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Top management challenges and concerns for agronomic crop production in California: Identifying critical issues for extension through needs assessment

Jessica Kanter[1] | Nicholas Clark[2] | Mark Edward Lundy[1,3] | Vikram Koundinya[4] | Michelle Leinfelder-Miles[5] | Rachael Long[6] | Sarah E. Light[7] | Whitney B. Brim-DeForest[7] | Bruce Linquist[1] | Dan Putnam[1] | Robert B. Hutmacher[1] | Cameron M. Pittelkow[1]

[1] Dep. of Plant Sciences, Univ. of California, Davis, Davis, CA 95616, USA

[2] Univ. of California Cooperative Extension, Kings County, Hanford, CA 93230, USA

[3] Univ. of California, Agriculture and Natural Resources, Davis, CA 95618, USA

[4] Dep. of Human Ecology, University of California, Davis, Davis, CA 95616, USA

[5] Univ. of California Cooperative Extension, San Joaquin County, Stockton, CA 95206, USA

[6] Univ. of California Cooperative Extension, Woodland, CA 95695, USA

[7] Univ. of California Cooperative Extension, Sutter-Yuba Counties, Yuba City, CA 95991, USA

Correspondence

Cameron M. Pittelkow, Dep. of Plant Sciences, Univ. of California, Davis, Davis, CA 95616, USA.
Email: cpittelkow@ucdavis.edu

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Abstract

Agronomic cropping systems in many regions face growing economic and management challenges as well as new regulations designed to address negative environmental and social externalities. At the same time, public support for agricultural education and extension is decreasing. Hence, new approaches are necessary to understand the most pressing on-farm issues and help prioritize critical needs. With a diversity of agronomic crops and new regulations for water and nitrogen, California is an important case study for other regions. The objective of this study was to identify major grower and industry concerns, management challenges, and motivations in making management decisions. In 2020, 483 growers, consultants, and allied industry of agronomic crop production responded to an online survey. The crops most widely grown by respondents included rice (*Oryza sativa* L.), alfalfa (*Medicago sativa* L.), wheat (*Triticum aestivum* L.), and corn (*Zea mays* L.). Four out of the five top concerns were related to water. Weed control and irrigation/water management were primary management challenges, though differences occurred by crop and region. The highest priorities considered in grower management decision-making were water, profitability, and land stewardship. Crop rotation benefits were a primary reason for growing agronomic crops, with profitability and tradition ranking closely behind. This study highlights opportunities to guide research and extension efforts based on critical needs identified by growers and industry, while also informing larger policy and institutional decisions regarding new programs and funding to address key issues in agronomic crop production.

Abbreviations: NSJV, northern San Joaquin Valley; SGMA, Sustainable Groundwater Management Act; SSJV, southern San Joaquin Valley; UCCE, University of California Cooperative Extension.

1 | INTRODUCTION

Agronomic crops are the basis of our world's food, feed, and fiber production systems. To better balance economic, social, and environmental outcomes, regulations are being introduced in many regions to account for negative externalities associated with crop production. However, government approaches to improve agricultural sustainability differ considerably, for example with more regulations in Europe than the United States, and there is an opportunity to learn from these experiences (Hutchins, 2021). California is unique because of new regulations for water and nitrogen inputs, making it an important case study for highly productive agricultural regions in the United States and beyond (Lubell et al., 2020; Rudnick et al., 2021). It is unclear how increased regulations will impact grower priorities and decision-making at the farm-level, particularly in relation to existing crop management challenges and other recent changes in farm economics, market demand, land use, labor availability, and pressures to conserve natural resources. In the changing context of California agriculture, adaptive research approaches are required to (a) better understand the concerns and management challenges of growers and others working in agronomic crop production, and (b) identify critical needs to inform the development of multi-faceted research and extension programs that are responsive to environmental and regulatory pressures.

Agronomic crops, also known as field crops, represent a significant share of irrigated land area in the Central Valley of California (Hanak et al., 2019; Johnson & Cody, 2015). Agronomic crops including small grains (e.g., wheat [*Triticum aestivum* L.] and barley [*Hordeum vulgare* L.]), rice (*Oryza sativa* L.), corn (*Zea mays* L.), dry bean (*Phaseolus vulgaris* L.), sorghum (*Sorghum bicolor* L.), oilseeds {e.g., sunflower [*Helianthus annuus* L.] and safflower [*Carthamus tinctorius* L.], cotton [*Gossypium* spp.], and forage [livestock feed] (e.g., alfalfa [*Medicago sativa* L.] and other irrigated pastures} were planted on an average of 1.6 million ha annually from 2000 to 2020, occupying more land than fruit, nuts, or vegetables (USDA, NASS, 2020). Therefore, production of these crops has large implications for agricultural sustainability in terms of land, water, and agrochemical use, but their economic value is much lower, estimated at US$3.3 billion compared to $21.5 billion for fruit and nuts in 2019 (California Department of Food and Agriculture, 2020). However, forage crops also support a $7.3 billion dairy industry, the single most valuable commodity in the state (California Department of Food and Agriculture, 2020). California's agricultural landscape is changing as higher value tree crops are replacing traditional agronomic crops. Since 2000, area planted to agronomic crops has declined by more than 40,000 ha per year, with a corresponding shift towards greater planting frequency of high revenue perennial tree crops such as almonds [*Prunus dulcis*)(Mill.) D. A. Webb], pistachios (*Pistacia vera* L.), and walnut (*Julans californica* S. Wats.) (USDA, NASS, 2020).

Core Ideas

- Water-related issues are of greatest concern while weed control is top challenge for agronomic crops in California.
- Availability of water, profitability, and land stewardship were the highest priorities in management decisions.
- Crop rotation benefits and profitability were the primary reasons for growing agronomic crops.
- Extension must balance immediate needs with long-term education to adapt to future challenges.

The future of farming in California will be shaped by forces that develop beyond the farm level, and there is a pressing need to understand how these forces intersect (Baur, 2020). Examples of new legislation and regulation that impact farming include the Sustainable Groundwater Management Act (SGMA), which is the state's first law regulating collective groundwater use, nitrogen use reporting for the Irrigated Lands Regulatory Program and the reissued Dairy General Order regulated by the California Water Quality Control Board, the Salt and Nitrate Control Program approved by the California Water Quality Control Board, and new or impending agrochemical regulations. Meanwhile, farms face growing economic challenges including increasing costs of inputs, land, and labor in combination with unpredictable markets. Documenting the concerns and motivations of growers, consultants, and allied industry can highlight the most important topics for research and extension, and serve as a guide for policymakers and administrators regarding where resources should be allocated.

As part of the University of California's Division of Agriculture and Natural Resources, University of California Cooperative Extension (UCCE) is responsible for agricultural research, education, and outreach throughout the state. The mission of UCCE is to solve applied problems and disseminate practical information to stakeholders, wherein UCCE Advisors and Specialists serve as a valuable link between land-grant universities and growers by developing programs that address stakeholder needs (Garst & McCawley, 2015). However, land-grant universities continue to face declining support, which has affected UCCE programming by reducing staff and internal budgets of core resources such as research farms and matching grant programs. Given the diversity of crops and production regions in California, combined with reduced numbers of UCCE personnel, it is important to understand the most pressing on-farm issues facing growers and industry to inform extension efforts.

Needs assessments help demonstrate program value and set priorities for future programming based on input from a range of stakeholders (McClure et al., 2012; Seevers & Graham, 2012). Needs assessment generally refers to methods, efforts, and activities involved in or used for identifying needs of a target group, providing a method for UCCE personnel to learn what is already known and what gaps in knowledge remain (McCawley, 2009; Royse et al., 2009). In many cases, needs assessments are surveys used to identify stakeholders' challenges and concerns, helping UCCE understand how they can improve delivery of programs and services (Garst & McCawley, 2015). While UCCE Advisors have conducted regional needs assessments for local clientele, to our knowledge there have been no prior efforts to comprehensively gather statewide information for agronomic crop production in California. Gathering such information is an important step in directing future UCCE programs, while gaining greater support for these programs will require a robust coalition of agricultural interests and the demonstration of meaningful outcomes and impacts.

The primary goal of this study was to conduct a needs assessment for agronomic crop production in California based on feedback and input from growers, consultants, and allied industry professionals. The specific objectives were to (a) identify top concerns and management challenges for different crops and regions and (b) understand the primary reasons for growing agronomic crops and priorities considered in management decisions. This needs assessment identifies critical opportunities to improve regional and statewide research and extension efforts by providing insights into the decision-making processes of agronomic crops clientele and supporting program planning and allocation of resources.

2 | MATERIALS AND METHODS

2.1 | Survey development

The needs assessment was an online survey developed by a team of UCCE Advisors and University of California-Davis faculty working in agronomic crop production and administered using Qualtrics survey software (Qualtrics). We followed recommended protocols for conducting an agricultural extension needs assessment based on existing literature (Donaldson & Franck, 2016; Koundinya et al., 2020; Martins et al., 2019). The first step in developing questions was to collect and summarize previous needs assessments shared by individual UCCE Advisors and Specialists. Based on overarching themes from past needs assessments and the objectives of this collaborative effort, questions were drafted covering the areas of management challenges, concerns for the agronomic crops industry, grower motivations for implementing management practices, importance of extension topics and associated level of satisfaction with UCCE efforts, and extension preferences (i.e., who respondents communicate with about crop production practices and how they prefer to receive information).

The final survey included a total of 21 questions and was estimated to take 15–20 min to complete. The full list of survey questions is included in the Supplemental Material. The first three topics – concerns, management challenges, and motivations – are the focus of this paper. Results regarding importance and satisfaction of extension topics, as well as communication and information preferences, will be shared in additional publications and used internally by UCCE to improve programming. The survey was reviewed by the University of California Institutional Review Board who determined that the survey questions posed "minimal risk" to participants and was approved as "exempt" as defined by federal regulation 45 CFR 46. Prior to launching the survey, it was piloted by 10 growers and other industry professionals to ensure questions were clear and garnered reliable responses. Often these individuals had collaborated with UCCE, were considered to be representative of the target audience, and were willing to dedicate their time to providing a thorough review and discussion of questions.

The needs assessment was a cross-sectional census survey attempting to collect responses from anyone currently involved in the agronomic crop production in California (dissemination information below). We included a screening question asking respondents if they grow, consult on, or work in allied industry of agronomic crops in California to improve the accuracy of clientele representation. If respondents replied "yes," they were prompted to take the survey, but if they responded "no," they were not able to continue. The first question on the survey (following the screening question) asked respondents to identify their primary vocation (defined as taking up 75% or more of their work time) between "grower," "consultant" (example, Certified Crop Advisor [CCA] or Pest Control Advisor [PCA]), "allied industry" (example, Input supplier, processor, etc.), or "other." This allowed management-related questions to be directed only to growers while still gaining broader insights from consultants and allied industry.

To identify concerns and challenges, respondents were asked to rank their level of concern (very concerned, somewhat concerned, or not concerned) from a list of 15 topics. Next, respondents who identified as growers or consultants were asked to select their highest priority management challenges from a list of eight common management challenges identified by our internal team of UCCE Advisors and Specialists. To understand the motivations for growing agronomic crops and priorities considered in management decisions, we asked respondents who identified as growers and consultants to rank how often certain factors affect their management decisions for agronomic crop production (always, often, sometimes, rarely, or never). We also asked growers to select their primary reasons for growing agronomic crops from a list of nine commonly cited reasons, as determined by our internal team.

2.2 | Survey dissemination

The dissemination strategy for our online survey was to encourage as broad of participation as possible from growers, consultants, and allied industry of agronomic crop production in California. Because no comprehensive list of such individuals exists, the initial dissemination effort was focused on UCCE contacts representing different crops and production regions. A centralized contact list was compiled from individual UCCE Advisors and Specialists working in agronomic crops and duplicates were removed. While this centralized contact list (n = 4,813) contained statewide representation, one aim was also to reach people who UCCE might not already be serving. Therefore, to expand the representation of respondents in our survey, influential groups or organizations external to UCCE were also contacted to help distribute the survey. This list included commodity boards, crop associations, Farm Bureaus, County Agricultural Commissioners, third-party Water Quality Coalitions, and input distributors. These partner stakeholders were provided with an anonymous link to the survey if they agreed to share it with their clientele. The geographic distribution of partner stakeholders who shared the survey is in the Supplemental Material. The survey software (Qualtrics) was able to track which responses came from the original centralized contact list and which responses came from the anonymous link. However, with the anonymous link, the response rate could not be measured. Since our goal was to gather responses from a wide range of participants, we accepted this limitation in our methodology. While online surveys provide flexibility and the potential to reach many individuals through different networks and organizations, they also have drawbacks such as possibly underrepresenting important demographics (e.g., those with poor internet access or less familiar with technology). Other important strengths and weaknesses of our methodology are discussed in the Supplemental Material.

In July 2020, stakeholders on the centralized contact list (n = 4,813) and external organizations were sent an email invitation to complete the online survey. The survey was open from 23 July 2020 until 1 Sept. 2020 with three reminders sent to those on the centralized contact list, as suggested by the Dillman method to maximize response rate (Dillman, 2007). The first 100 participants to complete the survey were offered an incentive of a $10 gift certificate. As stated on the survey, all information was kept anonymous, and respondents were informed that the survey would be used to better guide UCCE research and extension efforts by highlighting the most important issues facing agronomic crop production in California and helping set priorities for future programming.

It is important to consider how the timing and method of survey distribution may have influenced results. Crop production activities occur year-round in California, especially for the range of different crops considered here (e.g., growers manage both winter small grains and summer irrigated crops). Given this, we chose late summer to administer the survey, as this is a slower time for many field activities prior to harvest for summer irrigated crops and our chance to get the maximum participation in our study. However, it is possible that some individuals may have been managing their fields during this period, which could slightly decrease the representativeness of the survey population. While there is a chance that response rate could have been higher if the survey was administered during winter, the number of responses we got is consistent with the other surveys conducted by UCCE. Similarly, there are limitations to distributing the survey through UCCE contact lists and external organizations. Our goal was to achieve broad participation beyond UCCE's participant lists in order to identify concerns and challenges that could be addressed through research and extension. From a methodology standpoint, this is a different research objective than characterizing the entire population of those working in agronomic crop production in California. Therefore, all interpretation of results and conclusions from this study apply to the data collected, and we do not attempt to generalize the findings to the broader population of California agriculture, but instead use them for designing our own extension and education programs to meet the identified needs. To evaluate the representativeness of responses, we analyzed the survey population in terms of geography, economic value produced, crops grown, and age as compared to agricultural census data from USDA, NASS (2020) in the Supplemental Material.

2.3 | Data analysis

The data were cleaned by removing duplicate responses using IP address information collected by Qualtrics. Unanswered questions were considered missing data and were excluded from analysis of the particular question, but all other responses from that individual were still included for the remaining questions. Results were either analyzed at the state level or disaggregated by crop or region. Responses were categorized according to seven distinct geographic regions: Sacramento Valley, northern San Joaquin Valley (NSJV), southern San Joaquin Valley (SSJV), Low Desert, Intermountain, Coastal, and Sierra Nevada. The counties within each region are displayed in the Supplemental Material. Only growers were asked about management challenges, priorities considered in management decisions, and primary reasons for growing agronomic crops. When questions were asked to all respondents, data was presented as an aggregation of all responses, due to the fact that little variation was seen when separating data among growers, consultants, and allied industry respondents.

The purpose of this research was to characterize responses and identify needs, thus frequency distributions were used to analyze responses for each question. This approach is consistent with other recent studies (Koundinya et al., 2020; Martins et al., 2019) and allows for clear and direct interpretation of data following established methods and recommendations for needs assessments (Donaldson & Franck, 2016). The frequency distribution does not represent a mean value with an associated variation for different groups. Inferential statistics would be helpful if the objective was to make conclusions that extend beyond the specific data sample (Milton et al., 2021). Similarly, inferential statistics are necessary when testing a hypothesis (e.g., comparing responses between two groups). However, these were not the goals of our survey. For each crop and region, the level of concern for agronomic crop production was further converted into a numeric value by calculating means for each category using the following scale: very concerned = 3, somewhat concerned = 2, or not concerned = 1. Within each group, concerns were ranked based on means, with the highest mean corresponding to the greatest concern (Supplemental Tables S1 andS2). Because individuals managed multiple crops/regions and could select multiple topics of concern within each crop/region, responses are not fully independent and do not satisfy requirements for analysis of variance.

3 | RESULTS

3.1 | Demographics

The survey garnered a total of 483 responses: 320 responses from the centralized contact list (6.6% response rate) and 163 responses from the anonymous link, for which response rate could not be calculated. Respondents represented all seven regions of California with some level of participation in every county (Figure 1a). The most responses came from San Joaquin County (n = 89) and the least responses came from Plumas County (n = 11). Of the 483 respondents, 51% identified as growers, 26% as consultants, 18% as allied industry, and 5% as connected to California agronomy but not as a grower, consultant, or allied industry, respectively (Figure 1b). This latter "other" category included regulatory agencies, research or nonprofit organizations, Resource Conservation Districts, landowners, managers, and aerial applicators.

TABLE 1 Demographic information of respondents. Demographic questions were optional, with 80% of respondents providing answers

Category	Respondents	Proportion of total
	no.	%
Age		
25 yr and under	5	1
26–34 yr	47	12
35–44 yr	97	25
45–54 yr	80	21
55–64 yr	81	21
65–74 yr	53	14
75 yr and over	15	4
Prefer not to say	6	2
Race		
White or Caucasian	317	78
Black or African American	5	1
Hispanic or Latino	22	5
Asian or Asian American	4	1
American Indian or Alaska Native	7	2
Native Hawaiian or Pacific Islander	1	0.25
Other	22	5
Gender identity		
Male	308	81
Female	58	15
Identity not listed	1	0.25
Prefer not to say	15	4
Years of experience		
2 yr or less	6	3
3–9 yr	35	19
10–19 yr	56	30
20–29 yr	30	16
30+ yr	60	32

Demographic questions related to age, gender identity, and race were optional, and 80% of respondents provided answers (Table 1). Notably, the age of respondents appeared to be centrally distributed with 67% of respondents indicating they were between the ages of 35 and 64 yr. Respondents overwhelmingly identified as male (81%) and white or Caucasian (78%).

Hectares managed by growers ranged from 0.4 to 4,249 ha (average = 596 ha; median = 279 ha; standard deviation = 891), with 56% of these hectares being owned and

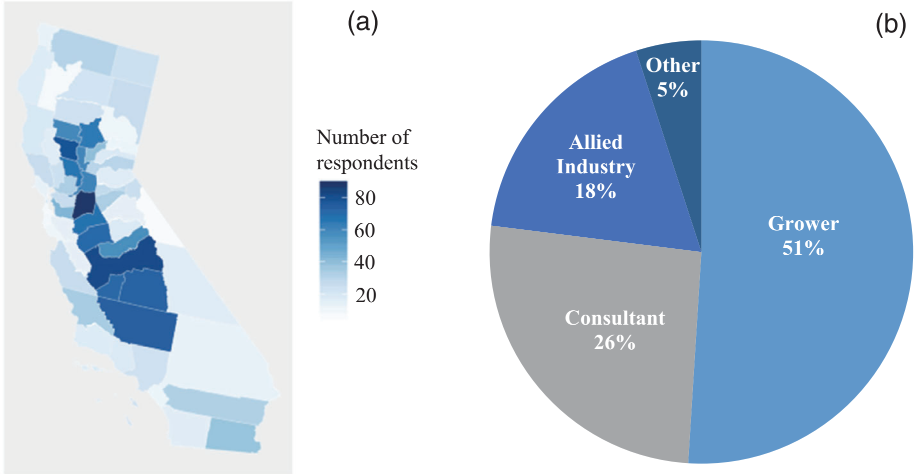

FIGURE 1 (a) Geographic distribution of survey respondents across California and (b) primary vocation of respondents. Results represent all data. The Central Valley had the most respondents and is where the majority of agronomic crop production is located. The Central Valley includes the regions of southern San Joaquin Valley (SSJV), northern San Joaquin Valley (NSJV), and the Sacramento Valley (see Supplemental Material for which counties are included in each region)

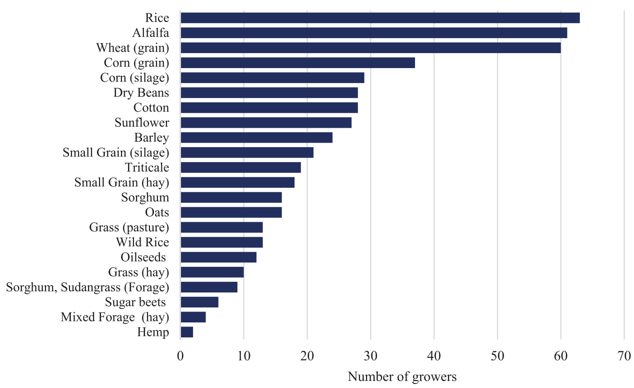

FIGURE 2 Crops grown by respondents identifying as growers. Growers selected the top three crops grown in the last 3 yr based on greatest land area

44% of these hectares leased (Table 2). Only 78% of growers answered this question about how many hectares they managed. The average area devoted to field crops out of a growers' total cropland was 59%, while other crop categories include tree and vine crops (22%), vegetable crops (16%), and other (3%). The five agronomic crops most frequently grown by respondents whose primary vocation was "grower" included rice, alfalfa, wheat (grain), corn (grain), and corn (silage), representing 48% of total responses (Figure 2). The next five crops most frequently grown were dry bean, cotton, sunflower, barley, and small grain silage, representing 25% of total responses.

3.2 | Concerns and challenges

When asked about their concerns for field crop production, 65% of respondents were very concerned about regulations on water use, 61% were very concerned about water costs, and 59% were very concerned about regulations on chemical use (Figure 3). In contrast, the topics that ranked lowest for "very concerned" included changing weather and climate, market access, and soil degradation. Respondents were given the opportunity to write in other concerns that did not fall into the above categories. Written responses included concerns around pesticide restrictions and lack of tools ($n = 3$), pesticide nontarget impacts ($n = 2$), crop changes ($n = 3$), loss of agricultural knowledge ($n = 2$), economics and consolidation ($n = 4$), politics and non-agricultural perceptions of agriculture ($n = 2$), and COVID-induced problems ($n = 1$).

Grower and consultant concerns varied by crop and region (Supplemental Tables S1 and S2, respectively). For instance, the topics with the greatest level of concern for those working in rice were regulations on chemical use (2.54 ± 0.43) and input costs (2.51 ± 0.39), while the top concerns for alfalfa included regulations on water use (2.78 ± 0.61) and water costs (2.68 ± 0.56) (Supplemental Table S1). For wheat (grain) the top concern was the commodity price of the crop (2.60 ± 0.43), while for corn (grain) it was labor availability (2.55 ± 0.38). Regulations on chemical use ranked as the second greatest concern for both wheat (grain) and corn (grain) (2.53 ± 0.39 and 2.51 ± 0.38, respectively). Regulations on water use was a top concern for corn (silage) (2.88 ± 0.71), dry bean (2.59 ± 0.44), cotton (2.59 ± 0.43), and sunflower (2.67 ± 0.51). Commodity price was also a top concern for dry bean (2.75 ± 0.56) and cotton (2.59 ± 0.45), while input costs was a top concern for sunflower (2.59 ± 0.44).

In all seven regions, "regulations on water use" and "water costs" were ranked as the top concerns (Supplemental Table S2). Based on mean responses, the greatest concern for

TABLE 2 Characterization of survey respondents and primary vocation by region (all data). Top crops grown, area managed, and distribution of cropland in agronomic crops are shown for respondents identifying as growers. Column heading abbreviations: SSJV = southern San Joaquin Valley; NSJV = northern San Joaquin Valley; Sac Valley = Sacramento Valley. The SSJV, NSJV, and Sac Valley make up the Central Valley, where the majority of agronomic crop production is located (see Supplemental Material for which counties are included in each region)

Category	Overall	SSJV	NSJV	Sac Valley	Low desert	Intermountain	Coastal	Sierra Nevada
Respondents, no.	483	120	128	178	57	50	135	96
Primary vocation, no.								
Grower	244	25	36	95	10	12	41	37
Consultant	125	35	39	24	9	8	44	27
Allied industry	78	56	50	49	34	25	38	28
Other	36	4	3	10	4	5	12	4
Top crops grown (crop)								
First	rice	corn (silage)	alfalfa	rice	wheat (grain)	alfalfa	wheat (grain)	rice
Second	alfalfa	alfalfa	corn (silage)	alfalfa	alfalfa	small grain (hay)	Rice	corn (grain)
Third	wheat	small grain (silage)	dry bean	wheat (grain)	small grain (hay)	grass & grass mixtures	Corn (grain)	wheat (grain)
Area managed, ha								
Median	279	607	344	405	222	526	40.5	405
Min.	0.4	121	1.4	3.2	0.4	40.5	40.5	1.2
Max.	4,249	3,642	4,249	4.047	1,052	4,047	971	4,047
SD	891	1,071	1,152	991	394	1,722	223	841
Distribution of cropland, %								
Agronomic	59	51	39	60	48	55	58	55
Trees	22	30	48	23	25	6	26	22
Vegetables	16	17	13	12	23	14	15	18
Other	3	2	0	5	4	25	1	5

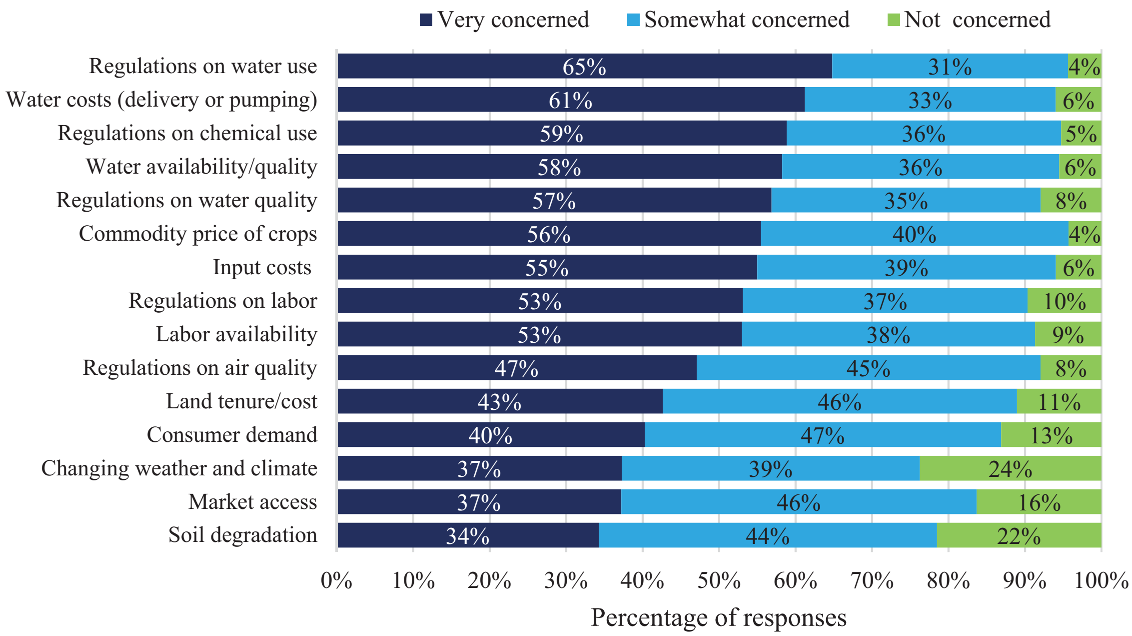

FIGURE 3 Concerns for agronomic crop production in California, ranked by highest percentage of responses for "very concerned." Results represent all respondents

TABLE 3 Top management challenges and primary reasons for growing agronomic crops. Respondents were able to select more than one response for each category. Topics are ranked highest to lowest according to the frequency of responses. Management challenges were identified for each of the top three crops for respondents identifying as growers and consultants ($n = 389$), thus numbers may exceed the total number of participants. Primary reasons for growing agronomic crops were identified by growers only ($n = 244$)

Top management challenges	Respondents	Primary reasons	Respondents
	no.		no.
Irrigation/water management	409	Crop rotation benefits	218
Weed control	386	Profitability	201
Insect pest control	342	Crop traditionally grown on my farm	193
Nutrient management	342	Stable markets	183
Labor	301	I am limited by farm resources	182
Soil management	300	Capacity for deficit irrigation or fallowing	149
Disease control	278	Supports wildlife habitat	143
Harvest operations	255	Soil is not suitable for other crops	137

regulations on water use was in the SSJV (2.84 ± 0.83), the Intermountain region (2.81 ± 0.78), and the NSJV (2.80 ± 0.77). In addition, the greatest concern for water cost was observed in the same three regions – SSJV (2.80 ± 0.75), Intermountain (2.71 ± 0.66), and NSJV (2.66 ± 0.62). The third highest ranking concern of the NSJV, SSJV, and Low Desert regions was "water availability/quality," while "regulations on water quality" was the third highest ranking concern for the Intermountain region. The third highest ranking concern for the Coastal and Sierra Nevada regions was "regulations on chemical use." The category of "input costs" ranked in the top three concerns for the Sacramento Valley only.

When growers were asked about management challenges for each of the top three agronomic crops they grow, weed control and irrigation/water management were highest (Table 3). Soil management, disease control, and harvest operations ranked lowest. When broken down by the top eight agronomic crops managed by survey respondents, the highest-ranking management challenges differed (Figure 4). Irrigation/water management was the top management challenge for alfalfa and corn silage, while weed control was the top management challenge for dry bean, sunflower, and cotton. For rice, irrigation/water management and weed control were tied as the top management challenge. Nutrient manage-

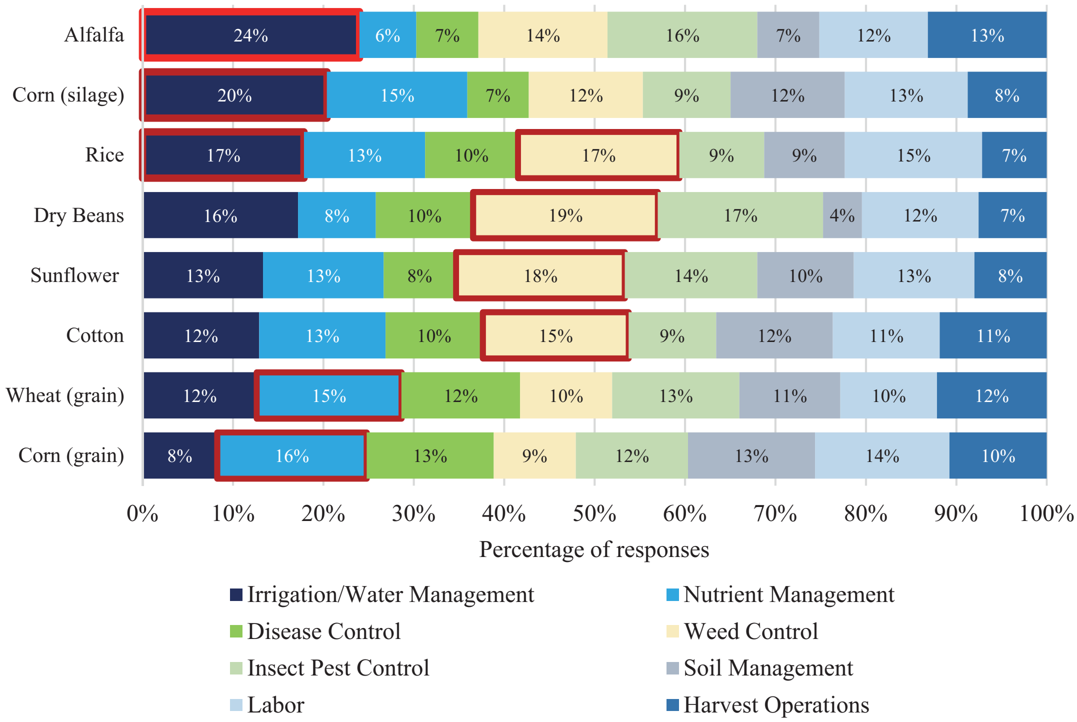

FIGURE 4 Top management challenges for the primary agronomic crops grown by respondents identifying as growers (n = 244). The greatest management challenge for each crop is outlined in red

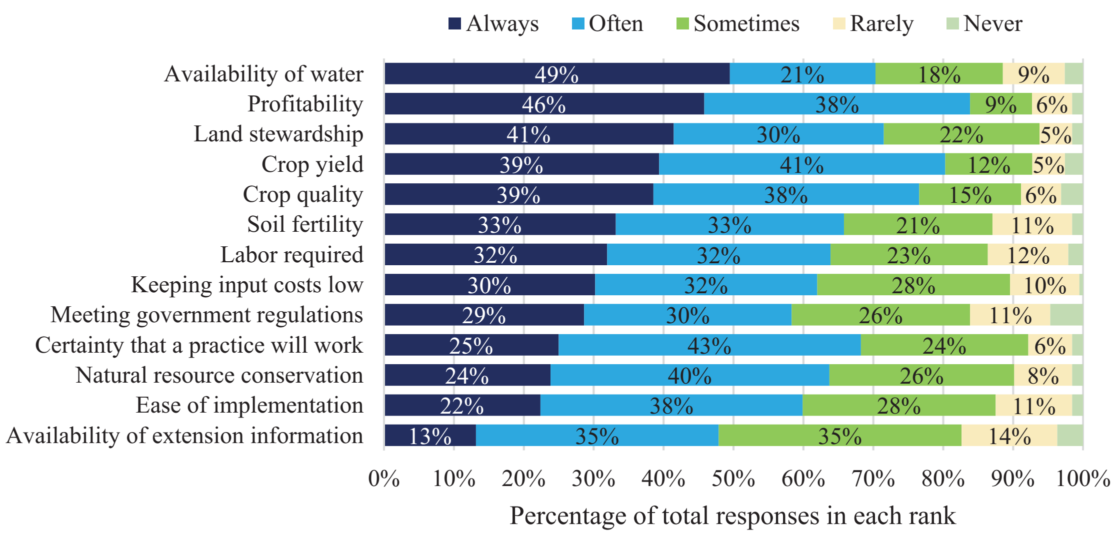

FIGURE 5 Top priorities considered in management decisions by growers (n = 244)

ment was the top management challenge for wheat and corn grown for grain.

3.3 | Priorities and motivations

Regarding on-farm decision making, the highest priorities considered in management decisions were the availability of water (49%), profitability (46%), and land stewardship (41%) (Figure 5). The lowest priorities considered in management decisions were natural resource conservation (24%), ease of implementation (22%), and availability of extension information (13%).

When asked about their primary reasons for growing agronomic crops, crop rotation benefits ranked as the top reason, while profitability and tradition rank closely behind

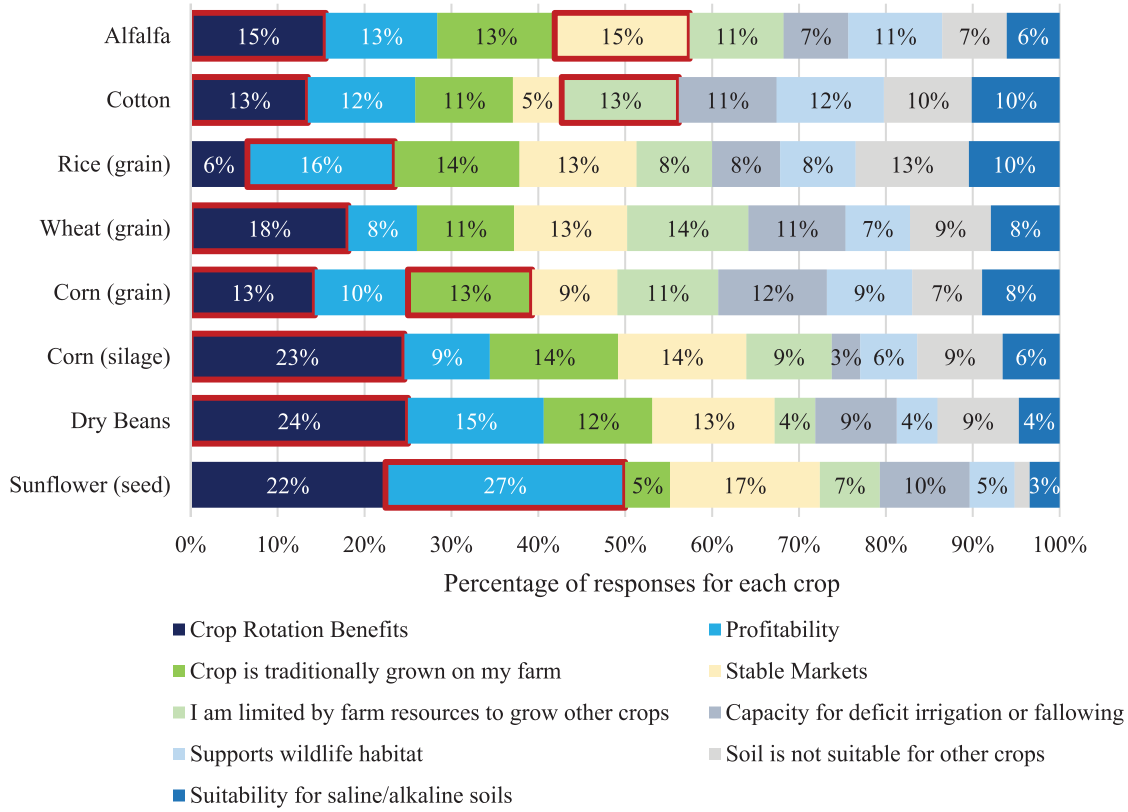

FIGURE 6 Primary reasons for growing agronomic crops by respondents identifying as growers ($n = 244$). The top eight crops grown by respondents are included, and the biggest motivation for growing each crop is highlighted in red

(Table 3). Primary reasons for growing agronomic crops differed slightly by crop grown (Figure 6). Crop rotation benefits were the primary reason for growing alfalfa, cotton, wheat, corn (grain and silage), and dry bean. Another primary reason for growing alfalfa included stable markets, while another primary reason for growing cotton included being limited by resources to grow other crops. Tradition was also ranked as a primary reason for growing corn for grain. Profitability was the primary reason for growing rice and sunflower.

4 | DISCUSSION

4.1 | Water is the key concern

Water-related issues were clearly the most prominent in our survey, representing four out of the top five concerns listed by respondents. Specifically, regulations on water use and water costs were the two issues that had the greatest number of respondents expressing that they were “very concerned”. Signed into law in 2014, SGMA requires groundwater-dependent regions to stop overdrafting groundwater and develop plans to balance withdrawals and recharge (AB 1738, SB 1168, and SB 1319). This is the first time California has legislated the collective management of groundwater and growers are concerned about upcoming changes and the uncertainty it brings. Recent research highlights many challenges of implementing SGMA in terms of stakeholder cooperation, participation, and representation in collective management and variable governance structures (Lubell et al., 2020). Groundwater contributes 38% of California’s water supply in an average year, and up to 46% or more during dry years, while some agricultural and disadvantaged communities rely on groundwater for up to 100% of their water supply (California Department of Water Resources, 2020). This suggests that tensions will grow in the future as pumping regulations are enacted to prevent groundwater overdraft. Water is an essential input for crop production in this region, and therefore impacts on cost, availability, or quantity will limit the capacity of growers to manage this resource.

More than one-third of the country’s vegetables and two-thirds of the country’s fruits and nuts are grown in California (California Department of Food and Agriculture, 2020). A decrease in water availability because of new regulations has implications for maintaining the same area under irrigation into the future and could mean completely rethinking land use and resource management in California and food systems in the greater United States. Impacts of groundwater decline were already being felt before SGMA was signed into law.

Due to the increasing incidence of prolonged drought, California saw a decline of more than 80,000 ha of irrigated land between 2004 and 2006, while nearly 100,000 ha had to be idled in 2014 alone (Ayars et al., 2015). It is projected that an additional 200,000 ha of land in the San Joaquin Valley may have to be retired to address groundwater overdraft issues under SGMA, representing around 5–10% of current irrigated area (Hanak et al., 2019). Uncertainty and difficulty around water resource planning and management is amplified by increasing unpredictability of weather patterns and insufficient storage (including groundwater recharge) to capture surface water during wet years. Annual rainfall varies greatly in California – more notably than in other parts of the country – which makes predicting rainfall year-to-year a challenge (California Department of Water Resources, 2015; Dettinger et al., 2011). The Sacramento Valley has higher rainfall than the San Joaquin Valley, and SGMA is going to impact the SSJV much more. For these reasons, it was unsurprising that irrigation and water management were ranked as top management challenges for survey respondents and that regulations on water use were the greatest concerns in the San Joaquin Valley.

While there is uncertainty around the future of water in California, agronomic crops can provide some flexibility in land use that permanent crops cannot provide. For instance, fields can transition in and out of production based on available water. In addition, land under summer annual crops could be used for groundwater recharge during winter periods, which entails flooding agricultural fields intentionally when freshwater is available to increase capture and storage in depleted aquifers. This practice has gained attention to help balance levels of pumping and recharge for groundwater basins under SGMA (Hanak et al., 2019; Waterhouse et al., 2020). Preliminary research indicates this may also be possible in perennial field crops such as alfalfa, with few negative effects occurring for crop productivity in a short-term study (Dahlke et al., 2018). However, water quality is also a factor to consider when practicing managed aquifer recharge, and caution is particularly needed to prevent nitrate and salt leaching leading to groundwater contamination (Waterhouse et al, 2020). At the same time, research suggests that agronomic crops that are part of a flooded area for recharge can serve as intermittent wetlands for migratory birds (Shuford et al., 2019). Given the increasing importance of groundwater recharge in California, evaluating the benefits and risks for agronomic crops represents an area for future research.

4.2 | Concerns around chemical use

A large portion of respondents (59%) expressed that they are "very concerned" about regulations on chemical use, such as pesticides, fertilizers, and herbicides. California agriculture is more regulated than any state in the country. Given new or impending bans on agrochemicals in the state, it makes sense that growers are concerned about losing tools and finding alternatives. California's recent ban on chlorpyrifos – an inexpensive and effective pesticide used nationwide since 1965 – highlights this issue. Chlorpyrifos exposure has been linked to harmful health effects, including neurodevelopmental disorders (Gómez-Giménez et al., 2017; Gómez-Giménez et al., 2018; Rauh et al., 2011; Silva et al., 2017). California, along with Hawaii and New York, banned chlorpyrifos despite the U.S. Environmental Protection Agency (USEPA) removing the ban at the federal level in 2019. California users were required to stop using this active ingredient on 31 Dec. 2020 while other states continue to use this product, although this is still an active issue and future changes are likely. Approximately 1 yr after this survey was disseminated (August 2021), the USEPA revoked all food tolerances for chlorpyrifos nationwide, meaning applications to food commodities will no longer be allowed if registered food uses are canceled.

The ban on chlorpyrifos has, and will likely continue to be noticed, where it was most heavily used. This includes Fresno, Tulare, Kern, and Kings counties, all of which have strong representation in our survey. The period between 1991 and 2012 saw large increases in chlorpyrifos use in these four counties (up to 97%) (Bale, 2014). Effects will also be felt heavily in alfalfa production since chlorpyrifos is the most popular wide-spectrum insecticide for management of key alfalfa pests, such as alfalfa weevil (*Hypera postica*) and aphids (Long et al., 2019). In our survey, 65% of alfalfa growers and consultants said that they were "very concerned" about regulations on chemical use.

There are also impending regulations on neonicotinoids in California, which are commonly used on cotton, corn, and grains. Neonicotinoids have become the most widely used class of insecticide in the world (Casida & Durkin, 2013; Jeschke et al., 2011). However, recent evidence has linked these chemicals to honeybee (*Apis mellifera*) colony collapse and declining pollinator health (Henry et al., 2012; Wood & Goulson, 2017). Also, because of the high solubility of neonicotinoids in water, they readily leach into water bodies and can persist over multiple years, which has implications for aquatic species (Gupta et al., 2008; Tisler et al., 2009). In July 2018, the California Department of Pesticide Regulation (DPR) announced that they would not consider applications of any new uses of neonicotinoid insecticides until re-evaluation of these chemicals is completed (DPR, 2021). An addendum was published in January 2019, and the investigation is ongoing (DPR, 2021).

In addition to chemical bans, there are significant challenges with getting new products registered in California. California is unique in that tens of thousands of residents live near farmland and agricultural production requires laborers throughout the year. Therefore, the effects of pesticide use at the agricultural-urban boundary and the potential effects on farmworkers are key evaluation factors for product registration by the California DPR, (DPR, 2017). In contrast, federal pesticide law (Federal Insecticide, Fungicide, and Rodenticide Act, FIFRA) mandates that the USEPA consider the economic benefits of a pesticide when deciding whether to register it, whereas the financial advantages of using a pesticide cannot outweigh the health risks of use under California law. This is beneficial for communities, farmworkers, and consumers – yet California growers and input suppliers are disadvantaged when market competitors have access to chemicals not available for crop production in California.

Another challenge that is unique to agronomic crops in California, such as wheat, is that the market for new crop protection products is relatively small compared to other regions where higher acreage crops like corn, soybean [*Glycine max* (L.) Merr.], or wheat is produced. This reduces the financial incentive for chemical companies to support the research and regulatory processes necessary to register new products in the state. Limiting the availability of different chemistries or modes of action results in challenges with pesticide management since the overuse of individual products increases the likelihood of pests developing resistance. Accordingly, the decreasing efficacy of a product might cause certain pesticides to be used less frequently by growers faster than regulatory bans.

4.3 | Weed management challenges

Weed control was ranked as the top management challenge by growers and consultants. Weed control as a category in our survey was broad and could mean many things – new weed species, herbicide resistance, drift issues, or regulating the use of certain herbicides. Total weed control costs in the United States are more than $11 billion a year, most of which is spent on herbicides (Koleva & Schneider, 2009). The direct annual cost to monitor and control invasive weeds in California is estimated at around US$82 million (Brusati, 2009). Herbicide resistance is a growing concern in cropping systems throughout the state, particularly in rice (Hanson et al., 2014).

Weed management is a broad and complex issue, and UCCE must work directly with agronomic crop producers to determine future directions of weed management research. Knowledge is continually developing about how to effectively conduct research and outreach for greater impact. For example, the "co-production" of knowledge between "experts" and "users" is especially important in weed research, which is strongly impacted by crops and regions (Kettenring & Adams, 2011; Matzek et al., 2015; Roux et al., 2006). Without practitioner insight, researchers might produce studies with limited relevance to local management conditions (Esler et al., 2010; Kettenring & Adams, 2011; Matzek et al., 2015). Additionally, UCCE has seen a reduction in regional weed control specialists and the UC Division of Agriculture and Natural Resources has not hired a weed specialist for agronomic crops since the last specialists' retirement in 2013. Not replacing UCCE personnel who retire is perhaps why loss of agricultural knowledge was listed as a concern by respondents.

4.4 | Raising awareness around climate change

It is notable that when asked about concerns for agronomic crop production, a quarter of the respondents (24%) stated they were not concerned about changing weather and climate. Yet, the Salinas Valley and the San Joaquin Valley – particularly the corridor between Fresno and Merced – as well as the Imperial Valley – are predicted to be some of the most vulnerable agricultural regions to climate change (Pathak et al., 2018). The increased rate and scale of weather variability in California today is unprecedented for farmers and ranchers, and there is a wealth of evidence that changing weather and climate will impact agronomic crops (Hatfield et al., 2014; Natural Resources Agency, 2014). Therefore, despite this issue not ranking as a high-priority concern among respondents, UCCE should consider programming around education on the predicted impacts of climate change, which will bring unprecedented challenges and needs. An earlier study using process-based crop models predicted that heat waves in May will become common in the state, causing yield losses of 1–10% for corn, rice, and sunflower, while heat waves in June will affect corn and sunflower production (Hatfield et al., 2014). The effects of elevated CO_2 concentration have been associated with reduced nitrogen and protein content in some agronomic crops, causing a reduction in grain and forage quality (Morgan et al., 2004).

Climate change will also impact the other management challenges discussed above. Water resources, particularly surface water supply derived from snowpack, are projected to decline significantly (California Department of Water Resources, 2015; Pathak et al., 2018). Weed management will also experience new challenges. For instance, while glyphosate has been projected to lose its efficacy on weeds as CO_2 levels rise, there are also predictions that increased atmospheric CO_2 concentrations will have a positive impact on several weed species, which may contribute to increased risk of crop loss due to weed pressure (Vilá et al., 2021). As a result, both herbicide use and costs are expected to increase as CO_2 levels rise (Koleva & Schneider, 2009). In a recent survey for California rangelands, practitioners overwhelmingly recognized an increase in weed problems in the past 5–10 yr and acknowledged a negative effect of California drought on weed management given the invasive nature of weeds (Yue et al., 2020). To help deal with impacts of climate change on agronomic crop production, UCCE should think critically about how to raise awareness around predicted climate impacts and focus on adaptation strategies, like testing new varieties adapted to warmer climates. This is a good example in needs assessments where growers are not necessarily requesting education on climate change, and it may have limited short-term benefits in terms of management, but the evidence about negative impacts on agronomic crops suggests more weight should be given to this issue. Our conclusions about education will depend on whether climate change is incremental or transformative, meaning immediate drastic effects will occur. If incremental, then allied industries may be able to develop technologies to adapt, whereas education is more necessary if climate change is transformative.

4.5 | Priorities and motivations

Results indicate that growers' priorities in management decisions often reflect more immediate than long-term challenges. For instance, pressures such as water resources and economic viability of farming operations appear to take priority over longer-term adaptations to a changing climate. Therefore, it is crucial that UCCE is conscious of this tension in developing programs, and efforts are made to balance immediate priorities (e.g., crop yield and quality), while helping growers adapt to broader future challenges like evaluating drought or heat-tolerant crop varieties.

Water availability was not only the key concern, as discussed above, but also the highest priority consideration for grower management decisions. Profitability ranked second as a priority but also as a primary reason for growing agronomic crops, immediately following the benefits of crop rotation. We did not define crop rotation benefits in our survey, thus grower perceptions could include economic or ecological dimensions. Common benefits include economic profitability, as well as helping to manage pests, diseases, and weeds, or improving soil health and on-farm biodiversity (Li et al., 2020; Liebman & Dyck, 1993; Rusch et al., 2013).The economics of rotations depend not only on long-term profits but risk management, timing of operations, and other system-level factors (Hendricks et al., 2014). In California, the sequence of crops grown in different regions is flexible and variable, but often agronomic crops, which tend to be lower in value, are rotated with higher-value crops. Therefore, agronomic crops may not be expected to show profits on their own, but only in the context of the rotation, especially if the agronomic crop contributes positively to the production of other crops, for example by reducing pest management costs of subsequent crops. Agronomic crops also provide other practical opportunities for field management and logistics. For instance, producing wheat in the last year of the life of drip tape allows wheat to be harvested in mid-summer, providing several months to replace the irrigation system before the start of fall rains. From an ecological perspective, however, the benefits of crop rotation are not always immediately evident, and current economic pressures could discourage rotation with lower value agronomic crops.

Land stewardship was another priority in management decisions for growers. Land stewardship was not explicitly defined in our survey and it can mean different things to different people. Care for the land can be motivated by economic returns, social norms, and farmer values (Mills et al., 2017). Growers may view land stewardship in economic terms, where investments in soil and water resources (e.g. subsurface drip irrigation) are important for maintaining profitable production over the long-term. Land stewardship has also been described in an ethical context as a "deeply held inner conviction that compels and inspires people to be responsible caretakers of the land entrusted to them" (Nelle, 2017). Interestingly, while 41% of growers said that they always consider land stewardship when making management decisions, only 24% said that they always consider natural resource conservation.

On the surface, land stewardship and natural resource conservation appear to be similar in their goals to conserve resources for future generations. However, land stewardship likely encompasses broader values with more flexibility, providing greater autonomy for growers to make decisions based on their specific experiences and farm needs (e.g., planting cover crops to improve soil health or implementing practices to address nutrient management, compaction, or soil cracking concerns to support future gains in production). The motivation for land stewardship has also been described as "present benefits to the landowner; benefits to future generations; and the benefits that accrue to society outside the boundary of the land" (Nelle, 2017). In contrast, several important natural resource conservation issues in California, such as water and nitrogen management, are increasingly managed by state agencies under a regulatory framework with strict compliance and reporting protocols that represent a challenge for growers. Thus, an important distinction that may be influencing grower decision-making is that natural resource conservation is more of a public value that does not provide individual economic gains.

To achieve broader environmental goals and provide public goods associated with agronomic crop production in California, it may be effective for UCCE to leverage the concept of land stewardship in extension efforts. This is also important for policymakers in thinking about expanding economic incentive programs for land stewardship, such as the Healthy Soils Program administered by the California Department of Food and Agriculture, or various conservation programs offered by USDA-NRCS. However, if incentive programs are to be attractive to growers, they must be developed with an understanding that building healthy soil is a long-term investment and immediate impacts may not be observed. Addressing economic challenges to conservation practices is key, as several studies have found that farmers' ethical drive for land stewardship appears to decline as economic pressures increase (James & Hendrickson, 2008; Stuart, 2009). It has also been argued that dependencies on agricultural markets limit farmer choice, including the "freedom to make ethical decisions" since farmers will do what they can to reduce risk (Hendrickson & James, 2016). Thus, to support growers in their land stewardship practices, providing long-term economic support is necessary to obtain public environmental benefits.

Finally, land tenure is an important consideration in supporting land stewardship in management decisions. Almost half of respondents in this survey (44%) farm on leased land. If conservation practices are implemented, the ecological gains will not necessarily benefit the producer who dedicates time and resources to achieve them, and the tenant's autonomy may be limited by the landlord (Dula, 2017). Meanwhile, landowners might be interested in returns only, and not support long-term investments in the farm, such as compost or cover crops. As the loss of family farms and consolidation of land continues, the trend toward tenant farming is increasing. Uncertainty over how long a farmer will continue to farm-leased land could make it difficult to make long-term investments in the land without support from the landowner.

5 | CONCLUSION

In this study we identified critical issues and factors influencing decision-making for growers, consultants, and allied industry working in agronomic crop production in a rapidly changing context. Results highlight that growers and industry face many environmental and economic uncertainties in California, which has implications for other regions considering increased regulations. Water-related issues stood out as both the greatest concern and primary management challenge. Agricultural water resources are under threat from a changing climate and decreasing water supply, particularly under the new legislation of SGMA. Weed control is also a primary management challenge and the future of certain agrochemicals in California is uncertain. Currently, there are only a few weed UCCE advisors and no statewide weed specialist working in agronomic crops. Together these findings indicate UCCE needs to devote more people and resources to practical solutions for water/irrigation and weed management. While economic profitability and availability of water were important priorities in management decisions, results also demonstrate that growers highly value crop rotation benefits and land stewardship, which represent areas for future research and potential integration into outreach efforts. The scope of this paper was to generate statewide conclusions, but there was important variability in results given the diversity of crops and production regions. Such differences should be accounted for in developing or adapting future UCCE programs, in combination with other forms of needs assessments and individual experience. To address the challenges and priorities identified here, UCCE must continue developing innovative and cost-effective extension programs while working closely with growers to develop applied information that integrates practitioner knowledge and is relevant to the realities and constraints of agronomic crop production.

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AUTHOR CONTRIBUTIONS

Jessica Kanter: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Visualization; Writing-original draft. Nicholas Clark: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Mark Edward Lundy: Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing-review & editing. Vikram Koundinya: Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing-review & editing. Michelle Leinfelder-Miles: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Rachael Long: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Sarah E. Light: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Whitney B. Brim-DeForest: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Bruce A Linquist: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Dan Putnam: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Robert B. Hutmacher: Conceptualization; Investigation; Methodology; Project administration; Writing-review & editing. Cameron M. Pittelkow: Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing-review & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Nicholas Clark https://orcid.org/0000-0002-6550-3771
Mark Edward Lundy https://orcid.org/0000-0003-4043-0841
Vikram Koundinya https://orcid.org/0000-0003-2353-6468
Sarah E. Light https://orcid.org/0000-0002-9089-4006
Whitney B. Brim-DeForest https://orcid.org/0000-0003-0547-4777
Cameron M. Pittelkow https://orcid.org/0000-0001-8654-9552

REFERENCES

Ayars, J. E., Fulton, A., & Taylor, B. (2015). Subsurface drip irrigation in California–Here to stay? *Agricultural Water Management*, *157*, 39–47. https://doi.org/10.1016/j.agwat.2015.01.001

Bale, R. (2014). *5 striking things we've learned about pesticides in California*. Reveal. https://revealnews.org/article/5-striking-things-weve-learned-about-pesticides-in-california/

Baur, P. (2020). When farmers are pulled in too many directions: Comparing institutional drivers of food safety and environmental sustainability in California. *Agriculture and Human Values*, *37*, 1175–1194. https://doi.org/10.1007/s10460-020-10123-8

Brusati, E. (2009). *The cost of weeds to California*. Cal-IPC News, 17, 6–7, 13. http://www.cal-ipc.org/resources/news/pdf/Cal-IPC_News_Spring09.pdf

California Department of Food and Agriculture. (2020). *California agricultural statistics review, 2019-2020*. CDFA. https://www.cdfa.ca.gov/Statistics/PDFs/2020_Ag_Stats_Review.pdf

California Department of Pesticide Regulation (DPR). (2017). *A guide to pesticide regulation in California: 2017 Update*. DPR. https://www.cdpr.ca.gov/docs/pressrls/dprguide/dprguide.pdf

California Department of Pesticide Regulation (DPR). (2021). *California notice to stakeholders*. DPR.

California Department of Water Resources. (2015). Hydroclimate report water year 2015. https://cawaterlibrary.net/document/hydroclimate-report-water-year-2015/

California Department of Water Resources. (2020). Groundwater. https://water.ca.gov/Water-Basics/Groundwater

Casida, J. E., & Durkin, K. A. (2013). Neuroactive insecticides: Targets, selectivity, resistance and secondary effects. *Annual Review of Entomology*, *58*, 99–117. https://doi.org/10.1146/annurev-ento-120811-153645

Dahlke, H. E., Brown, A. G., Orloff, S., Putnam, D., & O'geen, T. (2018). Managed winter flooding of alfalfa recharges groundwater with minimal crop damage. *California Agriculture*, *72*(1), 65–75. https://doi.org/10.3733/ca.2018a0001

Dettinger, M. D., Ralph, F. M., Das, T., Neiman, P. J., & Cayan, D. R. (2011). Atmospheric rivers, floods and the water resources of California. *Water*, *3*(2), 445–478. https://doi.org/10.3390/w3020445

Dillman, D. A. (2007). *Mail and internet surveys: The Tailored Design Method 2007 update with new internet, visual, and mixed-mode guide*. John Wiley & Sons, Inc.

Donaldson, J. L., & Franck, K. L. (2016). *Needs assessment guidebook for extension professionals*. University of Tennessee Institute of Agriculture.

Dula, J. (2017). *Access to land: Leasing farmland*. California Farmers Union.

Esler, K. J., Prozesky, H., Sharma, G. P., & Mcgeoch, M. (2010). How wide is the "knowing-doing" gap in invasion biology? *Biological Invasions*, *12*, 4065–4075. https://doi.org/10.1007/s10530-010-9812-x

Garst, B., & McCawley, P. (2015). Solving problems, ensuring relevance, and facilitating change: The evolution of needs assessment within cooperative extension. *Journal of Human Sciences and Extension*, *3*(2), 26–47. https://www.jhseonline.com/article/view/684

Gómez-Giménez, B., Felipo, V., Cabrera-Pastor, A., Agustí, A., Hernández-Rabaza, V., & Llansola, M. (2018). Developmental exposure to pesticides alters motor activity and coordination in rats: Sex differences and underlying mechanisms. *Neurotoxicity Research*, *33*, 247–258. https://doi.org/10.1007/s12640-017-9823-9

Gómez-Giménez, B., Llansola, M., Hernández-Rabaza, V., Cabrera-Pastor, A., Malaguarnera, M., Agusti, A., & Felipo, V. (2017). Sex-dependent effects of developmental exposure to different pesticides on spatial learning. The role of induced neuroinflammation in the hippocampus. *Food and Chemical Toxicology*, *99*, 135–148. https://doi.org/10.1016/j.fct.2016.11.028

Gupta, S., Gajbhiye, V. T., & Gupta, R. K. (2008). Soil dissipation and leaching behavior of a neonicotinoid insecticide thiamethoxam. *Bulletin of Environmental Contamination and Toxicology*, *80*, 431–437. https://doi.org/10.1007/s00128-008-9420-y

Hanak, E., Escriva-Bou, A., Gray, B., Green, S., Harter, T., Jezdimirovic, J., Lund, J., Medellin-Azura, J., Moyle, P., & Seavy, N. (2019). *Water and the future of the San Joaquin Valley*. Public Policy Institute of California.

Hannah, W., Sandra, B., Daniel, M., Joseph, C., Philip, A. M. B., Helen, E. D., & William, R. H. (2020). Agricultural managed aquifer recharge – Water quality factors to consider. *California Agriculture*, *74*(3), 144–154. https://doi.org/10.3733/ca.2020a0020

Hanson, B. D., Wright, S., Sosnoskie, L. M., Fischer, A. J., Jasieniuk, M., Roncoroni, J. A., Hembree, K. J., Orloff, S., Shrestha, A., & Al-Khatib, K. (2014). Herbicide-resistant weeds challenge some signature cropping systems. *California Agriculture*, *68*(4), 142–152. https://doi.org/10.3733/ca.v068n04p142

Hatfield, J., Takle, G., Grotjahn, R., Holden, P., Izaurralde, R. C., Mader, T., Marshall, E., & Liverman, D. (2014). In J. M. Melillo, T. (T. C.) Richmond, & G. W. Yohe (Eds.), Agriculture. *Climate change impacts in the United States: The third national climate assessment* (pp. 150–174. Global Change Research Program. https://doi.org/10.7930/J02Z13FR

Hendricks, N. P., Smith, A., & Sumner, D. A. (2014). Crop supply dynamics and the illusion of partial adjustment. *American Journal of Agricultural Economics*, *96*, 1469–1491. https://doi.org/10.1093/ajae/aau024

Hendrickson, M. K., & James, H. S. (2016). Power, fairness and constrained choice in agricultural markets: A synthesizing framework. *Journal of Agricultural and Environmental Ethics*, *29*, 945–967. https://doi.org/10.1007/s10806-016-9641-8

Henry, M., Beguin, M., Requier, F., Rollin, O., Odoux, J. F., Aupinel, P., Aptel, J., Tchamitchian, S., & Decourtye, A. (2012). A common pesticide decreases foraging success and survival in honey bees. *Science*, *336*(6079), 348–350. https://doi.org/10.1126/science.1215039

Hutchins, S. H. (2021). Sustainable Agriculture in the U.S. vs. the EU. *CSA News*, *66*, 24–34. https://doi.org/10.1002/csan.20373

James, H. S., & Hendrickson, M. K. (2008). Perceived economic pressures and farmer ethics. *Agricultural Economics*, *38*, 349–361. https://doi.org/10.1111/j.1574-0862.2008.00305.x

Jeschke, P., Nauen, R., Schindler, M., & Elbert, A. (2011). Overview of the status and global strategy for neonicotinoids. *Journal of Agriculture and Food Chemistry*, *59*, 2897–2908. https://doi.org/10.1021/jf101303g

Johnson, R., & Cody, B. A. (2015). *California agricultural production and irrigated water use. Report R44093*. Congressional Research Service. https://crsreports.congress.gov/

Kettenring, K. M., & Adams, C. R. (2011). Lessons learned from invasive plant control experiments: A systematic review and meta-analysis. *Journal of Applied Ecology*, *48*, 970–979. https://doi.org/10.1111/j.1365-2664.2011.01979.x

Koleva, N. G., & Schneider, U. A. (2009). The impact of climate change on the external cost of pesticide applications in US agriculture. *International Journal of Agricultural Sustainability*, *7*, 203–216. https://doi.org/10.3763/ijas.2009.0459

Koundinya, V., Chiarella, C., Kocher, S., & Kearns, F. (2020). Disasters happen: Identifying disaster management needs of cooperative extension system personnel. *Journal of Extension*, *58*(5). https://tigerprints.clemson.edu/joe/vol58/iss5/12

Li, L., Hu, R., Huang, J., Bürgi, M., Zhu, Z., Zhong, J., & Lü, Z. (2020). A farmland biodiversity strategy is needed for China. *Nature Ecology & Evolution*, *4*, 772–774. https://doi.org/10.1038/s41559-020-1161-2

Li, Y. M., Roche, L. M., & Gornish, E. S. (2020). Bridging the research-implementation gap in weed management in California rangelands. *Rangeland and Ecology Management*, *73*(3), 348–357. https://doi.org/10.1016/j.rama.2020.01.007

Liebman, M., & Dyck, E. (1993). Crop rotation and intercropping strategies for weed management. *Ecological Applications*, *3*(1), 92–122. https://doi.org/10.2307/1941795

Long, R., Putnam, D. H., & Grettenberger, I. (2019). *The end of Chlorpyrifos in California will profoundly impact alfalfa IPM and pest resistance: What are the alternatives?*. Alfalfa and Forage News, UC Division of Agriculture and Natural Resources. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=38538

Lubell, M., Blomquist, W., & Beutler, L. (2020). Sustainable groundwater management in California: A grand experiment in environmental governance. *Society & Natural Resources*, *33*(12), 1447–1467. https://doi.org/10.1080/08941920.2020.1833617

Martins, J. P. N., Karle, B. M., & Heguy, J. M. (2019). Needs assessment for cooperative extension dairy programs in California. *Journal of Dairy Science*, *102*(8), 7597–7607. https://doi.org/10.3168/jds.2018-15959

Matzek, V., Pujalet, M., & Cresci, S. (2015). What managers want from invasive species research versus what they get. *Conservation Letters*, *8*, 33–40. https://doi.org/10.1111/conl.12119

McCawley, P. F. (2009). *Methods for conducting an educational needs assessment*. University of Idaho Extension.

McClure, M., Fuhrman, N., & Morgan, C. (2012). Program evaluation competencies of extension professionals: Implications for continuing professional development. *Journal of Agricultural Education*, *53*(4), 85–97. https://doi.org/10.5032/jae.2012.04085

Mills, J., Gaskell, P., Ingram, J., Dwyer, J., Reed, M., & Short, C. (2017). Engaging farmers in environmental management through a better understanding of behaviour. *Agriculture and Human Values*, *34*, 283–299. https://doi.org/10.1007/s10460-016-9705-4

Milton, G., Newberry, M. G., O'Leary, J. L. & Israel, G. D. (2021) *The savvy survey #16: Data analysis and Suey results*. Department of Agricultural Education and Communication, University of Florida, Institute of Food and Agricultural Sciences, https://edis.ifas.ufl.edu/publication/pd080

Morgan, J. A., Mosier, A. R., Milchunas, D. G., Lecain, D. R., Nelson, J. A., & Parton, W. J. (2004). CO_2 enhances productivity of the Shortgrass Steppe, alters species composition and reduces forage digestibility. *Ecological Applications*, *14*, 208–219. https://doi.org/10.1890/02-5213

Natural Resources Agency. (2014). *Safeguarding California: Reducing climate risk, an update to the 2009 California climate adaptation strategy*. http://resources.ca.gov/docs/climate/-Final_Safeguarding_CA_Plan_July_31_2014.pdf

Nelle, S. (2017). *What is land stewardship?*. Texas Wildlife. http://www.hillcountryalliance.org/wp-content/uploads/2017/01/Nelle_Stewardship.pdf

Pathak, T., Maskey, M., Dahlberg, J., Kearns, F., Bali, K., & Zaccaria, D. (2018). Climate change trends and impacts on California agriculture: A detailed review. *Agronomy*, *8*(3), 25. https://doi.org/10.3390/agronomy8030025

Rauh, V., Arunajadai, S., Horton, M., Perera, F., Hoepner, L., Barr, D. B., & Whyatt, R. (2011). Seven-year neurodevelopmental scores and prenatal exposure to chlorpyrifos, a common agricultural pesticide. *Environmental Health Perspectives*, *119*(8). https://doi.org/10.1289/ehp.1003160

Roux, D. J., Rogers, K. H., Biggs, H. C., Ashton, P. J., & Sergeant, A. (2006). Bridging the science-management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecology and Society*, *11*(1), 4. http://www.ecologyandsociety.org/vol11/iss1/art4/ https://doi.org/10.5751/ES-01643-110104

Royse, D., Staton-Tindall, M., Badger, K., & Webster, J. M. (2009). *Needs assessment*. Oxford University Press.

Rudnick, J., Lubell, M., Khalsa, S. D. S., Tatge, S., Wood, L., Sears, M., & Brown, P. H. (2021). A farm systems approach to the adoption of sustainable nitrogen management practices in California. *Agriculture & Human Values*. *38*, 783–801. https://doi.org/10.1007/s10460-021-10190-5

Rusch, A., Bommarco, R., Jonsson, M., Smith, H. G., & Ekbom, B. (2013). Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. *Journal of Applied Ecology*, *50*, 345–354. https://doi.org/10.1111/1365-2664.12055

Seevers, B., & Graham, D. (2012). *Education through Cooperative Extension* (3rd ed.). University of Arkansas.

Shrestha, A., Hembree, K. J., & Va, N. (2007). Growth stage influences level of resistance in glyphosate-resistant horseweed. *California Agriculture*, *61*, 67–70. https://doi.org/10.3733/ca.v061n02p67

Shuford, W. D., Reiter, M., Sesser, K., Hickey, C., & Golet, G. (2019). The relative importance for agricultural and wetland habitats to waterbirds in the Sacramento-San Joaquin River Delta of California. *San Francisco Estuary and Watershed Science*, *17*(1). https://doi.org/10.15447/sfews.2019v17iss1art2

Silva, J. G., Boareto, A. C., Schreiber, A. K., Redivo, D. D. B., Gambeta, E., Vergara, F., Morais, H., Zanoveli, J. M., & Dalsenter, P. R. (2017). Chlorpyrifos induces anxiety-like behavior in offspring rats exposed during pregnancy. *Neuroscience Letters*, *641*, 94–100. https://doi.org/10.1016/j.neulet.2017.01.053

Stuart, D. (2009). Constrained choice and ethical dilemmas in land management: Environmental quality and food safety in California agriculture. *Journal of Agricultural and Environmental Ethics*, *22*, 53–71. https://doi.org/10.1007/s10806-008-9129-2

Tisler, T., Jemec, A., Mozetic, B., & Trebse, P. (2009). Hazard identification of imidacloprid to aquatic environment. *Chemosphere*, *76*, 907–914. https://doi.org/10.1016/j.chemosphere.2020.127160

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). (2020). *Crop production, 2019 Summary*. https://www.nass.usda.gov/Quick_Stats/

Vilà, M., Beaury, E. M., Blumenthal, D. M., Bradley, B. A., Early, R., Laginhas, B. B., Trillo, A., Dukes, J. S., Sorte, C. J. B., & Ibáñez, I. (2021). Understanding the combined impacts of weeds and climate change on crops. *Environmental Research Letters*, *16*(3), 034043. https://doi.org/10.1088/1748-9326/abe14b

Wood, T. J., & Goulson, D. (2017). The environmental risks of neonicotinoid pesticides: A review of the evidence post 2013. *Environmental Science and Pollution Research International*, *24*(21), 17285–17325. https://doi.org/10.1007/s11356-017-9240-x

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