Setting Research and Extension Priorities for Agronomic Crop Production in California

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Abstract

Agronomic crop production in California faces a number of challenges related to farm economics, market demand shifts, environmental regulations, labor availability, and conservation of natural resources. Given the diversity of crops and production regions in California, combined with a reduction of University of California Cooperative Extension (UCCE) personnel, a statewide needs assessment was conducted to identify the major concerns of UCCE's agronomic crops clientele and their preferences for different types of extension material programming.

Between July - August 2020, 483 growers, consultants, and allied industry of agronomic crop production responded to an online survey. Based on the responses, water clearly ranked as the top concern for California agronomy, while weed control and irrigation/water management were identified as the top management challenges. Crop rotation benefits were a primary reason for growing agronomic crops, with profitability and tradition ranked closely behind. In addition to water and profits, land stewardship was a high priority for growers when making management decisions. From a broader list of topics covered by UCCE research and extension, the top gaps in issues that clientele consider to be priority vs. their satisfaction with delivery of information on these topics include testing new products, water conservation and storage, irrigation management, weed control, and soil health. Based on the gap in priority and satisfaction, UCCE's agronomy advisors should consider focusing research and extension efforts on these topics.

The results or this needs assessment survey provide insights into the priorities and decision-making process of agronomic crops clientele, helping to improve regional and statewide research and extension efforts, and identifying opportunities for collaboration.

Acknowledgements

I would like to express gratitude for my thesis committee: to Cameron Pittelkow for approaching me about working on this project and being incredibly encouraging every step of the way; to Mark Lundy for getting this project started and providing amazing insight on the analysis and interpretation of the data; and to Vikram Koundinya for answering my plethora of emails about survey methodology and providing expertise on needs assessment processes. I would also like to thank the members of the UC Cooperative Extension Agronomy Program Team who helped develop this needs assessment, disseminated it to their clientele, and continue to be huge sources of support as we work to share our results more broadly. In particular, I would like to express thanks to Nick Clark for helping push this project forward, and to Bruce Linquist, Sarah Light, Whitney Brim-DeForest, Michelle Leinfelder-Miles, Rachael Long, and Dan Putnam for sharing your insight and feedback throughout the process. None of this would have happened without you all - it has been such a pleasure collaborating and getting to know you all.

I express gratitude for all the organizations, farm bureaus, agricultural commissioner's offices, commodity boards, and resource conservation districts that shared our survey; and, to those who took time to fill it out and share their experiences with us. We will use the information gained to strengthen research and extension throughout the state.

I would also like to thank the International Agricultural Development Graduate Group students, faculty, and staff – especially Angie Nguyen and Kate Scow for advising and supporting me throughout my time at UC Davis. Finally, to my family and friends who have been there for me throughout graduate school; to my parents, who are both big city kids and still question why their daughter wants to work with farmers and study soil, but support me and encourage me, nonetheless.

<u>Setting research and extension priorities for agronomic crop production in California</u>

1. INTRODUCTION

Agronomic crops are the basis of the world's food and fiber production systems (Cassman et al. 2003). In California, agronomic crops include small grains, rice, corn, beans, oilseed, cotton, and forages, and represent a significant share of irrigated acreage in the Central Valley (Johnson and Cody 2015; Hanak et al. 2019). Agronomic crops were planted on an average of 4 million acres annually from 2000-2020, occupying more land than the categories of fruit and nuts or vegetables and melons and generating a total of $4.3 billion (USDA, NASS 2020; California Department of Food and Agriculture 2018). Yet, the agricultural landscape is changing in California due to water scarcity, economic challenges, competition for land, weed pressure, and new regulatory requirements related to water and nutrient management. Since 2000, acreage planted to agronomic crops has declined by more than 100,000 acres per year, with a corresponding shift towards high value perennial crops such as almonds, pistachios, and walnuts (USDA, NASS 2020). Given these changes, there is a need to better understand the concerns and management challenges of growers and others working in agronomic crop production.

As part of the University of California's Division of Agriculture and Natural Resources (UC ANR), Cooperative Extension (CE) is responsible for agricultural research, education, and outreach throughout the state. The mission of Cooperative Extension (CE) has always been to solve practical problems and disseminate useful information to its stakeholders (Garst & McCalwley 2015). CE Farm Advisors serve as a valuable link between land grant universities and growers, remaining relevant by developing programs that address stakeholder problems, issues, and concerns (Garst & McCawley 2015). However, land-grant universities continue to face funding uncertainties, which has affected CE programming and staffing. CE currently operates with approximately half the staff positions it did in 1990 (California Department of Pesticide Regulation 2020). With less funding from its traditional sources, such as the USDA, state government, and county governments, less Farm Advisors are hired, and therefore each advisor must cover more territory and a broader range of crops than in the past. In addition, self-generated funds have increased by 63% over the past five years, placing a greater burden on UC staff to find their own funding to carry out research and outreach (UC ANR 2019). More recently, the COVID-19 crisis has forced the reevaluation of spending priorities in the state budget. Making the case for CE moving forward will require a robust coalition of agricultural interests and the demonstration of results and impact (California Department of Water Resources 2020).

CE recognizes the importance of using evaluation data to demonstrate program value and set priorities for future programming based on input from a range of stakeholders (McClure et al. 2012). A common evaluation tool for CE programming is a needs assessment (Boone et al. 2002; Seevers & Graham 2012). Needs assessment generally refers to methods, efforts, and activities involved in or used for identifying needs, providing a method to learn what has already been done and what gaps in understanding remain (Royse et al. 2009; McCawley 2009). In many cases, needs assessments are surveys used to identify stakeholders' challenges and/or concerns, and help CE understand how they can respond with programs and services (Garst and McCawley 2015). Needs assessments are important because what one person identifies as a need might be irrelevant to another person and needs are subject to change over time (Royse et al. 2009; Altschuld & Watkins 2014). Therefore, research indicates that targeted strategies for developing CE programs are more likely to be effective than approaches broadly directed toward the general population (Dancker et al. 2001; Syme et al. 2000). A recently conducted needs assessment survey of 150 dairy producers in California demonstrated the importance of regionally targeted strategies, with the top 5 CE priority topics identified by respondents differing based on region (Martins et al. 2019). The northern San Joaquin Valley and greater Southern California regions were found to have greater similarities in priorities than the Northern California region, perhaps explained by differences in average herd size, type of production system, and climate (Martins et al. 2019). Because California agriculture is diverse and each cropping system will respond to change differently, adaptation research and effective stakeholder engagement should be regionally focused (Pathak et al. 2018).

In the rapidly changing context of California agriculture, identifying the relative importance of different topics is critical for prioritizing extension activities and making the best use of limited resources, while incorporating feedback from clientele will help to increase the effectiveness and impact of extension programs. Many forces beyond the farm level shape what is or is not possible on the farm, and there is a pressing need to understand how these forces intersect (Baur 2020). New legislation, including the Sustainable Groundwater Management Act (SGMA), which is the state's first law regulating groundwater use in its history; new reporting requirements for the Irrigated Lands Regulatory Program; and new or impending agrochemical bans will shape the future of farming in California. Currently, it is unclear which issues are most pressing regarding grower management decisions and information needs. Equally important, the level of satisfaction with current extension activities is not well understood. Therefore, documenting the concerns and needs of growers, consultants, and allied industry will highlight the most important topics for research and extension to focus on, and guide policymakers and administrators on where resources and funding should be allocated.

Increases in California's agricultural productivity have long been sustained by expanding water supplies, increasing use of fossil fuel energy, and new technology – all of which are now under pressure because of scarcity, cost, and public opposition (Thompson 2009). Now, more than ever, UCCE would benefit from a statewide understanding of common goals, challenges, and preferences for research and extension across different regions and crops to determine how innovative collaborations and partnerships might be established to meet clientele needs. While individual CE Advisors have conducted needs assessments for their clientele, to our knowledge there have been no prior efforts to comprehensively gather statewide information. Therefore, the primary objective of this study was to set research and extension priorities for agronomic crop production in California based on feedback and input from growers, their consultants, and allied industry professionals. The specific objective was to conduct a survey to i) identify top concerns and management challenges, ii) understand the motivations for growing agronomic crops and priorities considered in management decisions, and iii) prioritize information needs that can be addressed through research and extension efforts in the future.

2. METHODS

2.1 Survey development

The needs assessment designed for this project was an online survey developed by members of the UCCE Agronomy Program Team and administered using Qualtrics survey software (Qualtrics, Provo, UT). The first step in developing questions was to collect and summarize previous needs assessments shared by individual members of the Agronomy Program Team for their specific crop or region. Based on overarching themes from past needs assessments and bearing in mind the objectives of this collaborative effort, questions were drafted and reviewed by a team of CE advisors and UC Davis faculty working in agronomic crop production. Prior to launching the survey, it was piloted by 10 growers and other industry professionals. In depth phone conversations with pilot participants allowed for robust feedback that was incorporated into a final version of the survey. The final survey included a total of 21 questions, covering the areas of management challenges, concerns for the agronomic crop industry, motivation, importance of extension topics and level of satisfaction with UCCE. We also asked respondents who they communicate with about crop production practices and how they prefer to receive information. The survey was reviewed by the Institutional Review Board (IRB) and approved as “exempt”.

The needs assessment survey was a cross-sectional census survey attempting to collect as many responses as possible from anyone currently involved in agronomic crop production in California. We tried to ensure that we were getting accurate representation of California agronomic crops clientele by including a screening question. The survey link took respondents to a page asking if they grow, consult on, or work in allied industry of agronomic crops in California. If they responded yes, they were taken to the survey, and 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 time) between “grower”, “consultant”, “allied industry”, or “other”. Depending on their response, we were able to direct management related questions specifically to growers, while still gaining insight from consultants and allied industry on broader topics.

To identify concerns and challenges faced by those working in agronomic crop production, respondents were asked to rank their level of concern (very concerned, somewhat concerned, or not concerned) from a list of 15 topics that influence crop production in California. Next, respondents who identified as growers or consultants were asked to select their highest priority management challenges from a list of 8 common management challenges identified by our internal team of CE Advisors and CE Specialists. To understand the motivations for growing agronomic crops and priorities considered in management decisions, we asked respondents who identified as growers to rank how often certain factors affect their management decisions for field crop production (always, often, sometimes, rarely, or never). We also asked growers to select their primary reasons for growing field crops from a list of 9 commonly cited reasons, as determined by our internal team.

To prioritize information needs that can be addressed through research and extension, we used Importance-Performance Analysis (IPA). This method is a quantitative approach for measuring how people feel about certain issues (Warner et al. 2016; Martilla & James 1977). The analysis generates a picture of how important specific topics are to clientele in comparison with how satisfying they are – or in this case, how satisfied clientele are with UCCE’s delivery of information on these topics (Levenburg & Magal 2004; Siniscalchi et al. 2008). Typically, the visual output of this method is an IPA matrix created by plotting importance and satisfaction on a two-dimensional graph having four quadrants (Hugo & Lacher 2014; Levenburg & Magal 2004; Martilla & James 1977; Siniscalchi et al. 2008). The boundaries of the quadrants are based on the means of the two measures and each quadrant is interpreted as having implications for prioritization of information. The idea is that focus should be placed on topics found in the “high priority” (high importance and low satisfaction) quadrant, while resources can be allocated away from the "lower priority" (low importance and low satisfaction and "possible overkill" (low importance and high satisfaction) quadrants (Hugo & Lacher 2014; Levenburg & Magal 2004; Martilla & James 1977; Siniscalchi et al. 2008). Focus should remain on topics that fall into the high importance and high satisfaction quadrant; however clientele is seemingly satisfied with UCCE's work in disseminating information on these topics.

Importance and satisfaction were each measured through a Likert-type scale, where participants were given a list of 19 topics commonly addressed by CE and asked to select if these topics were of "high priority", "medium priority", "low priority" to them. They also had the option to select "no opinion", which received a score of zero. With the same list of topics, respondents were asked to select "high satisfaction", "medium satisfaction", "low satisfaction", or "no opinion" based on how satisfied they were with UCCE's delivery of information on these topics. High priority and satisfaction were given a score of 3, medium priority and satisfaction were given a score of 2, and low priority and satisfaction were given a score of 1. Scores for priority and satisfaction were averaged and plotted to create an IPA matrix.

2.2 Survey dissemination

The target audience of our online survey was all California agronomic crop growers, their consultants, and allied industry. Because no comprehensive list of such individuals exists, contact lists from individual agronomic program team members were compiled and duplicates were removed. In July 2020, stakeholders (n=4,813) were sent an email invitation to take the online survey. The survey was open from July 23, 2020 until September 1, 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 also 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.

While the centralized contact list contained statewide representation, the team decided that an aim of this needs assessment was also to reach people who UCCE might not already be serving. Therefore, to avoid excluding any potential respondents, the team developed a list of influential groups or organizations external to UCCE that could distribute the survey. This list included commodity boards, crop associations, Farm Bureaus, County Agricultural Commissioners, Water Quality Coalitions, and input distributors. These partner stakeholders were contacted and asked if they would be willing to share the survey with their clientele. If they agreed to share the survey, an anonymous link to the survey was sent to them for dissemination. 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.

3. RESULTS

3.1 Respondent 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 every county in California, with the most representation from San Joaquin (n=89), Fresno (n=81), Colusa (n=79), Kern (n=75), and Tulare counties (n=73). The least responses came from Mono (n=6), Trinity (n=9), San Mateo (n=9), and Plumas (n=11) counties (Figure 1a). Of the 483 respondents, 51% identified as growers, 26% identified as consultants (PCAs and CCAs), 18% identified as Allied Industry, and 5% identified as being connected to California agronomy but not as a grower, consultant, or allied industry (Figure 2). The "other" category included regulatory specialists, researchers, non-profit organizations, RCDs, landowners, managers, and aerial applicators.

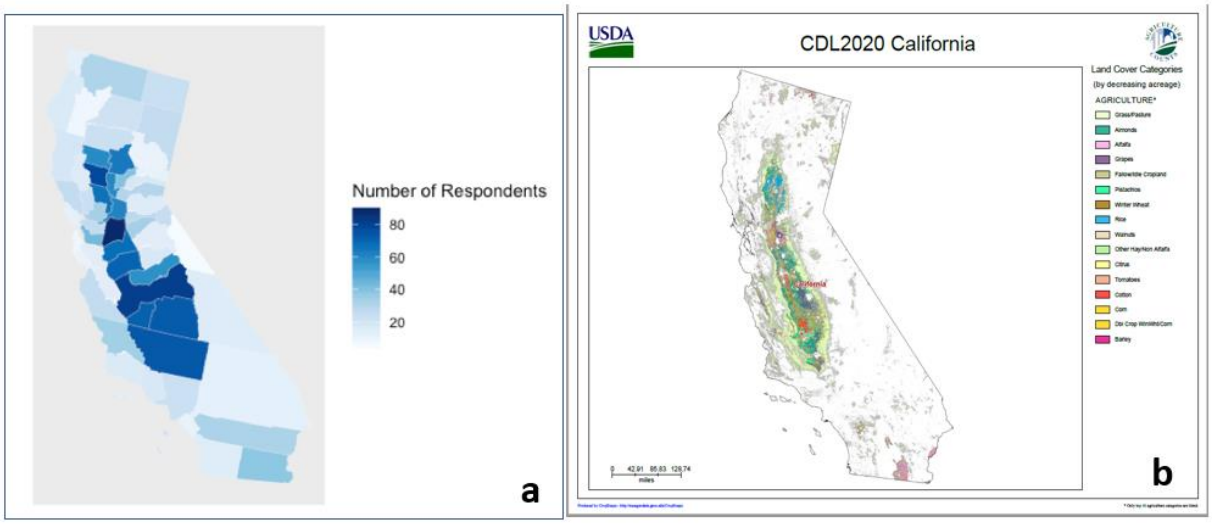

Figure 1*. Panel a shows the geographic distribution of survey respondents throughout the state; Panel b shows where crop land is concentrated in California, based on USDA data.*

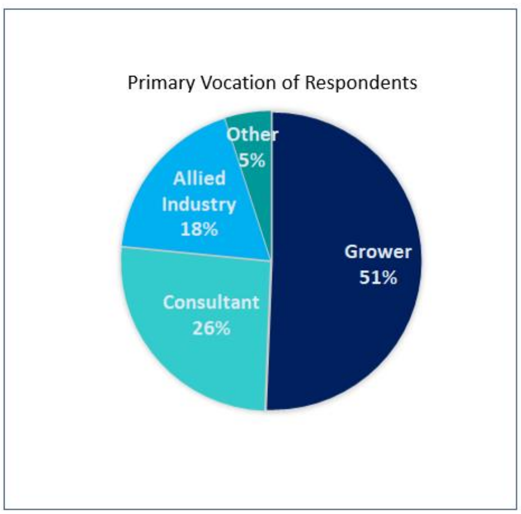

Figure 2*. Primary vocation of respondents*

		Respondents
Age	Under 25 years	5
	26-34 years	47
	35-44 years	97
	45-54 years	80
	55-64 years	81
	65-74 years	53
	75 years and over	15
	Prefer not to say	6
Race	White or Caucasian	317
	Black or African American	5
	Hispanic or Latino	22
	Asian or Asian American	4
	American Indian or Alaska Native	7
	Native Hawaiian or Pacific Islander	1
	Other	22
Gender identity	Male	308
	Female	58
	Identity not listed	1
	Prefer not to say	15
Experience growing agronomic crops	2 yrs. or less	6
	3-9 yrs.	35
	10-19 yrs.	56
	20-29 yrs.	30
	30+ yrs.	60

Table 1. *Demographic Information of Respondents**

*demographic information was designated as "optional", and therefore does not capture all respondents. However, 80% of respondents answered these demographic questions, so they are included here is a representative sample of our respondents.

Demographic questions related to age, gender identity and race were optional, but 80% of respondents provided answers. The most respondents fell between the ages of 35-44 (25%), followed by 55-64 (21%) and 45-54 (21%). 81% of respondents identified as male, 15% as female, and 4% preferred not to say or stated that their gender identity was not listed. 78% of respondents identified as white or Caucasian, 5% as Hispanic or Latino, <2% as American Indian, 1% as Black or African American, <1% as Asian or Asian American, and <1% as Native Hawaiian or Pacific Islander (Table 1).

		Overall	**SSJV**	**NSJV**	**Sac Valley**	**Low desert**	**Intermountain**	**Coastal**	**Sierra Nevada**
Respondents		483	120	128	178	57	50	135	96
Primary vocation	**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 3 crops grown	**1**	Rice	Corn (silage)	Alfalfa	Rice	Wheat (grain)	Alfalfa	Wheat (grain)	Rice
	2	Alfalfa	Alfalfa	Corn (silage)	Alfalfa	Alfalfa	Small Grain (hay)	Rice	Corn (grain)
	3	Wheat	Small Grain (silage)	Dry Beans	Wheat (grain)	Small grain (hay)	Grass & grass mixtures	Corn (grain)	Wheat (grain)
Acres managed		**Med**: 690 **Min**: 1 **Max**: 10,500 **SD**: 2,202	**Med**: 1,500 **Min**: 300 **Max**: 9,000 **SD**: 2,647	**Med**: 850 **Min**: 3.5 **Max**: 10,500 **SD**: 2,847	**Med**: 1,000 **Min**: 8 **Max**: 10,000 **SD**: 2,448	**Med**: 550 **Min**: 1 **Max**: 2600 **SD**: 974	**Med**: 1,300 **Min**: 100 **Max**: 10,000 **SD**: 4,256	**Med**: 100 **Min**: 1 **Max**: 2,400 **SD**: 551	**Med**: 1,000 **Min**: 3 **Max**: 10,000 **SD**: 2,079
Distribution (% of acreage)	**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%

Table 2*. Characterization of respondents' cropping systems by region. SSJV=Southern San Joaquin Valley, comprised of Fresno, Kings, Tulare, and Kern counties; NSJV=Northern San Joaquin Valley, comprised of Madera, San Joaquin, Merced, and Stanislaus counties; Sac Valley=Sacramento Valley, comprised of Solano, Yolo, Sacramento, Sutter, Yuba, Colusa, Tehama, Butte, and Glenn counties; Low desert comprised of San Bernardino, Riverside, and Imperial counties; Intermountain comprised of Siskiyou, Trinity, Shasta, Lassen, Modoc, and Plumas counties; Coastal comprised of Del Norte, Humboldt, Mendocino, Lake, Sonoma, Napa, Marin, Contra Costa, Alameda, San Francisco, San Mateo, Santa Cruz, Santa Clara, San Benito, Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, and San Diego counties; Sierra Nevada comprised of Sierra, Nevada, Placer, El Dorado, Amador, Calaveras, Alpine, Tuolumne, Mariposa, Mono, and Inyo counties.*

Acres managed by growers ranged from 1 to 10,500 acres (average=1,473 acres; median=690 acres; standard deviation=2,202), with 56% of these acres being owned and 44% of these acres leased (Table 2). It is important to note that only 193 of the 246 growers filled out this question about how many acres they managed. It was a "fill in the blank" type question, while the rest were multiple choice. Therefore, it may have been overlooked by respondents, or it may have been a sensitive question that should have been asked as closed ended with ranges as answer choices, rather than open-ended. The average acreage devoted to field crops out of a growers' total acreage was 59%, while other crop categories include tree and vine crops (22%), vegetable crops (16%), and other (3%). The top five agronomic crops grown by respondents whose primary vocation was "grower" included rice, alfalfa, wheat (grain), corn (grain), and corn (silage), representing 48% of total responses (Figure 3). The next five crops were dry beans, cotton, sunflower, barley, and small grain silage, representing 25% of total responses.

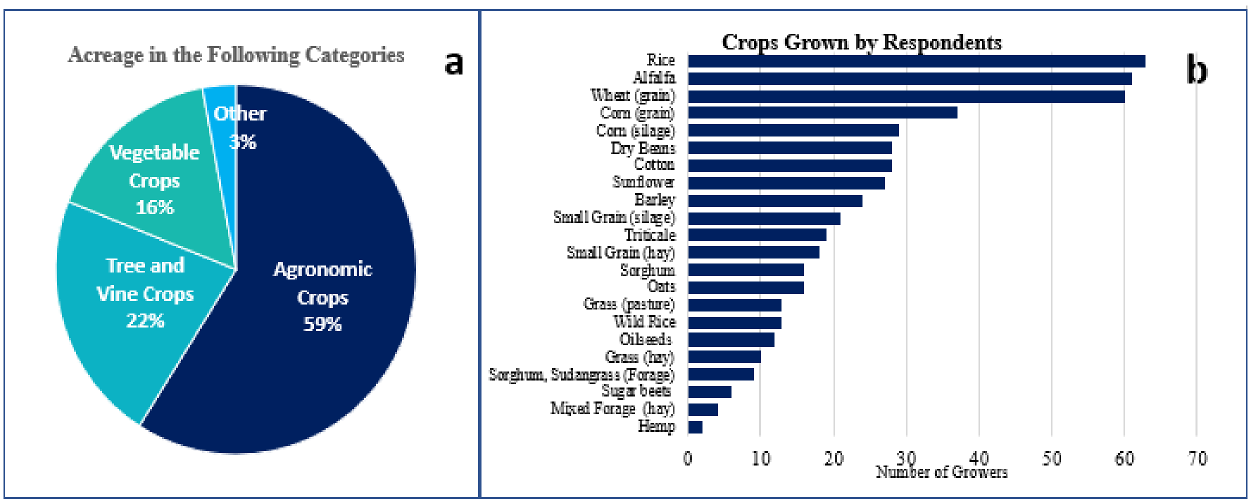

***Figure 3**. Panel* a *shows the average percentage of respondents' land that is in the following crop categories: agronomic crops, tree and vine crops, vegetable crops, and other. Panel* b *shows top crops grown by respondents identifying as growers.*

3.2 Concerns and Challenges for Agronomic Crop Production

When asked about their concerns for California 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 4). In contrast, the topics that ranked lowest for "very concerned" were more evenly split between the categories of very, somewhat, and not concerned. For example, for weather and climate, 37% said they were very concerned, while 24% said they were not concerned. For accessing markets, 37% said they were very concerned, while 16% said they were not concerned. Finally, 34% of respondents said they were very concerned about soil degradation while 22% said they were not concerned.

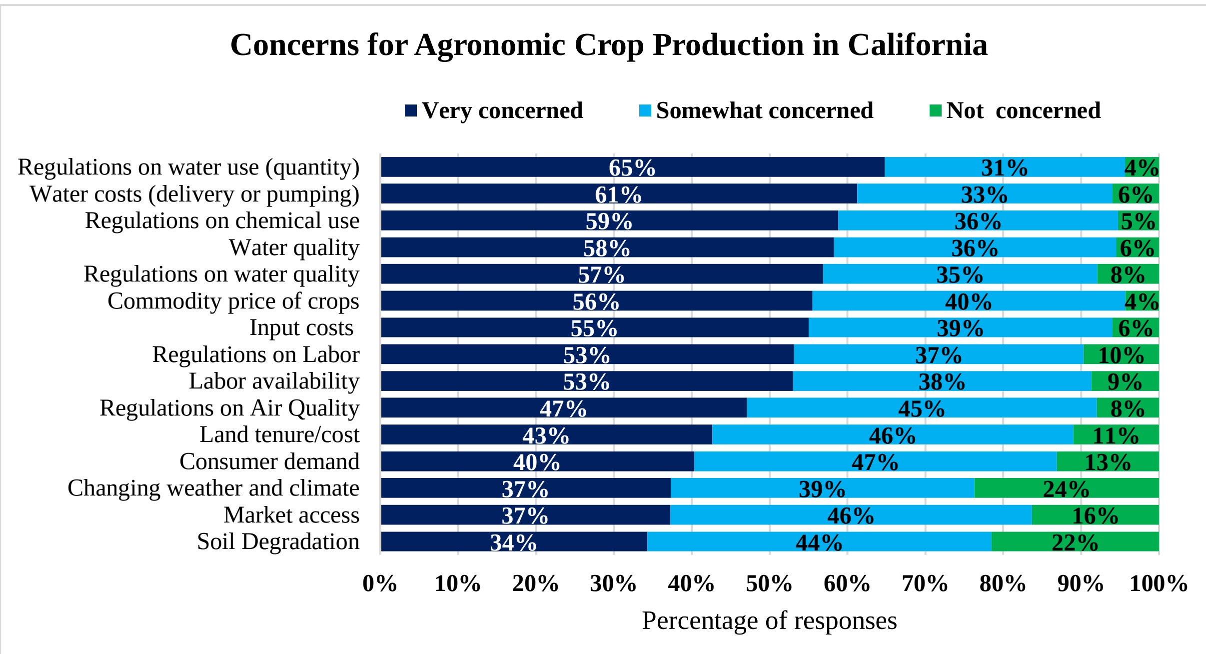

Figure 4. *Respondent Concerns for Agronomic Crop Production in California (n=420)*

Respondents were given the opportunity to write in other concerns that did not fall into the above categories. Notable responses include continued use of pesticides, defoliants, and other toxic substances; industrial production and centralization; loss of small farms; lack of experience of UC extension agents who are replacing those retiring; a growing number of pesticides that are unlawful in California but okay to use in other states; widespread transition into permanent crops; loss of farmers in county governments and other loss of knowledge by officials; and COVID induced problems.

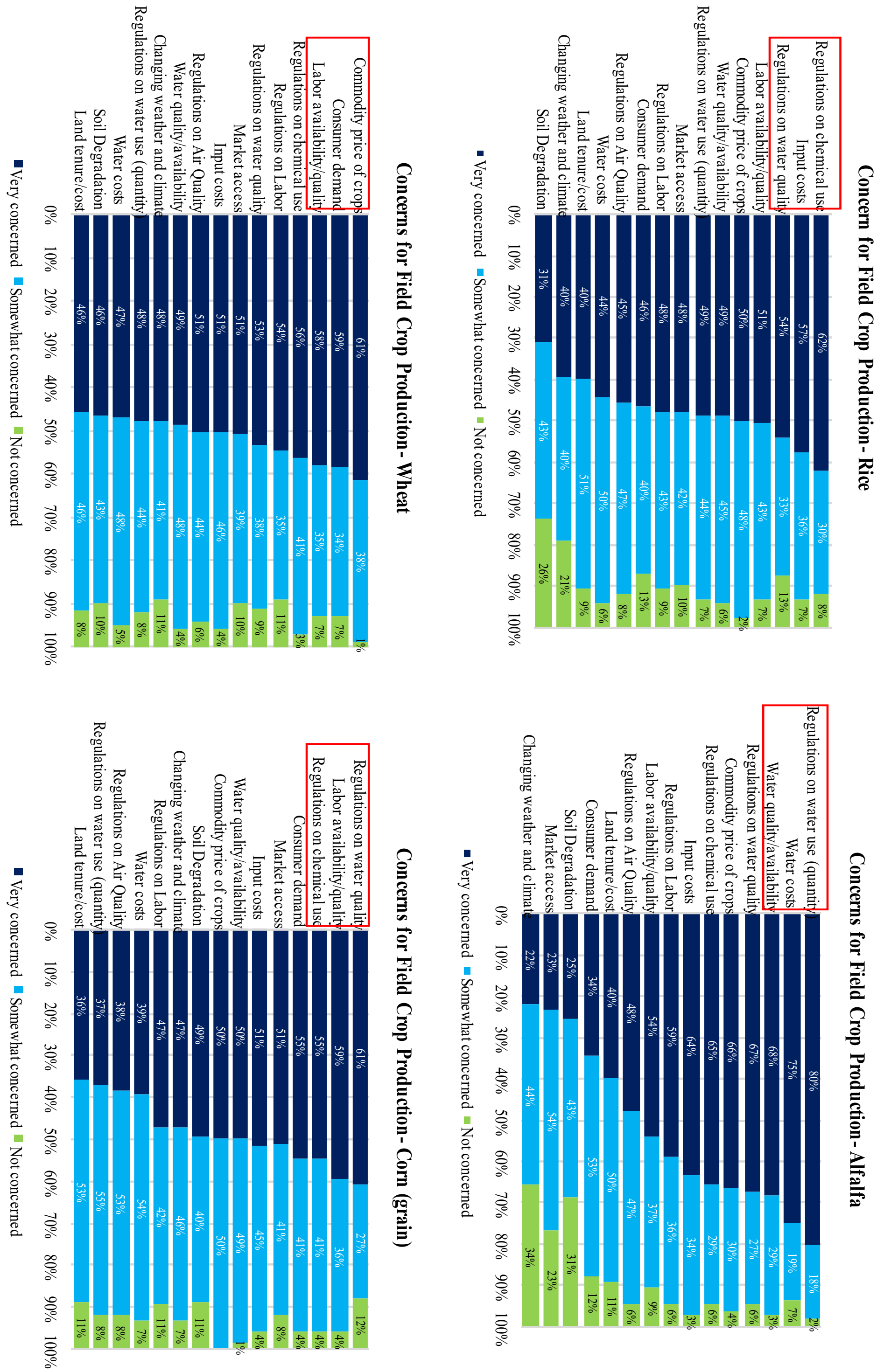

Figure 5. *Concern for Field Crop Production for rice growers and consultants, alfalfa growers and consultants, wheat growers and consultants, and corn (grain) growers and consultants.*

Concerns varied by crop (Figure 5) and region (Table 3). For instance, the top categories for anyone identifying as a rice grower and rice consultant were “very concerned” about included regulations on chemical use (62%), input costs (57%), and regulations on water quality (54%). The top categories that those growing or consulting on alfalfa were “very concerned” about included regulations on water use (quantity) (80%), water costs (75%), and water quality (68%). Respondents growing or consulting on wheat were “very concerned” about the commodity price of their crop (61%), consumer demand (59%), and availability of quality labor (58%). Finally, corn (grain) growers and consultants were “very concerned” about regulations on water quality (61%), availability of quality labor (59%), and regulations on chemical use (55%) (Figure 5).

All 7 regions ranked “regulations on water use (quantity)” and “water costs” as the top concerns relative to other concerns. Based on mean responses, the greatest concern for regulations on water use was seen in the Southern San Joaquin Valley (SSJV) (2.84 ± 0.83), the Intermountain region (2.81 ± 0.78), and the Northern San Joaquin Valley (NSJV) (2.80 ± 0.77), while 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 Northern and Southern San Joaquin Valley and Low Desert regions was “water quality (availability)”, while “regulations on water quality” was the third highest ranking concern for the Intermountain region. The third highest ranking concern of the Coastal and Sierra Nevada regions was “regulations on chemical use”. The Sacramento Valley ranked “input costs” in the top three concerns.

Growers were asked about their top management challenges for the agronomic crops they grow. While several stood out, such as weed control and irrigation/water management ranking as the top challenges (Figure 6a), there was relatively strong representation across categories. Soil management, disease control, and harvest operations ranked lowest. When broken down by the top 8 agronomic crops, the highest-ranking management challenges differed among crops (Figure 6b). Irrigation/water management was the top management challenge for alfalfa and corn silage growers, while weed control was the top management challenge for dry beans, sunflower, and cotton growers. For rice growers, irrigation/water management and weed management were tied for first as the top management challenge. Nutrient management was the top management challenge for wheat and corn grown for grain.

	Sac Valley (n=178)	**NSJV (n=128)**	**SSJV (n=120)**	**Low Desert (n=57)**	**Intermountain (n=50)**	**Coastal (n=135)**	**Sierra Nevada (n=96)**
Market Access	2.08 ± 0.24	2.08 ± 0.25	2.02 ± 0.26	2.02 ± 0.22	2.18 ± 0.28	2.35 ± 0.40	2.20 ± 0.29
Consumer Demand	2.11 ± 0.25	2.11 ± 0.25	2.13 ± 0.28	2.11 ± 0.25	2.19 ± 0.28	2.37 ± 0.39	2.29 ± 0.33
Changing weather and climate	1.93 ± 0.16	2.09 ± 0.23	1.98 ± 0.20	2.06 ± 0.22	2.15 ± 0.26	2.41 ± 0.44	2.17 ± 0.27
Soil Degradation	1.99 ± 0.19	2.20 ± 0.29	2.10 ± 0.24	2.06 ± 0.21	2.07 ± 0.26	2.23 ± 0.30	2.25 ± 0.32
Land tenure/cost	2.27 ± 0.32	2.38 ± 0.38	2.28 ± 0.33	2.31 ± 0.60	2.47 ± 0.44	2.36 ± 0.37	2.29 ± 0.33
Regulations on Air Quality	2.35 ± 0.38	2.45 ± 0.44	2.43 ± 0.42	2.28 ± 0.34	2.33 ± 0.36	2.35 ± 0.37	2.29 ± 0.34
Input Costs	**2.53 ± 0.51**	2.51 ± 0.48	2.45 ± 0.43	2.35 ± 0.69	2.49 ± 0.52	2.39 ± 0.39	2.35 ± 0.38
Regulations on Labor	2.39 ± 0.41	2.50 ± 0.48	2.55 ± 0.52	2.34 ± 0.38	2.37 ± 0.41	2.36 ± 0.39	2.25 ± 0.32
Commodity price of crops	2.48 ± 0.45	2.54 ± 0.50	2.48 ± 0.45	**2.48 ± 0.80**	2.51 ± 0.50	2.41 ± 0.40	2.43 ± 0.42
Labor availability/quality	2.45 ± 0.45	2.52 ± 0.51	2.44 ± 0.43	2.32 ± 0.36	2.33 ± 0.37	2.45 ± 0.45	2.32 ± 0.37
Regulations on water quality	2.43 ± 0.46	2.60 ± 0.57	2.56 ± 0.51	2.43 ± 0.45	**2.62 ± 0.58**	2.50 ± 0.47	2.44 ± 0.45
Regulations on chemical use	**2.49 ± 0.49**	2.60 ± 0.57	2.53 ± 0.48	2.47 ± 0.47	2.52 ± 0.48	**2.51 ± 0.48**	**2.51 ± 0.50**
Water costs (delivery/pumping)	**2.49 ± 0.49**	**2.66 ± 0.62**	**2.80 ± 0.75**	**2.61 ± 0.56**	**2.71 ± 0.66**	**2.51 ± 0.47**	**2.47 ± 0.44**
Water quality/availability	2.44 ± 0.43	**2.68 ± 0.63**	**2.74 ± 0.70**	2.47 ± 0.48	2.50 ± 0.51	2.50 ± 0.47	2.45 ± 0.44
Regulations on water use (quantity)	**2.62 ± 0.58**	**2.80 ± 0.77**	**2.84 ± 0.83**	**2.65 ± 0.61**	**2.81 ± 0.78**	**2.52 ± 0.49**	**2.52 ± 0.50**

Table 3. *Level of concern (mean ± SE) for different topics categorized by region as indicated by respondents of the needs assessment survey. Mean response was calculated after assigning the following numeric values to respondent concern level: very concerned=3, somewhat concerned=2, and not concerned=1. The darker red colors represent higher concern, while the darker green represent lower levels of concern.*

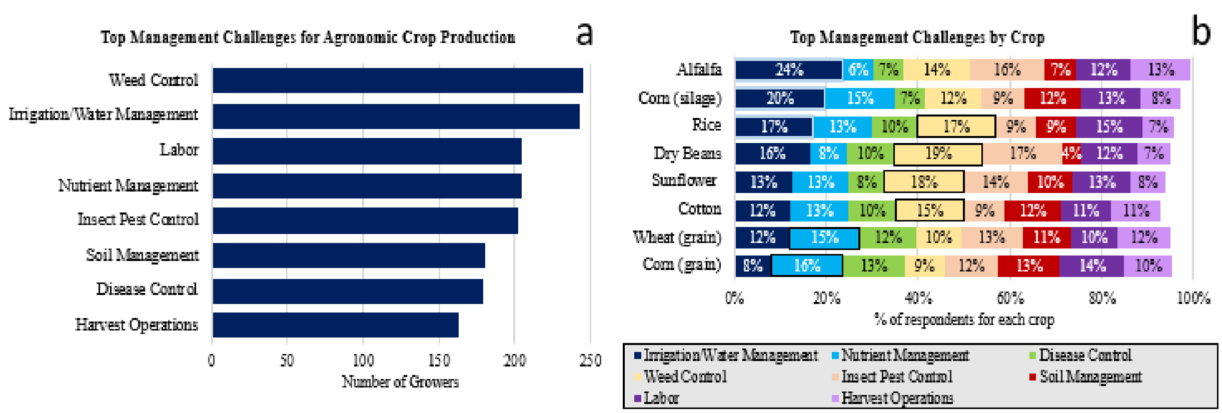

Figure 6. *Top Management Challenges for Agronomic Crop Production. Panel* a *shows growers' overall management challenges, while Panel* b *breaks down management challenges for the top 8 agronomic crops grown by survey respondents.*

3.3 Priorities and Motivations of Agronomic Crop Producers

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 7a). Regarding on-farm decision making, the highest priorities that were considered by growers when making management decisions included the availability of water (49%), profitability (46%), and land stewardship (41%) (Figure 7b).

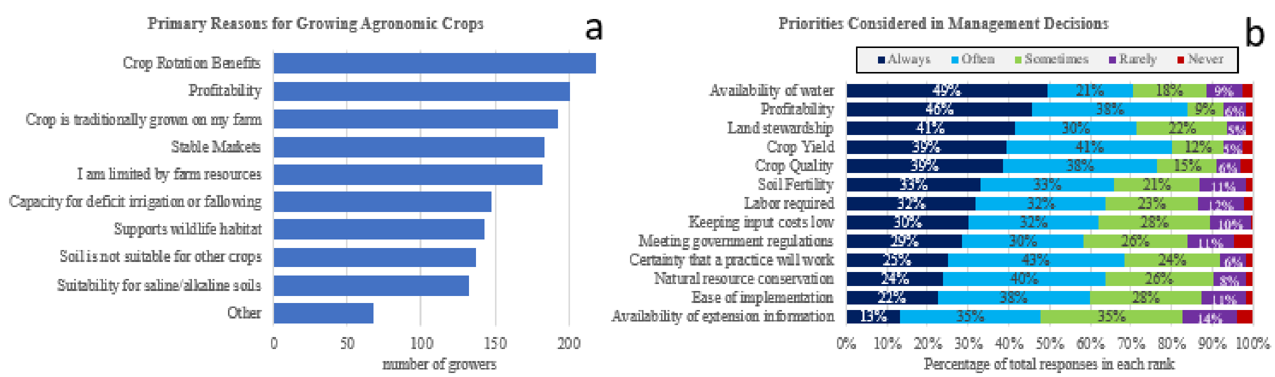

***Figure 7**. Panel* a *shows primary reasons for growing agronomic crops. Panel* b *shows top priorities considered in management decisions by growers.*

3.4 Prioritizing Information Needs

From a broader list of topics covered by UCCE research and extension, the top gaps in priority vs. satisfaction for high-priority issues were testing new products, water conservation and storage, irrigation management, weed control, and soil health. The topics that were considered low priority by respondents include Greenhouse Gas (GHG) emissions reduction, compost management, and manure management. Cover Crops was a topic that fell into the "possible overkill" category, based on IPA methodology.

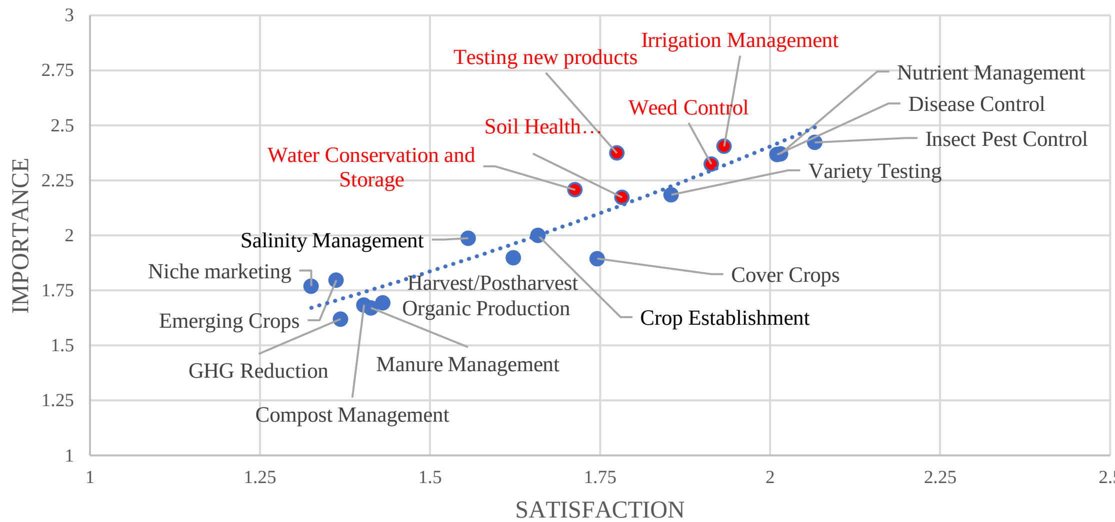

Figure 8. *Importance-Performance Analysis. The y-axis represents how important these topics are to respondents, while the x-axis represents their satisfaction with the delivery of information on these topics from UCCE. Topics in red represent topics where the importance to respondents exceeded their satisfaction with UCCE's delivery of information on these topics. The analysis indicates these should be considered as areas to focus on in future research and extension.*

4. DISCUSSION

4.1 Representativeness of Survey

Slightly more than 2/3rds of responses were from California's Central Valley (67%) which is where most of the state's agricultural production is located (Figure 1b). In 2017, counties with the highest total cropland were Fresno (1, 142,664 acres), Kern (954,059 acres), Tulare (721,368 acres), Merced (546, 460 acres), and San Joaquin (524, 356 acres). According to USDA NASS data from 2018, the district containing Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare had the highest total gross value of agronomic crops in 2018 ($2,930,181,000), while the district containing Butte, Colusa, Glenn, Sacramento, Solano, Sutter, Tehama, Yolo, and Yuba counties had the second highest gross value of agronomic crops in 2018 ($1,254,496,000). Therefore, since 67% of our respondents represent these two districts, the geography of our respondents appears to be representative of where much of the agronomic crop production is taking place in the state. Representation is lacking most in Imperial county, which is a large producer of agronomic crops, particularly hay crops. In 2018, Imperial county had 341,229 acres in agronomic crops, ranking second in the state for gross value of alfalfa production ($218,455,000). However, it is important to note that the average farm size in Imperial County in 2018 (1,317 acres) is much larger than the state average of 348 acres, meaning that less people may be working larger areas of land. Therefore, looking only at acreage and economic value in agronomic crops may not be representative of how many people in our target population work in a particular region.

Regarding the top three field crops grown by respondents, agriculture census data from 2017 shows that rice represented 541,000 planted acres in California, alfalfa (for hay) 720,000 acres, and wheat 480,000 acres in 2016 (USDA, NASS 2017). Grain corn represented 420,000 planted acres, silage corn 315,000 acres, cotton 218,000 acres, dry beans 50,000 acres, and sunflower 46,600 acres. Therefore, crop representation in our needs assessment survey roughly follows the area planted throughout the state.

The results of our survey indicate that respondents are skewed slightly younger than the distribution of the industry population. According to the 2017 Census of Agriculture Online, the average age of California farmers is 59 years old (USDA NASS 2017). Nearly 60% of survey respondents were 54 years old or below, and the greatest number of respondents fell between the ages of 35-44 (25%). This may be related to the mode of survey delivery. Online surveys may be bias towards younger respondents with higher income and education (Bosnjak and Tuten 2001; Couper 2000; McDonald and Adam 2003). Additional drawbacks to online surveys include the fact that the survey presentation may vary based on browser settings and variations in hardware which may increase the likelihood of response error (Couper 2000). In addition, the flexibility of the internet and ease with which false identities can be created can make survey results unreliable (Cho and LaRose 1999).

Online surveys do have the advantage of allowing for large-scale and inexpensive data collection. With online surveys, costs per response decrease as sample size increases, while for surveys sent through postal mail, costs tend to increase significantly as sample size increases (Couper 2000; Watt 1999). Research comparing electronic surveys to postal surveys has confirmed that electronic survey content results may be no different than postal survey content results yet provide advantages of fast distribution (Yun and Trumbo 2000; Swoboda et al. 1997). Qualtrics Survey Software allowed us to customize survey questions based on the respondent's primary vocation. While paper surveys can also indicate that a set of questions are only for people that select a particular answer choice in a previous question, the online survey allows for a more customized experience through format and response control (Preece et al. 2001; Stanton 1998). Electronic surveys can also yield a significantly higher response rate than paper surveys (Koundinya et al. 2016). Because the objective of this study was to reach the broadest audience possible, an online survey that could be completed on a computer or mobile phone platform was selected.

4.2 Concerns and Challenges for Agronomic Crop Production

4.2.1 A Focus on Water

Water-related issues were clearly the most prominent in our survey responses, representing 4 out of the top 5 concerns listed by respondents. Specifically, regulations on water use and water costs were the two concerns that had the highest number of respondents expressing that they were "very concerned". The Sustainable Groundwater Management Act (SGMA), signed into law by Governor Brown in 2014, requires groundwater-dependent regions to stop over drafting groundwater and develop plans to balance pumping and recharge (AB 1738, SB 1168, and SB 1319). Since this is the first time groundwater use is subject to regulations in California, growers are expectedly concerned about changes that will occur as a result. 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 groundwater pumping regulations are enacted.

Water is generally the most-limiting input for crop production, and therefore impacts on cost, availability, or quantity will limit the capacity for growers to manage this resource. California has approximately 2.8 million ha of irrigated land, which produces nearly 90% of the harvested crops in the state (Ayars et al. 2015; Tanaka 2006). A decrease in water availability because of new regulations has implications for maintaining the same area under irrigation into the future. Impacts of water decline were already being felt before SGMA was signed into law. Due to increasing incidence of prolonged drought, California saw a decline of more than 200,000 acres of irrigated land between 2004 and 2006, while nearly 250,000 acres had to be idled in 2014 alone (Ayars et al. 2015). It is projected that an additional 500,000 to 1 million acres of land in the San Joaquin Valley alone may have to be retired due to SGMA (Hamann 2020). Uncertainty and difficulty around water resource planning and management is amplified by increasing unpredictability of weather patterns. Annual rainfall varies greatly in California - more notably than other parts of the country - which makes predicting rain fall year to year a challenge (Dettinger et al., 2011; Hydroclimate Report Water Year 2015). For these reasons, it was unsurprising that irrigation and water management were ranked as a top management challenge for survey respondents.

4.2.2 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. Given new or impending bans on agrochemicals in California, it makes sense that growers are concerned about 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 (Rauh et al., 2011; Gómez-Giménez et al., 2017; Silva at el., 2017; Gómez-Giménez et al., 2018). In 2015, the Environmental Protection Agency (EPA) proposed a federal ban for chlorpyrifos on all food crops, but soon after, the federal government under the Trump administration concluded the science was "unresolved" and removed the ban. Regardless, California, along with Hawaii and New York, decided to move forward with banning chlorpyrifos. In California users were required to stop using these products on December 31, 2020. Other states continue to use these agrochemicals, leaving California growers to feel like they are at a competitive disadvantage.

The ban on chlorpyrifos has and will likely continue to be felt 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 1991-2012 saw large increases in chlorpyrifos use in these four counties (up to 97%). During this time, 7.2 million pounds of chlorpyrifos was used in Fresno county, 6.1 million pounds was used in Tulare county, 5.4 million pounds were used in Kern counties, and 3.2 million pounds was used in Kings county (Bale, 2014). Effects will also be felt heavily in alfalfa production since chlorpyrifos is the most popular side-spectrum insecticide for management of key alfalfa pests, such as the alfalfa weevil (*Hysperia postica*) and aphids (Long, Putnam, and Grettenberger, 2019). In our survey, 65% of alfalfa growers and consultants said that they were "very concerned" about regulations on chemical use.

There are other impending regulations on neonicotinoids in California, which are commonly used on cotton, corn, and grains. Neonicotinoid pesticides have become the most widely used class of insecticide in the world (Jeschke et al 2011; Casida and Durkin 2013). However, recent evidence has linked these chemicals to honeybee die off and declining pollinator health (Henry et al. 2012; Wood and Goulson 2017). Because of the high solubility of neonicotinoids in water, it has also been found that they readily leach into waterbodies 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 announced that they will not consider applications of any new uses of neonicotinoid insecticides until re-evaluation of the chemicals are completed (DPR 2021). An addendum was published in January 2019, and the investigation is ongoing (DPR 2021). This prospective ban is particularly worrisome to certain stakeholders. A recent study found that in 2011 between 79-100% of maize acreage in the USA were treated with neonicotinoids (Douglas and Tooker 2015).

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 intensively farmed areas and the production is often labor-intensive. Therefore, the effect of pesticide use at the agricultural-urban boundary and the potential effect on farmworkers are key evaluation factors for product registration by the California DPR, while there is not as much emphasis on these factors at the federal level by the U.S. EPA (California Department of Pesticide Regulation). In addition, federal pesticide law (the Federal Insecticide, Fungicide, and Rodenticide Act, FIFRA) mandates that the U.S. EPA consider the economic benefits of a pesticide when deciding whether to register it. California law does not allow consideration of economic benefits in the decision to register a pesticide unless there is no feasible alternative. Therefore, the financial advantages of using a certain pesticide cannot outweigh the health risks of use under California law. This is beneficial for communities, farmworkers, and consumers – yet, it may seem unfair to growers and input suppliers when market competitors have access to chemicals that they do not.

4.2.3 Weed Management Challenges

Weed control was ranked as the top management challenges by growers and consultants. Current estimates of losses on global crop production show that weeds cause the largest losses (34%), followed by insects (18%), and diseases (16%) (Oerke 2006). Total weed control costs in the U.S. are more than $11 billion a year, most of which is spent on herbicides (Koleva 2009). The direct annual cost to monitor and control invasive plants in California is estimated at around $82 million (Brusati 2009). One of the most widely used herbicides is glyphosate. Although the Environmental Protection Agency has repeatedly stated that glyphosate is safe, California has led the charge in holding Monsanto accountable for Roundup's link to cancer in humans and the death of important insects. As early as 2017, California added glyphosate to its list of carcinogens under Proposition 65 and the state has a growing number of cities and counties banning or restricting glyphosate. To date, more than 40 communities in the state of California have restricted the use of glyphosate in some capacity (CALPIRG 2021).

Yet, weed management as a category in our survey was broad and could mean many things - new weed species, herbicide resistance, drift issues, or preventing the use of certain herbicides, Therefore, UCCE must work directly with agronomic crop producers to determine future directions of weed management research. Herbicide resistance is a growing concern in cropping systems throughout the state, particularly in rice (Al-Khatib et al. 2019). 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 limited by the spatial and temporal scales of its studies (Roux et al. 2006; Kettenring and Adams 2011; Matzek et al. 2015). Without practitioner insight, researchers might produce studies with limited relevance to local management conditioners (Esler et al. 2010; Kettenring and Adams 2011; Bayliss et al. 2013; Matzek et al. 2015; Roche et al. 2015).

4.2.4 Lack of Emphasis on Climate Change

It is notable that when asked about concerns for California agronomic crop production in California, a quarter of the respondents (24%) stated they were not concerned about changing weather and climate. Yet, it has been predicted that some of the most vulnerable agricultural regions to climate change are the Salinas Valley and the San Joaquin Valley - particularly the corridor between Fresno and Merced - as well as the Imperial Valley (California Energy Commission 2012; 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 this changing weather and climate will impact agronomic crop production (Natural Resources Agency, 2014; Hatfield et al. 2014; Morgan et al. 2002; Morgan et al. 2004). An earlier study using process-based crop modeling predicted that heat waves in May will become common, causing yield losses of 1-10% for corn, rice, and sunflower, while heat waves in June will affect corn and sunflower production (Hatfield 2014). High nighttime temperatures could also speed up reproductive development and decrease the length of the grain-filling period, resulting in reduced yields (Hatfield 2014). The effects of elevated CO_2 has been associated with reduced nitrogen and protein content in some agronomic crops, causing a reduction in grain and forage quality (Morgan 2002, 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 (Pathak 2018; Westerling 2006; DWR 2015). Weed management will also experience new challenges. For instance, while glyphosate has been projected to lose its efficacy on weeds as CO2 levels rise, there are also predictions that increased atmospheric CO2 concentrations will have a positive impact on several weed species, which may contribute to increased risk of crop loss due to weed pressure (Ziska 199, 2001, 2003, 2010). As a result, both herbicide use and costs are expected to increase as CO2 levels rise (Koleva 2009). In a recent survey for California rangelands, practitioners overwhelmingly recognized an increase in weed problems in the past 5-10 years and acknowledged a negative effect of California drought on weed management given the adaptive responses of weeds (Yue et al. 2020).

4.3 Priorities and Motivations of Agronomic Crop Producers

Results indicate that growers' priorities in management decisions are often more immediate than long-term. Immediate pressures, such as water resources and economic viability of farming operations appear to take priority over longer-term adaptations of a changing climate. Therefore, it is crucial that UCCE evaluate the tradeoffs between balancing short-term priorities while helping growers adapt to future challenges.

Water availability was the top priority consideration for grower management decisions. In many cases, growers are limited by what they can grow or the acreage they can farm due to limited water supplies, hence water availability dictates year to year operations. Therefore, UCCE should focus on helping growers adopt on-the-ground, practical solutions to dealing with impending water shortages. Providing new research about how to maintain production levels with reduced water resources or increasing water use efficiency is one avenue with more immediate impacts, while improving soil health to increase the water holding capacity of our agricultural lands should be considered for the long-term. There is much to do in terms of research and extension and UC needs to devote more people resources to practical solutions for water and irrigation management.

The benefits of crop rotation were a primary reason for growing agronomic crops. Crop rotation is a foundational practice for increasing on-farm biodiversity and can help manage pests, disease, weeds (Li et al. 2019; Liebman and Dyck 1993; Rusch et al. 2013). However, the benefits of crop rotation are not always immediately evident, and current economic pressures could discourage rotation with lower value agronomic crops. Therefore, UCEE should think about how the benefits of crop rotation, which cannot be practiced in perennial systems as it can in annual systems, can be leveraged to gain funding for more research and extension in agronomic crops. For example, this could include impacts on groundwater recharge or soil carbon and GHG emissions, which appeal to future challenges, while also addressing more immediate needs, such as weed management. Crop rotations can also reduce agrochemical use, which might help address concerns about agrochemical regulations (Lechenet et al. 2014). Bans on agrochemicals are outside of UCCE's control and future effects of products that are tested in the short-term are unknown. Investing resources in long term solutions, such as increasing on-farm biodiversity, could prevent the need for continually testing new inputs that may end up having the same fate as chlorpyrifos, neonicotinoids, and glyphosate. UCCE has received more than $5 million in grant funding through the California state budget to work on developing alternatives to chlorpyrifos. In assessing alternatives, UCCE should think about integrating practices that serve as long-term adaptation strategies, especially considering 55% of total respondents said that they were "very concerned" about input costs.

Land stewardship, which was not explicitly defined in our survey but has been described by others as a "deeply held inner conviction that compels and inspires people to be responsible caretakers of the land entrusted to them" (Nellie 2017, p. 20), was a top priority in management decisions for growers. The motivation for land stewardship is based on "present benefits to the landowner; benefits to future generations; and the benefits that accrue to society outside the boundary of the land" (Nellie 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. Land stewardship and natural resource conservation are similar in their goals to conserve resources for future generations. However, land stewardship is not a list of practices - it is instead about a person's relationship to the land, originating from an ecological conscience that defines right and wrong (Nie, 2008). Natural resource conservation in the United States, on the other hand, is often rooted in prescriptive regulation, meaning the government mandates how a resource may be used and explicitly directs the behavior of regulated interests (Nie, 2008).

The history of natural resource management in the United States is rooted in the courts. Several environmental agencies have expressed that they view excessive regulation and litigation as a serious threat to effective land management and efficient administration (Nie, 2008). For extension, this is important to note because the emphasis on land stewardship shows that growers do highly value ethical treatment of the land, while lack of emphasis on natural resource conservation may demonstrate an aversion to regulations aimed at achieving healthier land management goals. UCEE should leverage the concept of land stewardship in extension efforts, without making it feel too prescriptive. This is also important for policymakers in thinking about expanding incentive-based programs for land stewardship rather than basing the care for natural resources on punitive measures. One topic that illustrates ample opportunities for both UCCE and policymakers to work together is soil health. However, if incentive programs are to expand, they must be developed with an understanding that building healthy soil is a long-term investment and immediate impact may not be observed. Thus, providing long-term support to growers is necessary.

While participants appear to possess a strong land ethic, the importance of long-term support in incentive programs is important because profitability is a greater priority in management decisions than land stewardship. This is unsurprising given high land, labor, and input costs in California combined with low crop value for some agronomic crops. Several studies have found that farmers' ethical drive for land stewardship appears to decline as economic pressures increase (James and Hendrickson 2008; Stuart 2009). Dependencies on agricultural markets limit farmer choice, including the "freedom to make ethical decisions" since farmers will do what they can to reduce the risk of losing any of their crop (Hendrickson and James 2016). Going back to the example of using neonicotinoid coated seeds for pest management, growers have limited choice in the seed they purchase, and will generally favor the insurance of seed coatings when they do have a choice (Frank and Tooker 2020). Therefore, widespread voluntary change to stop using these products is not likely unless the market system in which agricultural commodities are bought and sold changes. The constrained choices growers face pose major impediments to research and policy interventions aimed at cultivating new farming ethics, such as climate smart farming practices

(Stuart and Schewe 2016). This is why the work of UCCE must also engage the institutions, such as policymakers and industry, that drive or constrain farmer management choices (Baur 2020).

4.4 Prioritizing Information Needs

Based on the Importance-Performance Analysis (IPA), topics that had the largest gaps in priority vs. satisfaction were testing new products, water conservation and storage, irrigation management, weed control, and soil health. These align with respondents' greatest concerns and management challenges discussed above. Lower priority needs included greenhouse gas (GHG) emissions reduction, which suggests that climate impacts and the need for GHG mitigation efforts should be framed differently to practitioners. In other words, what inspires policymakers and researchers to act against climate change may not be the same for those working on the ground. Finally, cover crops was a topic that fell into the "possible overkill" category, based on IPA methodology. While the principles of cover cropping can address management challenges expressed by growers, such as improved soil-water dynamics and weed suppression, clientele feel that the current information on cover cropping may be in excess. Understanding where to focus attention or scale back efforts highlights the importance for closing the research-implementation gap by creating adaptive research-management programs (Yue et al. 2020).

4.4.1 Testing New Products

Likely because of agrochemical regulations in California, "testing new products" is of high importance. Before federal or state regulators register a new pesticide, they must have data on how it behaves under California specific field conditions. With bans on chemicals that have historically been used in large quantities and the need for data on pesticide behavior in California specific field conditions, agronomic crop clientele is eager to see new products tested. But it is important for UCCE to consider that bans on agrochemicals are outside of their control and future effects of products that are tested in the short-term are unknown. Therefore, extension should consider ecosystem-based pest management practices, including planting hedgerows and increasing crop diversity, over a reliance on chemical control (Morandin et al. 2011, 2014; Long et al. 2017; Flint and Roberts 2009).

Integrated Pest Management (IPM), which is an adaptive, ecosystem-based approach to pest control, is a step in the right direction, and UCCE and put a lot of effort into developing IPM resources (UC IPM). This may be why respondents expressed high satisfaction with UCCE's delivery of information on insect pest and disease control. Investing resources in long term solutions will prevent the need for continually testing new inputs that may end up having the same fate as chlorpyrifos, neonicotinoids, and glyphosate.

4.4.2 The connection between water conservation and storage, irrigation management, and soil health

Water conservation and storage and irrigation management are also of high importance to respondents. The immediate need for water to grow crops has led UCCE and industry to focus on developing new technologies to help growers adapt to limited water resources. Drip irrigation, for example, was introduced to California agriculture in 1969 and has since been widely studied and advocated for in its ability to increase yields and save water (Taylor et al. 2014). UCCE worked hard to identify the economic and agronomic performance of drip irrigation, which resulted in widespread adoption. Adoption in drip irrigation has further accelerated by CDFA's State Water Efficiency and Enhancement Program (SWEEP) – a program that provides financial incentives for growers to install drip irrigation systems, among other system components that will reduce on-farm water use and energy (CDFA 2020).

While drip irrigation does reduce water use per acre, it has not served to save much water in the aggregate because of cropland expansion. Since a drip line can reach anywhere, hundreds of thousands of acres of marginal farmland, including hillsides that could never be watered with furrow irrigation, as well as saline soils, have come under cultivation since the introduction of drip (Arax 2019). Data from a USDA survey found that on average, farmers who report turning to UCCE as a source of irrigation information tend to use more irrigation water (Chatterjee et al. 2019). Therefore, the challenges California is facing with reduction in water supply is not just a consequence of drought, but also of the growth of cultivated lands (Arax 2019). In addition, drip irrigation does not replenish the aquifer like furrow irrigation does. One of the sustainability indicators that must be considered in Groundwater Sustainability Plans (GSPs) under SGMA is groundwater-level declines, which occur when groundwater withdrawals exceed recharge of the aquifer system (USGS 2020). With drip irrigation, the aquifer system will not be recharged.

Therefore, balancing technological fixes where long-term impacts are largely unknown, with ecosystem-based change is key. Based on the IPA, there is also a gap in priority and satisfaction for research and extension on "soil health", indicating that respondents are interested in seeing more work done in this area. While many soil health principles are known, there is much to be studied around applying healthy soils practices in California, and farmers are more likely to adopt new farming practices when expert or knowledge-making institutions speak to the feasibility of adoption (Baur 2020). Therefore, UCCE should consider focusing resources on the practical application of healthy soils practices at local levels. Because water is a unifying concern statewide, quantifying the ability of healthy soils to retain water across different regions may be a good place to start. While precipitation and temperature affect the potential amount of water available, the actual amount of available water depends on soil type, water holding capacity, and the rate at which water filters through soil (Hatfield 2014). While water holding capacity and infiltration can be improved with management, soil type is inherent to a location, which is why research should be localized. Increasing soil organic matter (SOM) will have a greater impact on available water holding capacity in sandy soils than in silty clay loam and silt loam soils (Libohova et al. 2019). Another focus could be to localize water needs around SGMA Groundwater Sustainability Plan (GSP) for different subbasins. For instance, some Groundwater Sustainability Agencies (GSAs) will be monitoring water use through satellite evapotranspiration (ET) data – therefore, a practical solution could be helping growers to reduce evaporative losses from soil from through mulching and tillage (Jalota and Prihar 1998).

4.4.3 Weed Control

Based on the IPA, "weed management" is also an area for UCCE to prioritize. Considering this was a top management challenge for respondents, as well, there is a lot more work that needs to be done in weed management for agronomic crops. Currently, CE's integrated weed management strategies fall under Integrated Pest Management (IPM), and much of the research on integrated control methods has been done at the plot and field scale, rather than the management scale (Schohr et al., 2020). A bibliometric analysis demonstrated that current work in the field of invasion biology, which includes weed control, consists mostly of research related to "knowing" (developing a purely intellectual understanding), while research aimed at strategically applying or implementing knowledge is poorly represented (Esler et al. 2010). While invasions of a new weed species provide a platform to investigate ecological theories and laws, there is also a direct, practical need to understand possible management interventions (Lawton 1999; Esler et al. 2010). In addition, the scale of emphasis is rarely at the local level and there is a lack of reporting of costs of management, which is an obstacle to making research on weed control methods useful (Esler et al. 2010; Matzek et al. 2015). If costs of control are included, they are typically calculated at the experimental scale, which may not accurately reflect management costs (Esler et al. 2010). Thus, more localized, applied research in weed management is needed.

Contributing to the lack of applied research in weed management is the fact that UCCE has seen a reduction in regional weed control specialists and UC ANR has not hired a weed specialist for agronomic crops since the last specialists' retirement years ago. Because of its' importance to agronomic crops clientele, UC ANR should advocate for new advisors and specialists with a background in weed control. Current trends in commodity industry funding reflects the value the nut crop industries see in UCCE. For instance, four staff research associates who joined UCCE scientists in 2020 were funded by the California Walnut Board, the Almond Board of California, and the California Pistachio Research Board – together, they have provided $425,000 to cover annual salaries, benefits, travel, and equipment for the new UCCE staff (Warnert 2020). In November 2020, the Almond Board of California also hired a Senior Specialist in Pest Management to focus on pest management and weed control (Perez 2020). The lack of funded farm advisors from a centralized agronomy commodity board should be considered in UC ANR's new hires that come from the general fund.

4.4.4 Re-framing Climate Smart Agriculture

Notably, "Greenhouse gas (GHG) emissions reduction" ranked low in priority in the IPA analysis. While there is recognition of the need to reduce GHGs at the state level - as evidenced by the Global Warming Solutions Act (AB 32) and multiple other climate change adaptation efforts - there seems to be a disconnect between agricultural producers, policymakers, and scientists when it comes to climate change. One hypothesis for why climate change is not seen as a pressing problem is how it is framed and communicated to farmers. The threat of global warming is usually broadly targeted, and the detrimental effects are often intangible. The "psychological distance" associated with climate change impacts that occur further away or well into the future require higher levels of cognitive abstraction (Spence 2012). When it is communicated as a global problem that affects everybody, there may be less impetus to act because the problem seems far away and out of the farmer's control. For instance, greenhouse gas mitigation is a problem requiring global cooperation to address, while adapting to challenges faced at the local level appeals to a farmer's self-interest (Sanna et al. 2009; Sanna et al. 2010). Therefore, framing climate change in terms of local consequences may motivate actions because personal risks are psychologically close (Spence 2010).

Farmers face increasing pressure to adopt practices that align with various societal visons of better agriculture, which may overwhelm farm management capacity (Baur 2020). State level policy initiatives often fund UC ANR research and extension activities, thereby setting their direction. These programs tend to focus on things that growers do not always value. For example, there is a strong emphasis on Greenhouse Gas (GHG) emissions reductions in CDFA's Climate Smart Agriculture programs – for the Healthy Soils Program GHG reduction estimations are the main metric of progress.

Yet, GHG reduction was ranked as the lowest priority topic by respondents in our survey. This result highlights the tension between issues that are relevant for growers versus policymakers. Water conservation and storage, weed control, and soil health were all high priority topics for survey respondents, and all of these can be addressed by implementation of healthy soils practices. Practices that reduce GHG emissions might also result in benefits that are more tangible to growers, such as increased fertilizer use efficiency and lower input costs. Therefore, policymakers should think about how these programs can measure and display these tangible benefits rather than only focusing on GHG reduction, to inspire greater adoption. If these programs highlighted reduction in weeds and improved water holding capacity of the soil as benefits of healthy soils practices, the outcomes are the same but the emphasis is landowner-centered. The central tenet of a landowner-centered approach is empathy for the landowner wherein the needs, desires, constraints, and experiences of landowners are placed at the forefront (Brown 2009).

4.4.5 Closing the research-implementation gap through adaptive research-management programs

The fact that cover crops fall into the "possible overkill" quadrant of the IPA matrix suggests the importance of adapting practices to specific regions and cropping systems. Cover crops have been proven to help with the top management challenges of our respondents, such as water conservation and storage, soil health, and weed suppression (Shackelford et al., 2019, Mitchell et al., 2017, Brennan and Smith, 2005). Yet, respondents overall did not rank them as highly important. Perhaps part of this perception of overkill is framing cover cropping to mean a very specific thing– for instance, the only UC research assessing the costs and benefits of winter cover cropping in California assumes a mix of bell beans, winter peas, and common vetch (DeVincentis et al. 2020). The idea behind specific cover crop mixes is important in being able to comparatively quantify their benefits, but the goals of cover cropping can be achieved in other ways. For example, soil erosion can be managed through the maintenance of ground cover on the soil surface, but what that ground cover is can be adapted to what works best in certain climates and cropping systems (O'Neal 2005, Wischmeier 1978). Simply keeping roots in the ground can improve water infiltration, feed soil biology, protect surface water quality by reducing runoff, provide competition for weeds, increase soil organic matter, and enhance carbon sequestration.

If a grower is planting small grains or forage for agronomic crop production, keeping the ground covered during the winter can achieve some of the benefits of winter cover cropping. In this way, agronomic crop producers may already be "cover cropping". There is opportunity here to expand agronomic crop production for those who currently fallow their fields in the winter. Not only will this increase land use efficiency, but it can diversify farm income for those who currently fallow their fields in the winter. If there is only research on a specific way of managing a potentially cost prohibitive mix of cover crop seed, only farmers who find this specific method feasible may adopt this practice. Supporting growers' autonomy in choosing practices that achieve target principles within the context of their farming system may lead to increased conservation outcomes, since autonomy can lead to integration of conservation behaviors into a landowner's sense of self and stewardship ethics (Frey 1997; Deci et al. 1999).

Yet, we cannot solely rely on landowner's stewardship ethics, and must continually question the adaptive capacity of our institutions. Many institutions are designed to pursue narrow or siloed objectives (Baur 2020). Within the current research reward system, in which citation is an indication of impact within academia, there may be a disincentive for scientists to publish applied and local scale research and interdisciplinary research (Esler et al. 2010; Rhoten and Parker 2004). In many conservation fields, scientific research does not always translate into on-the-ground action, which is known as the "knowing-doing gap" (Ester et al. 2010; Bayliss et al. 2012). Yet, local scale implementation research tends to draw less attention from the international scientific community (Esler et al. 2010). Managers need more applied research, but researchers are more rewarded for publishing basic research (Esler et al. 2010; Bayliss et al. 2012). A survey of California managers in 2012 documented that respondents relied little on published research in making management decisions, and for the research that was published, basic research was more than twice as high as that desired by managers', who preferred a greater level of applied and interdisciplinary research (Matzek et al. 2015). In addition, there was a mismatch between researcher and stakeholder priorities for specific topics in basic research and published studies frequently failed tests of relevant as indicated by scale-appropriateness, usability, timeliness, and accessibility (Matzek et al. 2015).

The disconnect between science and management can be characterized as the "research-implementation gap" (Yue et al. 2020). Managers tend to rely heavily on their own observations and those of their colleagues at other management agencies, rather than scientific research (Matzek et al. 2014). Conservation planners also rely heavily on experience-based information, rather than evidence-based information from experiments (Pullin and Knight 2005). Therefore, devoting more resources to obtaining management information from experienced practitioners and land managers can greatly increase understanding of factors that contribute to success and failures (Schohr et al, 2020). Interdisciplinary research that integrates landowners into the scientific process must be employed to solve larger challenges and address clientele concerns. Managers cannot separate their needs from the social and political context in which they work, so research should not either (Matzek et al. 2014). Focusing on problems in a vacuum when weeds, water, and soil management are all interconnected, is misleading, not to mention a less effective use of limited resources.

5. CONCLUSION

As the landscape of California agriculture changes, agronomic crop production faces many challenges. Water resources are under threat from changing climate and cropland expansion, there is a lot of uncertainty around the impacts of the Sustainable Groundwater Management Act (SGMA) on water supply, and California has seen large shifts away from agronomic crop production to perennial production. For these reasons, the UC Cooperative Extension Agronomic Program Team conducted a survey of agronomic crops clientele in summer 2020 with the objectives of documenting clientele needs, informing research and extension priorities, and serving as a foundation for future collaborative needs assessment efforts.

Results of the survey indicated that water-related issues are of great concern to the agronomic crops community and serve as a primary management challenge. Therefore, UC needs to devote more people and resources to practical solutions for water/irrigation management. Weed management is also a primary management challenge and was identified as a priority area for extension in the Importance-Performance Analysis. Currently, there is no statewide weed specialists working in agronomic crops in California, and there are only a few advisors as well.

In developing practical solutions for dealing with management challenges, UCCE must balance short-term growers' interests with long-term education to adapt to future challenges and regulations. Growers tend to want practical, immediate solutions that work at the management scale. In addition, UCCE must work with growers to develop information that integrates practitioner knowledge and is relevant to the realities of agronomic crop production. Based on projected climate change impacts, agricultural systems may have to undergo more transformative changes to remain productive and profitable in the long term (Easterling 2010). Attempts by UCCE and policymakers to develop solutions within the current framework of our production systems is not a long-term answer and primary management challenges will need to be dealt with again and again if we continue with "business as usual" without focusing on long term adaptation.

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