this study is place-based and potentially contextually localized in its results. As such, we suggest that further work across farming and other communities about their SGMA perceptions, concerns and policy preferences is essential to enable a greater understanding of groundwater issues and policy implementation in California. We hope that this work will inspire additional research in this area and contribute to a broader understanding of groundwater uses and policy preferences in a changing regulatory and environmental context.

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