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Climate adaptation needs of Asian farmers in the Central Coast of California

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Small-scale farmers in California are more vulnerable to adverse climate and weather related impacts, yet there is limited research on their climate adaptation needs. In this study, we conducted a needs assessment to address the gap on climate adaptation of small-scale Asian-origin farmers in the Central Coast of California. A majority of these farmers were Chinese speaking. We developed a sampling frame of 118 usable contacts from the county Extension office database to administer the survey in online or in-person formats. We also collected farmers' verbal comments made during the in-person surveying through researcher notes. Survey responses (n = 49) revealed that farmers were already building soil organic matter, altering labor schedules to cope with heat, rotating crops or intercropping, and applying for government assistance. We found a high interest and need for adaptation information on practices like reducing input use, securing access to insurance, and transitioning to renewable energy. However, lack of funding, high input costs, and regulatory compliance remained the most significant barriers to their adaptation efforts. For receiving adaptation information, farmers preferred Extension workshops and face-to-face communication. Some farmers also indicated strong preferences for farm demonstrations, field trips, and relying on their own knowledge and experience gained through farming. Based on the findings, we recommend that Extension focuses on practices that reduce financial burdens. Adaptation information and tools should be made available in Chinese online and offline formats. Extension providers should also facilitate farmer-to-farmer extension events, such as workshops and farm demonstrations. Additionally, Extension providers should consider collaborating with farmers more likely to adopt climate adaptation practices, so that they can later transfer their knowledge to other farmers. Findings from this study will inform the development of climate adaptation programming for small-scale Asian farmers in the region.

KEYWORDS

needs assessment, extension program development, climate change, climate-smart agriculture, decision support tools, Asian farmers, small-scale agriculture, California Central Coast

1 Introduction

Climate change is already impacting California's 59 billion dollar agricultural industry (CDFA, 2020). Farmers are experiencing extreme weather events such as dust storms (Adebiyi et al., 2025), wildfires (Swain et al., 2025; Qiu et al., 2025), extreme heat and high temperatures (Moyers et al., 2024). These stressors have resulted in increased pest damage (Jha et al., 2024;

Matzrafi, 2018), altered growing seasons (Pathak and Stoddard, 2018), and reduced yields (Pathak et al., 2018). Small-scale producers are especially vulnerable to climate change impacts, largely due to factors such as lack of financial resources and political marginalization (Dahlquist-Willard et al., 2015; Dobler-Morales et al., 2021). In California, assessing climate impact on small-scale producer is relevant, since they make up 74% of the state's total farms and provide fresh produce to its local markets (Thao, 2021).

One way researchers and policymakers are approaching these farmers' struggles is through climate-smart agriculture (Ikendi et al., 2024; Lewis and Rudnick, 2019). Climate-smart agriculture strategies look toward increasing agricultural productivity while also building agri-food resiliency and reducing greenhouse gas emissions. California has rolled out climate-smart agriculture incentive programs including Healthy Soils Program and the State Water Efficiency and Enhancement Program (Lewis and Rudnick, 2019). These programs have incentivized farmers to adopt soil management practices and provided funding to install water-efficient irrigation systems, respectively. However, eligibility requirements and influence on local sustainability planning mean these programs do not necessarily address the underlying social, political, and financial challenges small-scale farmers face.

Climate-smart agriculture approaches that insufficiently attend to these points may become an additional barrier for small-scale farmers to adapt to climate change impacts. While there have been several needs assessments conducted for California producers (e.g., Kanter et al., 2021; Ikendi et al., 2024), to the best of our knowledge, there is still a gap in research about the climate adaptation practices, needs, and perceptions of small-scale farmers in California (gross income <$250,000), including those who are socially disadvantaged (Taku-Forchu et al., 2024).

The U. S. Department of Agriculture defines socially disadvantaged farmers "as those belonging to groups that have been subject to racial or ethnic prejudice" (USDA NRCS, 2025). Information about these farmers are crucial to designing customized programs and implementations that truly support the full diversity of California farmers. To address this gap, our needs assessment study focused on an understudied population of small-scale Asian farmers in Santa Clara County, Central Coast of California.

1.1 Asian farmers in Santa Clara County in the Central Coast of California

Asian farmers have had a presence in Santa Clara since the 1800s, even in the face of exclusionary policies and other cases of institutionalized racism (Handley, 1997; Todd, 2022; Tsu, 2013). During Santa Clara's most productive horticultural years (1880–1940), Japanese, Chinese, and Filipino farmers grew strawberries, tended fruit orchards, and operated small-scale vegetable farms. In Post World War II, Japanese and Chinese horticulturalists helmed the region's chrysanthemum flower industry. Chrysanthemums remained an important agricultural commodity in Santa Clara until the 1980s, when competition from Latin America increased (Handley, 1997). This period was also when Asian farmers in the region started transitioning from growing flowers to vegetables. By then, urban development and the Silicon Valley boom had already pushed Asian farmers to the southernmost region of the county: areas in and around Gilroy, San Martin, and Morgan Hill.

Despite shifting away from agriculture as a main industry, farming in Santa Clara remains an important livelihood for Asian-origin farmers. For instance, there are 220 Asian producers and over 100 farms with Asian producers in the county (USDA, National Agricultural Statistics Service, 2022a,b). In 2022, most of these farms had low farm sales (gross income <$100,000) and were under 50 acres (USDA, National Agricultural Statistics Service, 2022b). These farms make Asian vegetables one of the top value vegetable categories in Santa Clara (County of Santa Clara, 2023), providing produce important to California's Asian diaspora (Zou et al., 2022).

This study focuses on a subset of this Asian farmer population with connections to the University of California Cooperative Extension/Agriculture and Natural Resources (UCCE/UCANR) in Santa Clara County. The UCCE in Santa Clara County currently serves 118 Asian farmers by providing various outreach and technical support (UCANR, 2021). Based on the researcher's observations during survey farm visits, most farmers are Cantonese-speaking Chinese who grow diverse Asian vegetables in protected agriculture systems like greenhouses and hoop houses. The existing connections these farmers had with UCCE made them well-equipped to receive the anticipated benefits arising from this study.

Furthermore, these farmers have first-hand experience of extreme weather events from recent years. Starting in 2020 and through most of 2022, Santa Clara County was in severe drought (Valley Water, 2023). These 3 years were also the driest recorded in California history (California Department of Water Resources, 2022). In Gilroy, the serious water shortage caused some farmers' wells to collapse. Immediately following these dry years, a major storm system swept through the region (Yu, 2023; Trent, 2024). This "weather whiplash" (California Department of Water Resources, 2023) from drought to flood oversaturated agricultural soils, submerged fields, and led to farmer crop failure and income loss. Recently, another large storm destroyed entire greenhouse structures and left at least one farm without electricity for weeks (C. Li, personal communication, December 19, 2024). Helping farmers in Santa Clara to better prepare and adapt to extreme weather events is critical to the continued success of their farm operations.

This study aimed to understand the climate adaptation perspectives, practices, and needs of small-scale Asian farmers in Santa Clara County in the Central Coast of California. Understanding the needs is a key step in extension program development and delivery; it helps identify and prioritize areas that will do best for communities over time (Ghimire, 2010; Koundinya, 2010). Needs assessments have informed programming of several programmatic areas like dairy (Martins et al., 2019), agronomy (Kanter et al., 2021), and climate change (Prokopy et al., 2016). The study contributes to research on climate-smart agriculture programs (Figure 1) for California producers.

2 Methods

This study is an expansion of an existing statewide survey assessing farmer climate adaptation needs (Ikendi et al., 2024). The research team provided us with their expert-validated and pilot-tested survey instrument that we adopted and modified for the purpose of this study. The survey contained 27 questions, including multiple-choice, Likert-type, and open-ended questions, that we adopted and modified for the purpose of this study. The survey was first Google translated into Simplified Chinese, after which two members, fluent in Chinese, edited it. We also converted Simplified Chinese into Traditional Chinese text. The Simplified and Traditional Chinese versions were both readable in Mandarin and Cantonese. In the 1960s, China began

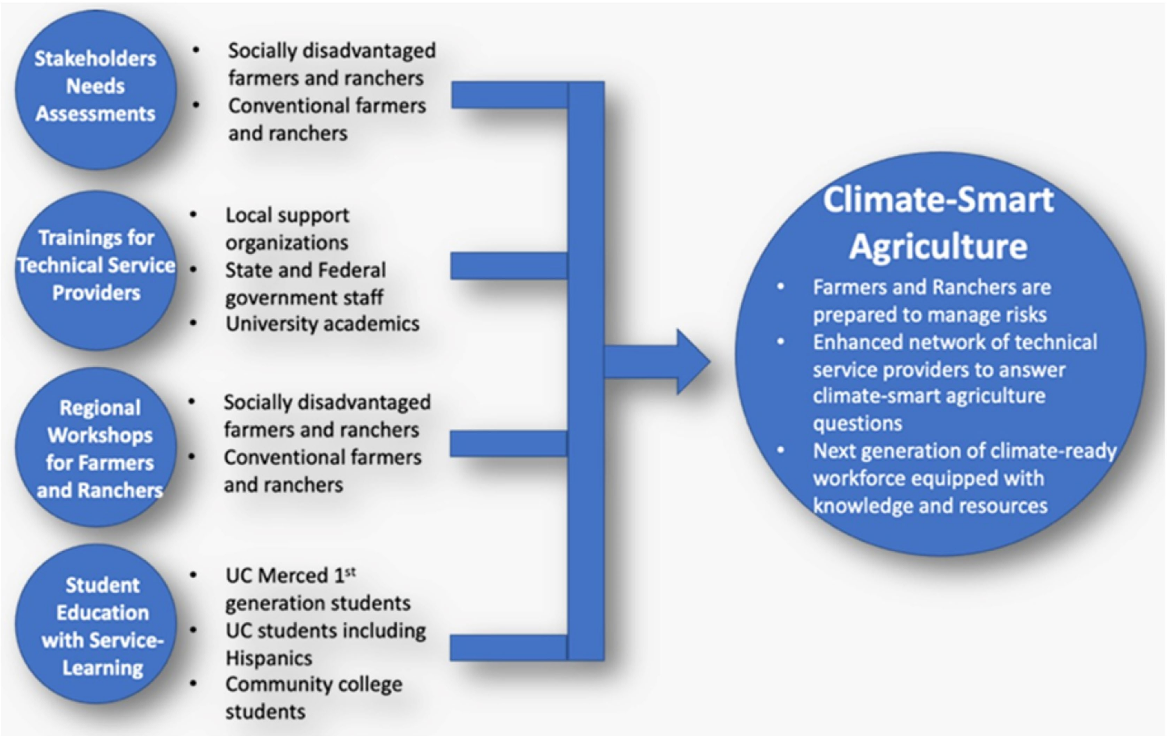

FIGURE 1
Multifaceted pathways to climate-smart agriculture in California. Source: Ikendi et al. (2024, p. 3).

the process of "simplifying" its written characters into what we term as Simplified Chinese today and the form of written Chinese before this is now called Traditional Chinese (Liu and Hsiao, 2012).

2.1 Data collection

We leveraged existing contacts of 118 Asian farmers from the UCCE at Santa Clara County to access the target survey population. The grower's list used includes names of Asian small-scale growers that have attended UCCE workshops and also the workshops offered by the Santa Clara County Division of Agriculture. However, many of these farmers do not own an email account, have little access to/familiarity with using the internet, or have limited literacy skills. To be culturally responsive to these realities (Koundinya et al., 2023), the survey was distributed using two methods, including in-person and virtual or physical collection.

The in-person method involved one member of the research team directly phoning farmers to introduce the survey. These calls were delivered in Mandarin or English, depending on the need. If the farmer expressed verbal consent to participate, an in-person appointment would be made for the farmer and researcher to fill out a printed copy of the survey together in their preferred language. At the beginning of in-person surveying, farmers then provided their written consent on paper. Farmers had an option to fill out the survey independently or have the researcher's help reading out questions and documenting responses. The responses were manually entered into a Qualtrics survey (separate from the virtually administered version) once the researcher collected the finished survey at the end of each farmer visit.

In total, 31 in-person survey responses were collected between November 5th, 2024, and February 25th, 2025, and were all used in the analysis. Additionally, the researcher also asked clarifying and follow-up questions when the survey data were collected and wrote field notes on any additional key information shared by farmers. Although the original study design was quantitative, the field notes collected were triangulated with survey data to provide more context for farmer perspectives, needs, and experiences.

In virtual and physical collections, emails with anonymous survey links were sent out on a case-by-case basis to farmers between November 5th and December 12th, 2024. This method included farmers who expressed preference for an online survey and those who had emails available in the UCCE's file. A total of 36 farmers were emailed, and one to three reminders were sent out to revive the responses (Dillman et al., 2014). Additionally, the survey was also distributed through anonymous links and QR codes in a WeChat group message application, text messages, and an Extension workshop event.

In the online survey, a CAPTCHA question was included in the beginning to filter AI-generated responses (Pinzón et al., 2024). Also, during Extension outreach activities, printed surveys were given to farmers to take home and fill out independently. Once the farmer completed the survey, they had the option to call the researcher to have the survey picked up or to drop the survey off at their UCCE office. We also used Extension events, and three survey appointments were made as a result of these in-person efforts to promote voluntary participation.

After data collection, we deleted fraudulent and bot responses based on the guidance of Pinzón et al. (2024). Of the 30 virtual surveys collected, 18 were determined to be usable after data cleaning and all 31 in-person surveys collected were all used. In total, the survey collected 61 responses, 49 of which were usable. The majority of usable respondents (45 out of 49) were Chinese speaking, and the remaining four were Indian, Vietnamese, and Korean farmers.

2.2 Data analysis

Survey data were exported from Qualtrics to Excel for categorization and then imported into SPSS Version 30 for analysis. We used Cronbach's alpha to determine data reliability on the Likert-type scale responses before robust analyses could be performed. All alpha coefficients were above 0.70. The alpha were: concern about climate impacts $\alpha = 0.928$, interest in adaptation practices $\alpha = 0.888$, need for information $\alpha = 0.945$, and barriers to adaptation $\alpha = 0.870$, indicating a strong consistency (Forero, 2023).

Results are presented in the form of frequency distribution tables. To analyze association between different variables of interest, chi-square tabulations were also conducted at $p \leq 0.05$ significance. For example, to facilitate extension programming, we performed a binary analysis using Chi Square between the survey mode (in-person or virtual, English or Chinese) ran against the preferred methods of Extension (email, extension workshops, group text etc.). The qualitative data from field notes were deductively coded and sorted according to the question categories already present in the survey.

2.3 Potential limitations

At the time of data collection, some farmers on the UCCE contact list were either no longer farming or preparing to retire or did not want to participate in the study. These aspects reduced the potential sample size of 153–118. Additionally, some farmers who used an online survey may have run into a language barrier, specifically, the English-only CAPTCHA question, which was displayed after the consent question, resulting in failure to complete the survey. Four online responses failed to make it past this captcha question. Since the survey was only shared with known farmer contacts, the likelihood of these four responses being bots was low (Pinzón et al., 2024).

Another limitation was the inconsistency in how the field notes were collected during in-person surveying. When the surveying researcher first began conducting in-person surveys, we did not know that the field notes would be used as data in the study. As such, there were variations in detail for the in-person surveying notes. We acknowledge larger sample size of the usable responses were Chinese ($n = 45$) who responded in Simplified and Traditional Chinese versions that were both readable in Mandarin and Cantonese compared to rest of the Asian groups ($n = 04$) that responded in English. All data were analyzed and presented as small-scale Asian farmers. A larger sample size of Asian ethnic sub-groups is recommended for comparison as a future study.

3 Results

3.1 Farmer and farm operation characteristics

3.1.1 Farmer sociodemographic characteristics

The survey population was all Asian-origin farmers in the Central Coast region (95.9% in Santa Clara County). Farmers who responded to gender were 47 and a majority were male (67.3%), and almost half (46.9%) identified as first-generation farmers (Figure 2). The average age was 53.2 years among the 42 farmers who responded, with a minimum of 35 years and a maximum of 75 years. Over half of farmers (57%) had farmed 11 years or more since age 18. Of the 31 farmers surveyed in-person, 22 had little proficiency in English.

Most farmers (71.4%) chose to take the survey in either Simplified or Traditional Chinese. Chi-square tabulations revealed there was a statistically significant ($p = 0.021$) correlation between which survey method respondents chose (online or not) and the language they took the survey in (Chinese or English). A majority of farmers who took the survey in Chinese took the survey in-person (77.1%), while the majority who took the survey in English took the survey online (57.1%).

3.1.2 Land tenure types

Farmers use privately owned land (51.0%) or privately leased land (55.1%), and 8.2% use both tenures for farming. None use *publicly* leased land. Privately *owned* land had an average of 16.4 ± 16.180 acres, a median of 10 acres, and a maximum of 60 acres. Privately *leased* land had an average of 16.8 ± 26.364 acres, a median of seven acres, and a maximum of 110 acres. Two values (100 and 110 acres) skewed the average for private *leased* land, and once excluded, the average became 9.7 ± 7.115 acres.

3.1.3 Crop production and sales profile

The majority of farmers (57.1%, $n = 46$) selected that 76–100% of their household income came from farming. Most grew vegetables (89.8%), and 89.4% of the farmers reported that at least 50% their income came from vegetable crops (Figure 3). Of the farmers ($n = 31$) surveyed in-person, 20 shared information on specific crops they grew, which included bok choy, tong ho (chrysanthemum greens), ong choy (water spinach), yam leaves, Chinese amaranth, and others.

3.2 Climate change perceptions and concerns

3.2.1 Climate change-related impacts on Asian farmers

The great majority (82.6%) of farmers agreed (agree + strongly agree) there is sufficient evidence that climate change is happening, regardless of whether they attribute it to natural or human causes (Figure 4). During in-person surveying, some farmers expanded on these observed impacts, including changes in temperature, precipitation, extreme weather events, pest incidence, and the timing of seasons. One farmer commented that they had to change which crops they grew since precipitation is no longer reliable compared to even 5 years ago. A majority of farmers (68.1%) did not feel confident that they had the knowledge or skills to manage anticipated climate-related impacts on their farms. However, most (91.8%) agreed (agree + strongly agree) they are interested in learning more about the impact of climate change on the agricultural industry.

3.2.2 Asian farmers' concerns about climate change-related impacts

Climate change-related impacts were aligned into three categories: water-related concerns, temperature-related concerns, and

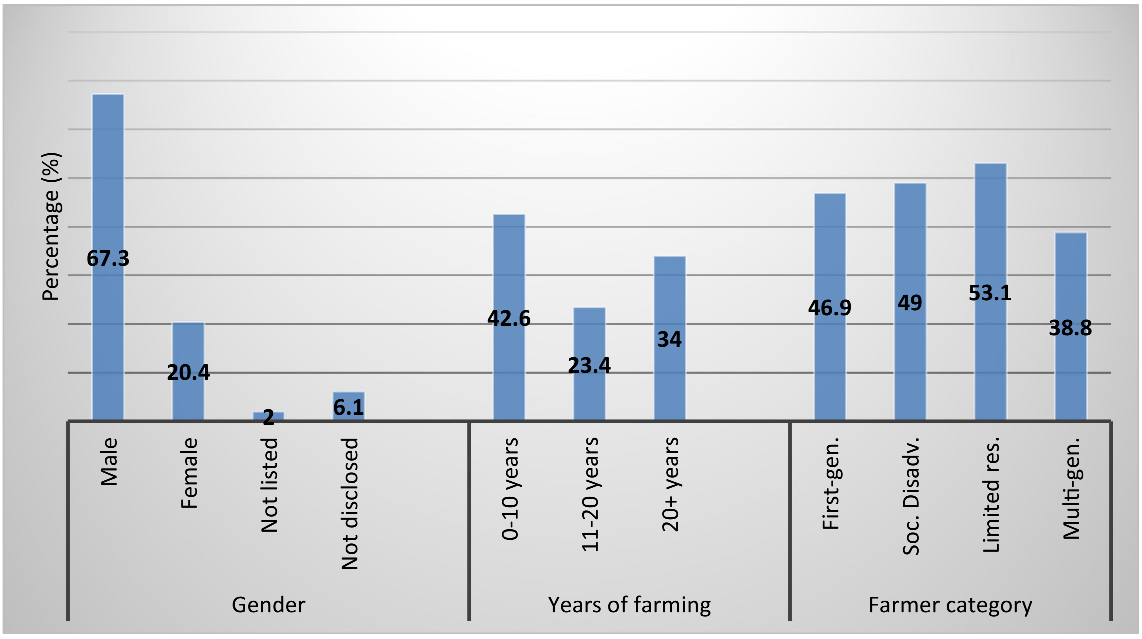

FIGURE 2
Asian farmers' sociodemographic characteristics in the Central Coast of California.

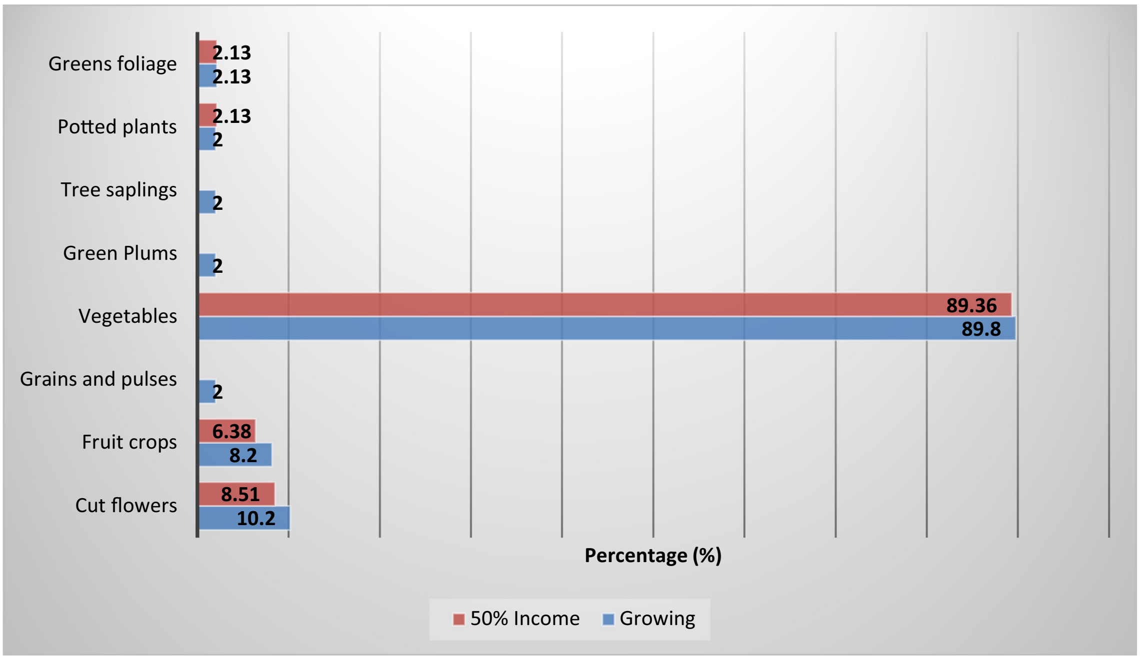

FIGURE 3
Crop production and sales income profiles of Asian farmers in the Central Coast of California.

disaster-related concerns (Table 1). Farmers were more concerned about temperature and disaster-related issues compared to water issues. For temperature-related issues, farmers were also *very concerned*, particularly about increased crop damage due to extreme heat (57.1%) and increased pest and disease pressure (53.1%). During in-person surveying, a second-generation farmer shared their concerns with increased temperatures inside their greenhouses and said that "*crops can get scorched, and the population of insect pests can explode*."

Another farmer who primarily grows in open fields spoke of an increase in aphids and an earlier onset of powdery mildew that impacted yield. For disaster-related concerns, most farmers were *very concerned* about increased *farm* loss (57.1%) and increased *crop* loss due to climate-related disasters (51.0%). Seven farmers during

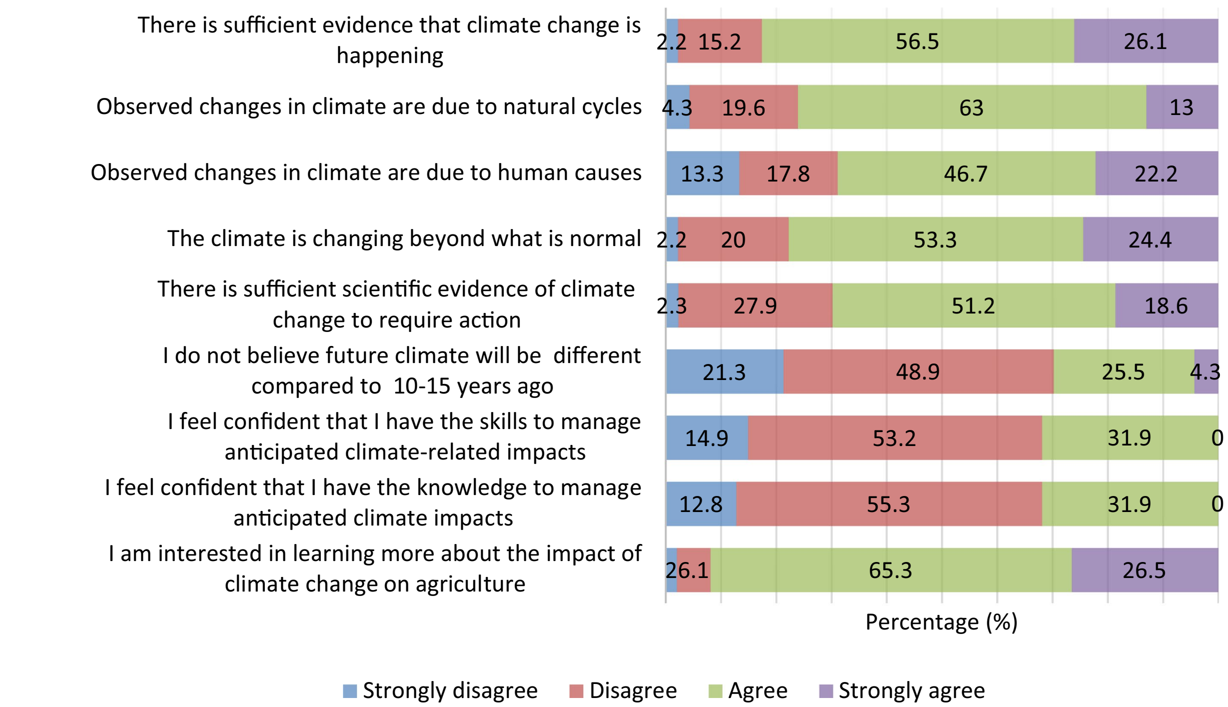

FIGURE 4
Climate change-related impacts and perceptions of Asian-farmers in the Central Coast of California.

in-person surveying expressed concerns about greenhouse damage due to high winds, storms, or soot from wildfire. One open field farmer also shared that when there is fire, soot blocks the sun, causing the crops to not grow.

On water-related issues, farmers were *very concerned* about reduced groundwater availability (39.6%). During in-person surveying, however, three farmers mentioned being *un*concerned about water-related issues, particularly groundwater availability. One farmer's lack of concern came from their belief that increasing development in the area would improve groundwater use efficiency and quantity. A different farmer mentioned being able to rely on groundwater, even during drought times.

3.3 Implementation, interest, and need for information on climate adaptation practices

The top adaptation practices farmers implemented (Table 2) were building soil organic matter (54.5%), altering labor schedules to cope with heat (45.7%), and rotating crops or intercropping (40.9%). Most farmers (89.1%) expressed interest in reducing input use, and 72.7% were interested in securing access to insurance or planting early maturing varieties (68.2%). During in-person surveying, 11 farmers also communicated interest in specific adaptation practices, including adopting solar energy, converting to electric machinery, diversifying production, improving irrigation, and adding an on-farm enterprise. For instance, one farmer said that electricity is very expensive now, which is why they would want to install solar if it could help reduce costs. A different farmer expressed interest in learning more about on-farm enterprises like beekeeping and honey making. Importantly, many farmers also indicated that their interest in these practices hinged on factors of feasibility.

On the other hand, farmers also expressed a lack of interest in certain practices because they believed implementing them would not be possible. For instance, eight farmers described disinterest in reduced tillage or no till since they believed it to be unnecessary. Among these eight, one second-generation farmer explained, *"I'm not interested in [no till] because I need row tilling to abate the weeds… I know people who try to push no till, [saying] it's better for nutrients [and] the health of the soil, but…it does not work for me."* Similarly, a different farmer stressed that not tilling wasn't possible for their kind of farming. A great majority grow vegetables that must be directly seeded into soft, loose soil. Tilling helps to achieve this desired soil condition for seeding their crops.

Farmers also reported *high* information needs for applying for government assistance (44.4%), building soil organic matter (44.4%), changing irrigation practices (26.1%), transitioning to renewable energy for farm use (25.6%), and securing access to insurance (23.3%). One farmer also indicated a need for information and practices that are relevant to their farm characteristics, specifically small-scale Asian vegetable farming. This farmer elaborated that "*a lot of the available resources do not make sense for my small scale farm.*" These comments indicate a need for information on climate adaptation practices applicable to small-scale Asian vegetable operations that may not be available in the general pool of resources shared online and/or in print.

3.4 Extension education and outreach

Farmers selected multiple methods of receiving information, and the majority preferred extension education events (56.3%) and

TABLE 1 The extent of concern about climate change-related impacts on the future of Asian farmers in the Central Coast of California.

Climate-related Impacts	*n*	Extent of concern (%)			
		Not at all	Somewhat	Concerned	Very
Water-related concerns					
Reduced groundwater availability	48	12.5	18.8	29.2	39.6
Increased uncertainty in water availability for irrigation	48	12.5	16.7	35.4	35.4
Reduced water availability for irrigation	48	16.7	18.8	29.2	35.4
Increased crop/water stress	49	12.2	20.4	46.9	20.4
Increased salinization	49	20.4	32.7	26.5	20.4
Temperature-related concerns					
Increased crop damage due to extreme heat	49	2	8.2	32.7	57.1
Increased pest and disease pressure	49	6.1	10.2	30.6	53.1
Increased drought severity	48	12.5	14.6	29.2	43.8
Increased frost damage	48	8.3	10.4	43.8	37.5
Reduced chill accumulations	48	39.6	20.8	29.2	10.4
Disaster-related concerns					
Increased farm losses due to climate-related disasters	49	6.1	8.2	28.6	57.1
Increased crop loss due to climate-related disasters	49	6.1	6.1	36.7	51.0
Increased flooding	48	12.5	12.5	35.4	39.6
Increased wildfire severity	49	38.8	16.3	22.4	22.4
Increased crop damage due to wildfire/smoke	49	38.8	22.4	22.4	16.3

face-to-face (54.2%) communications to receive information on adaptation practices (Figure 5). If climate adaptation and mitigation workshops for farmers were organized, a majority (59.6%) responded "*yes*" they were interested in participating, 31.9% "*maybe,*" and 8.5% "*no.*" Among those who said "no," two farmers elaborated that workshops were not helpful for them. One of them explained that they would not even remember what happened if they attended a workshop. Instead, this farmer preferred farm demonstrations.

We found some statistically significant associations between survey response format and preference for extension methods. Of the farmers who took the survey online, the majority (68.8%) indicated a preference for email and electronic sources of information ($p = 0.033$). However, only 36.4% who took the survey offline (in-person or on paper) indicated the same preference. A great majority (69.7%) who took the survey offline preferred face-to-face communication compared with 18.8% of online respondents indicating the same ($p < 0.001$). During in-person surveying, five farmers also said they lacked familiarity with using the Internet. Over half (54.3%) of Chinese language survey takers indicated a preference for group texting ($p = 0.011$).

3.5 Barriers to climate adaptation

The survey presented 23 barriers, of which farmers expressed access to investment capital or funds (57.8%), high input costs (46.8%), government regulations (38.3%), and access to appropriate insurance (33.3%) as the most *significant barriers* to implementing adaptation practices (Figure 6). During in-person surveying, farmers provided insight into their lived experiences with these barriers. One farmer shared about investment capital that money is a priority and a limiting factor for adopting new changes. Another farmer added that they were very interested in installing solar but did not have the funds to do so.

Some farmers also conveyed general challenges with government regulations. For instance, one farmer reported that the Food Safety Modernization Act (FSMA) policies on reusable boxes were not realistic for them to follow because of the cost. A different farmer also expressed frustrations with FSMA policies, stating they would stop growing altogether if the regulations became too strict. Besides FSMA, two other farmers mentioned that it was challenging to acquire the various permits related to operating their farms. These regulatory barriers were expressed in a more general way rather than a specific barrier to adaptation.

Five farmers elaborated on land tenure. One farmer had a history of constantly switching land for the past 17 years because their landlords would not renew their contracts. This farmer explained they were afraid to implement anything without the security of being able to stay. Another farmer shared how hard it was for them to adopt new practices when they did not own their farmland. In our study, a statistically significant ($p = 0.004$) relationship was found between the status of land ownership and land ownership as a significant barrier. Farmers (47.6%) who *did not* own land selected that land ownership was a *significant barrier* to adaptation.

3.6 Climate adaptation decision support tools (DSTs)

Most farmers (97.9%) answered either "*no*" or "*do not know*" to whether they are currently using decision support tools (DSTs). The

TABLE 2 The top 10 combined climate adaptation practices Asian farmers are interested in, implementing, and have a need for information in the Central Coast of California.

Adaptation practices	Interest (%)				Need for information (%)			
	n	No	Interested	Implem	*n*	No	Some	High
Build soil organic matter	44	6.8	38.6	54.5	45	20.0	35.6	44.4
Apply for government assistance	47	4.3	59.6	36.2	45	8.9	46.7	44.4
Change irrigation practices	46	17.4	63.0	19.6	46	23.9	50.0	26.1
Transition to renewable energy	46	28.3	67.4	4.3	43	25.6	48.8	25.6
Secure access to insurance	44	20.5	72.7	6.8	43	20.9	55.8	23.3
Alter labor schedules to cope with heat	46	10.9	43.5	45.7	43	20.9	58.1	20.9
Reduce input use	46	8.7	89.1	2.2	44	22.7	56.8	20.5
Reduce dependency on fossil fuels	46	34.8	63.0	2.2	43	34.9	46.5	18.6
Increase acreage	46	30.4	56.5	13.0	44	38.6	43.2	18.2
Mulching	46	28.3	43.5	28.3	46	39.1	43.5	17.4
Rotating crops or intercropping	44	25.0	34.1	40.9	44	45.5	38.6	15.9
Transition to perennial plants	44	29.5	38.6	31.8	44	45.5	38.6	15.9
Diversify production	45	26.7	66.7	6.7	44	31.8	52.3	15.9
Transition to annual crops	44	36.4	43.2	20.5	44	50	36.4	13.6
Switch to new crops	44	31.8	63.6	4.5	44	40.9	45.5	13.6
Change market strategy	44	31.8	63.6	4.5	43	34.9	53.5	11.6
Reduce soil disturbance	45	51.1	44.4	4.4	44	43.2	45.5	11.4
Plant early maturing varieties	44	29.5	68.2	2.3	45	24.4	64.4	11.1
Use of drought-tolerant varieties	45	31.1	55.6	13.3	44	36.4	54.5	9.1
Use of cover crops	44	29.5	59.1	11.4	44	40.9	50.0	9.1

only farmer who selected *"yes"* specified *"weather data"* as the DST they use. Despite a majority (65.3%) not knowing whether DSTs would be helpful, 56.5% still indicated interest in using them (Figure 7).

Comments made by farmers during in-person surveying revealed three main themes on DSTs: farmer knowledge, language barrier, and unfamiliarity with online tools. On farmer knowledge, some farmers expressed wanting to rely on *their own experience* rather than external tools. One second-generation farmer said, *"I want to rely on my own experience, my data, I do not want to be like, what should I grow? How much should I grow? Oh [let me consult] my computer,' [but what if] I cannot get access to it? I do not want to rely on technology…to tell me what to do."* Others spoke about language as a barrier to DST adoption. For example, one farmer indicated disinterest in DSTs because they were *all in English*, a language they could not understand. Besides language, five farmers also commented that their *unfamiliarity with the Internet* makes them not interested in online DSTs. One farmer said, *"I do not know how to use the Internet."* Furthermore, another farmer discussed *wanting physical* (as opposed to online) tools that can help in making decisions.

4 Discussion

The discussions provide a thorough synthesis of the results alongside literature on farmers' perceptions, concerns, and impacts on climate change; their information needs; barriers to address; preferred extension methods; and the use of climate adaptation decision support tools.

4.1 Climate change perceptions, impacts, and concerns

Climate change has already caused substantial negative impacts on nature and people, including to our food systems. Global scientific consensus (Intergovernmental Panel on Climate Change, 2023) on this matter is also reflected in how 82.6% of farmers agree that climate change is happening, whether they believe it is from natural or human causes. Our results also suggest that *belief* in climate change is not necessarily a precursor to *interest* in learning more about its impact on agriculture. Six out of the eight farmers who disagreed that climate change is happening stated they were interested in learning more about climate change impacts on the agricultural industry. Similarly, farmers did not have to *believe* in climate change to *implement* adaptation practices. Of the eight farmers who disagreed that climate change is happening, seven are *implementing* at least one of the 34 adaptation practices presented in the survey. These findings align with other findings in California, where farmers implement adaptations regardless of stated belief in climate change (Ikendi et al., 2024; Petersen-Rockney, 2022).

All the top five concerns (*concerned* + *very concerned*) indicated by farmers were temperature or disaster related. This study found a

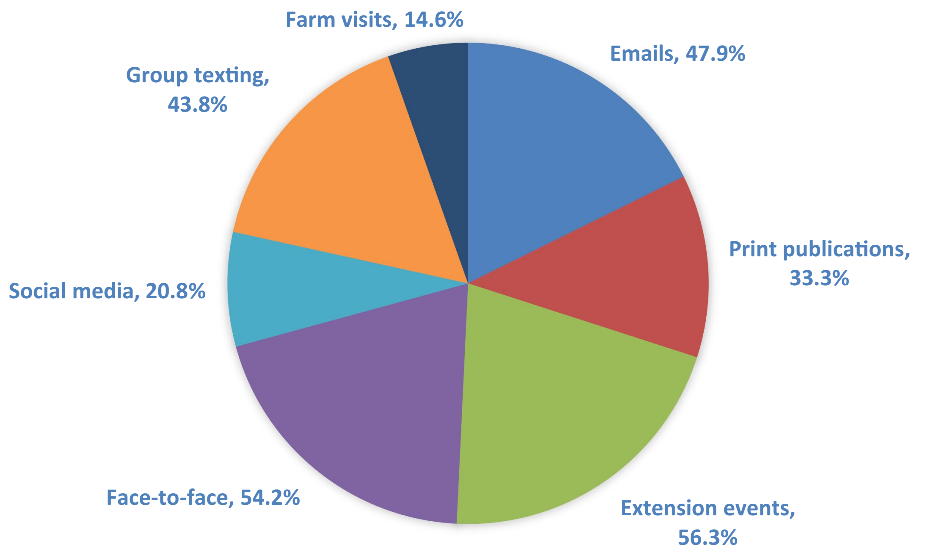

FIGURE 5
Percentage of preferred extension methods by Asian farmers in the Central Coast of California.

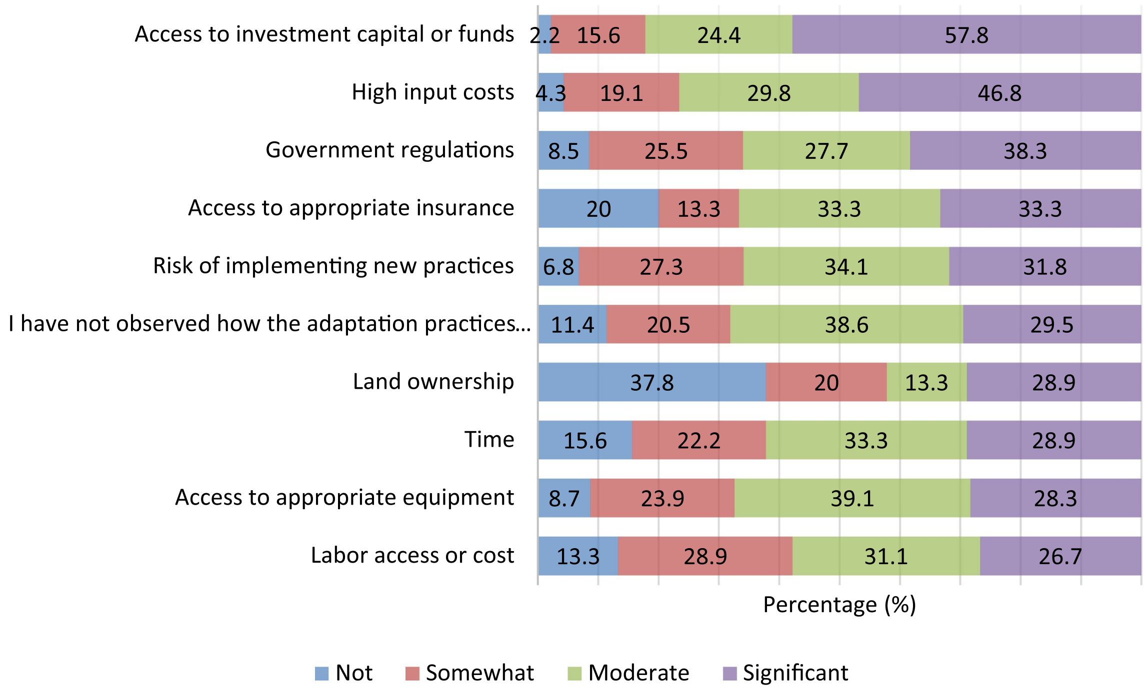

FIGURE 6
Top 10 barriers impeding Asian farmers' climate adaptation efforts in the Central Coast of California.

connection between farmers' responses and California's "weather whiplash" (California Department of Water Resources, 2023). In Santa Clara County, weather whiplash manifested as severe drought in 2022, immediately followed by extreme storms in the winter of 2022–2023 (Valley Water, 2023; NOAA, 2024a, 2024b). This drastic switch from extreme dry weather to wet caused unprecedented flooding and infrastructural damage. During in-person surveying, two farmers also mentioned experiencing flooding on their farms during the 2022–2023 winter season.

The top two concerns farmers had were increased crop damage due to extreme heat (57.1%) and increased farm loss (57.1%). These concerns are also reflected in what farmers are already experiencing. Farmers mentioned during in-person surveying that the leaves of their vegetable crops get *"scorched"* when it becomes too hot. They also spoke about heavy rainstorms damaging their greenhouse structures. In California, studies have shown that extreme heat has negative effects on perennial crops like almonds (Parker et al., 2020). High heat can reduce rates of successful flower pollination decrease fruit size, as

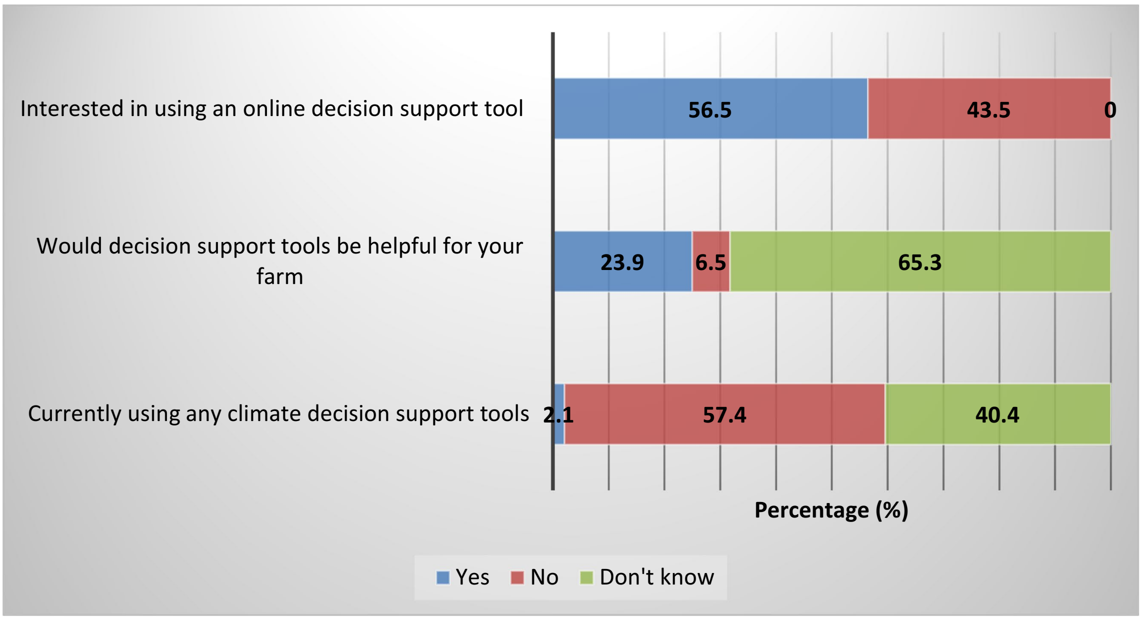

FIGURE 7
Percentage perception on adaptation decision support tools by Asian farmers in the Central Coast of California.

reported among Hmong farmers in the Central Valley (Taku-Forchu et al., 2024). Additionally, farmers' lived experiences with greenhouse damage from storm events present an opportunity to study and address infrastructure losses from climate-related disasters, particularly for greenhouse farms.

Some farmers surveyed offline worried about wildfire. Three farmers mentioned their experiences with wildfire soot negatively affecting their farms. Two other farmers related their concern to the series of destructive wildfires that broke out in and around Los Angeles in January 2025 (Swain et al., 2025; Qiu et al., 2025). The other farmer, who took the survey on paper, wrote about a similar *"Santa Ana wind condition,"* that contributed to the 2025 fires around Los Angeles becoming some of California's most devastating on record. As this farmer noted, parts of California's Central Coast region experience a similar orographic wind phenomenon, called the Diablo winds (Arthur et al., 2025; Hohn et al., 2025). A statistically significant ($p = 0.033$) association was found between wildfire concern and the 2025 Los Angeles fires. Before the fires, only 14.7% of survey respondents selected "*very concerned*" for increased wildfire severity. After the fires began, that percentage increased to 45.5%. In addition to farm impacts from soot and ash, wildfire also adversely affects farm worker health, key farm activities, and crop marketability and quality (Pinzón et al., 2025).

Farmers (39.6%) were less "*very concerned*" about reduced groundwater availability. These responses can be contextualized by comments farmers made, where some expressed their belief that groundwater will remain available. The relatively lower *concern* about water-related issues contrasts with the 55.6% of farmers being *interested* in reducing reliance on groundwater. Yet very few farmers (8.9%) expressed a *high need* for more information on reducing reliance on groundwater. To explain these findings, we can refer to how six farmers asserted that their operations *must* depend on groundwater. Alternatives to groundwater were viewed as infeasible, hence their indicated lack of need for more information. Compared to California's Central Valley farmers who struggle with water availability, impacts from severe drought, and land subsidence (Faunt et al., 2024), most farmers (95.9%) in this study farm in Santa Clara County, a municipality that has successfully recovered its groundwater to near predevelopment levels (Hanson, 2015). Farmers' lower *concern* for water-related issues may also be explained by their experiences with Santa Clara's comparatively healthier groundwater levels.

4.2 Need for information on climate adaptation practices

Farmers expressed a *high need* for information on climate adaptation practices they were already *implementing*. These included building soil organic matter (applying compost or manure), applying for government assistance, and changing irrigation practices. Farmers also had a *high need* for information on practices that they were *interested* in, such as transitioning to renewable energy for farm use and securing access to insurance. Of the farmers who indicated a *high need* for information on building soil organic matter, 52.6% were already implementing these practices. Currently, many farmers in the region are recipients of the Healthy Soils Program (HSP) grant, a government incentive grant that funds implementation of various on-farm soil health practices (CDFA, 2024a). Through receiving this grant, several surveyed farmers have been implementing compost applications on their farms.

One farmer described how mixing compost with their soil made it looser for better seeding. Besides improving texture, applying compost helps to improve soil health (Wright et al., 2022) and can help sequester carbon (Wong et al., 2023). While some farmers are already applying compost, providing more information on effective compost application methods can further reduce their need for chemical fertilizers. Reducing excessive fertilizer application is especially important for keeping nitrate levels of on-farm domestic wells below Maximum Containment Levels (MCL), as enforced by the Water Board (California Water Board, 2025).

On government assistance, there are several federal, state, and county government-funded programs relating to climate adaptation that small-scale farmers can apply for Lewis and Rudnick (2019). These include the HSP (CDFA, 2024a), State Water Efficiency and Enhancement Program (SWEEP) (CDFA, 2024b), Agricultural Resilience Incentive (ARI) (County of Santa Clara, 2025), and the California Underserved and Small Producers (CUSP) grant, a program providing small-scale farmers with financial relief for drought and extreme weather related needs (CFDA, 2025). Each of these grant programs have their application processes that can be challenging for farmers to navigate, especially in regard to time, technical familiarity, and language accessibility.

The UCCE staff in California's Central Coast region are among the technical assistance providers (TAP) that address these challenges by helping farmers apply for these grants. Despite this support, 63.8% of farmers did not indicate that they were already applying for government assistance. One probable reason for this is accessibility, both in terms of language and submission format. The majority of farmers took the survey in Chinese (71.4%) or offline (67.3%), and at least 21 of these farmers have limited English language proficiency.

In contrast, the application portals for HSP, SWEEP, ARI, and CUSP are all online and in English. Some program websites like CUSP have Google Translate features; however, such features still leave out farmers with limited online familiarity. To ensure information needs on government assistance for adaptation are met, information should be widely accessible through both print and digital means and in the preferred languages of farmers. Communication in multiple languages is an aspect of creating integrated biocultural diversity in agrifood systems (Ikendi, 2023; Maffi, 2018).

On changing irrigation practices, 44.4% who indicated a *high need* for information are also *implementing* it. This aspect is connected to how several farmers in our study have been awarded SWEEP funding to upgrade their irrigation systems (CDFA, 2024b). Irrigation system improvements under SWEEP include retrofitting booster pumps and installing more efficient sprinkler systems. Additionally, more information on effective irrigation practices can lead to water and energy savings and reduce nutrient leaching (Ayars et al., 2024; Jha et al., 2022). Existing resources on improving irrigation practices include CropManage, an online decision support tool (DST) with proven effectiveness at reducing nutrient and water application needs (Cahn et al., 2023). However, information on irrigation practices should be made available in multiple languages and for crops grown by Asian farmers.

A quarter of farmers (25.6%) also expressed a *high need* for information on transitioning to renewable energy, while only 4.3% of them are implementing this practice. In 2018, California passed Senate Bill 100 (SB 100), which requires 100% of California's energy by 2045 to be renewable or come from zero-carbon sources (California Air Resources Board, 2021; California Energy Commission, 2022). Similarly, there is growing attention on systems like agrivoltaics that combine agricultural and renewable energy production (Cox, 2025; Cuppari et al., 2024; Temiz and Dincer, 2024). Implementing solar energy on farms is one strategy for working toward the goals of SB 100. Farmers' interest and need for information on renewable energy also come from financial motivations. Several farmers during in-person surveying described how expensive energy bills have become and also verbalized interest in installing solar to cut energy costs.

All farmers in our study fall within region four of The Pacific Gas & Electric Company (PG&E) service territory (PG&E, 2024), and in 2020, average small agricultural PG&E energy rates increased by 32.9% (PG&E, 2025). Installing solar arrays is one way to reduce energy bills, although the upfront costs of installing solar remain a challenge for California farmers (Cuppari et al., 2024). Government programs like SWEEP (CDFA, 2024b) and the Rural Energy for America Program (Planetary Care Grant Agency, 2023) can help address these initial investments needed for installing solar on farms. Extension academics should help farmers leverage existing financial resources to transition to renewable energy.

Almost a quarter (23.3%) of farmers reported a *high need* for information on securing access to insurance. With climate change, farm revenues may become increasingly unstable. Securing appropriate farm insurance is one strategy to mitigate the financial challenges associated with instability. According to the USDA, there are currently no individual crop insurance programs for Asian vegetables (USDA Risk Management Agency, 2024a), which fall under the definition of specialty crops (USDA Agricultural Marketing Service, 2025). Despite this, there are crop insurance providers that offer Whole-Farm Revenue Protection (WFRP) and Micro Farm insurance plans (USDA Risk Management Agency, 2024b). These insurance plans are revenue-based (as opposed to crop-based) and are especially suitable for diversified and specialty crop farmers, such as those in our study. Many farmers during the in-person surveying communicated their lack of knowledge about crop or farm insurance options applicable to them. This scenario presents an opportunity for Extension educators to bridge this information gap and support farmers in securing access to appropriate insurance.

Farmers' information needs and adaptation interest reveal how incentives are a major motivator for farmers to adopt adaptation practices. As described above, successful incentives include having the cost for implementation covered (e.g., composting through HSP), improved farm infrastructure (e.g., irrigation upgrades through SWEEP), potential energy bill reductions (reflected by interest in solar), and increased financial security (farm insurance). Consequently, programs aimed at increasing farmer adoption of climate smart agriculture should continue to emphasize and invest in incentives for farmers.

4.3 Barriers to climate adaptation to address

The top two *significant* barriers reported were access to investment capital or funds (57.8%) and high input costs (46.8%). These barriers are linked to how applying for government assistance (44.4%) and reducing input use (20.5%) are practices that farmers indicated a *high* interest in, since both practices would reduce financial barriers. Comments made by farmers during in-person surveying also indicate money as a major barrier to adaptation. Currently, state government grants such as HSP (CDFA, 2024a) and SWEEP (CDFA, 2024b), and Santa Clara's ARI (County of Santa Clara, 2025) grant help financially support the implementation of adaptation practices for producers.

Many of the study participants have also benefited from these programs. Beyond grant funding, a reduction in input needs would further help address the financial challenges farmers encounter.

Farmers verbally described financial burdens associated with maintaining farming operations: costs of electricity, infrastructure repairs after storms or wildfires, labor, and equipment. These pre-existing burdens provide financial context for why many surveyed farmers were so hesitant to consider adopting new practices. One farmer stated that mulching was too expensive, and another explained their disinterest in windbreaks because they were "*expensive and require time to build*." If farmers' basic operating costs are reduced, farmers may be better financially positioned to consider and adopt climate adaptation practices.

Government regulations as a *significant* barrier (38.3%) to climate adaptation is also linked to the financial challenges farmers reported. In a study on producer perspectives from California's Imperial Valley, farmers spoke of financial burdens directly tied to government regulations, including labor and food safety regulations (Quandt, 2023). Results from our study parallel these findings. On cost and labor, one farmer shared how each box of vegetables is only around 10 dollars, yet labor costs can range from $10,000 to $12,000 in the summer months. With labor costs so high, California farmers struggle to compete with lower labor costs and overall produce prices in Mexico (Huang et al., 2022). These labor costs are directly related to policy. As of January 1, 2025, the state minimum wage is $16.50 (State of California Department of Industrial Relations, 2025), and farmers also have to comply with overtime pay policies outlined by California Assembly Bill 1,066 (Quandt, 2023).

Government regulations on food safety also present financial challenges to farmers. Under the Food Safety and Modernization Act (FSMA), policy-covered producers must follow specific requirements related to food-contact surfaces (United States Food and Drug Administration, 2024). Most of the surveyed farmers harvest vegetables into reusable cardboard boxes. For these farmers' circumstances, FSMA dictates that they must line their reused cardboard boxes with new paper or plastic for each harvest. Purchasing approved box liners becomes yet another operating cost that farmers may not be able to financially shoulder.

Land ownership was also a *significant* barrier to climate adaptation for 28.9% of farmers, particularly for those who did not already own land. Tenant farmers described land ownership as a challenge to adopting practices like windbreaks and implementing solar energy. Planting wind breaks or installing solar panels are both practices with costly investments that farmers may not wish to make with uncertain land tenureship. One study estimates that it would take 18 years before a residential solar project in California can recover its initial costs (He et al., 2024). Tenant farmers' hesitancy to adopt such practices aligns with existing findings; for instance, Murken and Gornott (2022) identified stable land tenureship as a requirement for adaptation practices with longer return-to-investment periods.

4.4 Preferred extension methods to receive information

The top preferred Extension methods selected were Extension education events, face-to-face communication, email, electronic sources, and group texting. Farmers who took the survey online were more likely to prefer email and electronic sources of extension information, while farmers who took the survey offline (in-person or on paper) were more likely to prefer face-to-face communication. To reach farmers with varying degrees of Internet and electronic device familiarity, Extension providers should provide adaptation resources in both electronic and print formats. These resources should also be made available in Chinese and other preferred languages of farmers.

Currently, local Extension educators organize various Extension education events throughout the year, and most of the farmers in our study already know about or have participated in some of these events. Extension event themes cover: disease, insect pest, and weed management, food safety, nutrient management, soil health, irrigation, various grant funding opportunities, cover cropping, and more (UCANR, 2025). A majority of farmers also indicated that they would be interested in participating in adaptation and mitigation workshops if they were organized. Despite this interest, some farmers mentioned that workshops would not be helpful for them. One farmer elaborated that *"seeing is believing,"* which is why farm demonstrations would be better for educating on adaptation practices. This aspect aligns with how 29.5% of farmers indicated that they "*have not observed how the adaptation practices work on another farm*", and this was a *significant* barrier to adopting climate adaptation practices. These findings reveal an opportunity for organizing farm demonstrations of adaptation practices.

Studies on facilitated farmer groups, including demonstration farms, have shown that this method results positively in promoting transformative learning in farmers (Cooreman et al., 2021; Nettle et al., 2022). Other studies on agroecological scaling have emphasized farmer-to-farmer knowledge sharing as an effective mechanism through which farmers are more likely to adopt new practices (Bernal et al., 2023). There is great potential for Extension providers to promote this kind of farmer-to-farmer extension (F2FE) (Sah et al., 2021).

High preference for group texting is related to how many farmers are currently receiving extension information through a Cooperative Extension group chat. The local Extension office has a WeChat group chat for staff to provide important updates and extension information in Chinese to farmers in the region. WeChat is a popular Chinese language messaging and calling application that many farmers in our study use (Thomala, 2025). During their survey, one Chinese-speaking farmer specifically mentioned that the Cooperative Extension WeChat group chat was very informative and helpful. Using a culturally appropriate messaging application like WeChat may also be why Chinese language survey takers were much more likely to prefer group texting compared to English language survey takers.

In other countries, group messaging through applications popular with locals, such as WhatsApp, has already been used by agricultural extension providers to share outreach information (Chowdary et al., 2024; Farida et al., 2022). Using WeChat to provide information on climate adaptation practices is a similarly culturally appropriate method to address farmer preferences for group texting.

4.5 Use of climate decision support tools (DSTs)

Most surveyed farmers either expressed that they are not using DSTs (67.4%) or that they *do not know* what they are (40.4%). Along with a majority (65.3%) of farmers not knowing if DSTs would be helpful for them, these responses suggest a general lack of knowledge about DSTs. These results align with literature on how DSTs are underutilized by farmers (Ikendi et al., 2024; Lu et al., 2021; Taku-Forchu et al., 2024). Accessibility considerations in terms of language, Internet familiarity, and crop type (Asian crops) also mean that existing California DSTs––for instance, CalAgroClimate (Pathak et al., 2018); GDD Calculator (Narimani, 2023); and CropManage (Youtsey, 2025)––do not support this specific farmer population (Chinese). To improve DSTs for this population, they must also be made available in Chinese, become relevant to the Asian crop types farmers have, and come in offline options that are simple for farmers to use. Furthermore, decision support resources provided by Extension providers must be developed with strong farmer input and participation to best meet farmers' needs (Iakovidis et al., 2025; Ikendi et al., 2025).

Notably, some farmers emphasized wanting to rely on lived experiences to make decisions rather than on an external tool. One farmer explained that external tools could malfunction, and that they favored their own or neighbors' experiences. Some research in California has similarly highlighted how farmers prefer "networks of trusted people, communities of practice, and reports" over external DSTs that are part of a more top-down model of Extension outreach (Ikendi et al., 2025). Relatedly, there is a need to incorporate local knowledge into extension activities to make them more effective in actual farmer adoption (Hainzer et al., 2022).

Farmer-to-farmer extension (F2FE) is a strong model for engaging local knowledge and communities (Sah et al., 2021). Bernal et al. (2023) also show how organizing F2FE workshops is more effective than conventional methods of disseminating agricultural practices. Considering farmers' comments and existing research, Extension providers may find more success in seeking collaboration with individual farmers more likely to adopt climate adaptation practices. Once these farmers have successfully adopted practices and developed their knowledge on implementation, Extension providers can organize F2FE events. This approach emphasizes farmer input and horizontal knowledge sharing rather than pushing for DSTs that may be less appropriate for this particular farm population.

5 Conclusion

Small-scale Asian farmers in the California Central Coast in this study varied in experiences and perceptions about climate change on their farms. Despite these variations, 91.8% are interested in learning more about the impact of climate change on the agricultural industry. Farmers were most concerned about increased crop damage due to extreme heat and increased farm losses due to climate-related disasters, which was connected to the region's "weather whiplash" of severe drought to intense rainstorms in 2022 and 2023. In contrast, farmers expressed less concern about reduced groundwater availability, likely due to the region's healthier groundwater levels. The most significant barriers to climate adaptation that farmers encountered were linked to financial constraints. These included access to investment capital or funds, inputs, and government regulations compliance.

Land ownership was also a barrier to adopting practices with longer return-to-investment periods. There was an overlap between practices farmers are currently implementing and those they expressed interest in, such as building soil organic matter, applying for government assistance, and changing irrigation practices. Many farmers leveraged existing government assistance and UC Cooperative Extension resources to implement these practices. Extension educators should lean into these resources when seeking to address the high information needs that farmers have for practices with low implementation, such as transitioning to renewable energy and securing access to insurance. Furthermore, relevant government staff must provide accurate and timely services related to climate adaptation, such as knowing to add less common Asian crop varieties to farm insurance systems.

Farmers' preferences for extension methods and DSTs were associated with Internet familiarity, existing UC Cooperative Extension methods, and English proficiency. To address the specific needs of this farmer population, extension information and DSTs should be made available in online and offline options, in the preferred languages of farmers like Chinese, and using culturally appropriate social media platforms like WeChat. Farmers also noted preferences for farm demonstrations and field trips that would make them more likely to adopt practices after witnessing them. Relatedly, other farmers expressed a strong desire to rely on their knowledge and experience. This aspect presents an opportunity for Extension providers to facilitate farmer-to-farmer extension events like workshops and farm demonstrations on sharing climate adaptation knowledge. This approach emphasizes horizontal knowledge sharing that may be more appropriate for this particular farm population. Findings from this study will inform the development of climate adaptation extension programming for small-scale Asian farmers in the California Central Coast.

6 Recommendations for extension practices

- Prioritize extension support on practice and strategies that reduce input costs for farmers and their farm operations. These include financial opportunities like grants to allow farmers to adopt practices they have expressed high interest in: building soil organic matter, changing irrigation practices, and transitioning to renewable energy.
- Develop and provide climate adaptation extension education and tools in both online and offline formats to reach farmers across varying degrees of Internet familiarity. Make climate adaptation information available in the languages farmers prefer.
- Collaborate with individual farmers who are more likely to become initial adopters of climate adaptation practices. Then, organize farmer-to-farmers extension events for initial adopters to share their successes and experiences with other farmers. This approach will in turn build more social capital and trust through bonding and sharing experiences.
- Provide extension education through workshops and face-to-face events, especially farm demonstrations and field trips that allow farmers to observe how adaptation practices work on another

farm. This approach can motivate farmers who are hesitant to adopt some practices because they have not seen other farmers successfully using them.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of California Davis under Institutional Review Board Number 1841798-2. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LP: Data curation, Visualization, Project administration, Formal analysis, Writing – original draft, Validation, Methodology, Investigation, Software, Writing – review & editing. SI: Validation, Project administration, Methodology, Writing – review & editing, Investigation, Data curation, Writing – original draft, Formal analysis, Visualization, Software. VK: Writing – original draft, Investigation, Resources, Visualization, Software, Project administration, Data curation, Funding acquisition, Conceptualization, Validation, Methodology, Writing – review & editing, Formal analysis, Supervision. AG: Resources, Funding acquisition, Project administration, Conceptualization, Validation, Methodology, Writing – review & editing, Supervision. TP: Resources, Project administration, Conceptualization, Validation, Methodology, Writing – review & editing, Supervision, Software.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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