FREP Final report

A. Project Information:

Report type: Final report
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Project title: Promoting the adoption of CropManage to optimize nitrogen and irrigation use through technical assistance with data loggers and cellular modems for Spanish speaking growers in Santa Cruz and Monterey Counties

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B. Abstract: Irrigation and nitrogen management is a critical, intertwined, and challenging component of specialty berry and vegetable crop production on the California central coast. Mismanagement can result in either excessive or insufficient supply of water and nitrogen to crops. Under application can negatively impact crop yield and crop quality, while over application can also damage crop quality, cause unnecessary expenses, and negatively affect environmental and public health. The goal of this project was to facilitate the understanding and adoption of management and decision-support tools to improve irrigation scheduling and nitrogen management among Spanish-speaking berry and vegetable producers. The Resource Conservation District of Santa Cruz County (RCDSCC) worked with 20 Spanish speaking growers over three years (2020-2022) to promote and facilitate adoption of *CropManage (CM)*, a public on-line tool developed by UCANR to support weather-based irrigation scheduling and nitrogen management. Using commercially available flowmeters, data loggers and modems, RCDSCC staff assisted growers to monitor irrigation water use, measure changes in soil moisture and soil nitrogen levels, and keep track of concurrent weather-based crop demand (estimated with *evapotranspiration* data from local weather stations). This information was entered in *CropManage* to generate management recommendations, keep records of applied water and nitrogen, and compare applied vs. recommended amounts. Participating growers received individual assistance, training, and periodic feedback during the growing season to assess and adjust their irrigation and nitrogen fertilizer scheduling to minimize over or under application. The project's education, outreach and direct technical assistance activities serving individual growers and groups in the field helped to remove some of the existing barriers for adoption of smart and automated tools to inform and improve irrigation and nitrogen management.

C. Introduction:

Groundwater and nitrogen management are two aspects of agricultural production being increasingly regulated in California to protect environmental and public health, as well as climate resilience. Inadequate management of these resources can result in either excessive or insufficient supply of water and nitrogen to crops. Under application can negatively impact crop yield and crop quality, while over application can also damage crop quality, cause unnecessary expenses, overdraft limited groundwater supply, and negatively affect environmental and public health through nitrate leaching and runoff. Over-pumping and overuse of groundwater resources is a serious issue in critically over drafted basins like the Pajaro and Salinas River watersheds. From the grower's perspective, water is relatively cheap compared to other inputs, particularly in high-value crops, so when in doubt, it is common to over-irrigate, as a "cheap insurance" practice. On the other hand, water fees and pumping costs can still be substantial and may potentially increase under SGMA. Regarding nitrogen, the State Water Board irrigated lands program for the central coast region 3 (Ag Order 4.0) requires stringent management and reporting to prevent nitrate leaching from farms. Therefore, growers are likely to adopt a system that gives sound recommendations on water and nitrogen application if they can trust it will not reduce crop yield or product quality. *CropManage* is an online decision-support tool developed by the UC Cooperative Extension (https://cropmanage.ucanr.edu/) that assists growers with water and nitrogen management and record keeping (Cahn et al 2011 and 2015). The software has built-in crop water and nitrogen uptake models for various specialty crops (based on years of local research), and it uses customer-defined data inputs including evapotranspiration (ET) data from local weather stations (CIMIS), ranch settings, soil nitrogen tests and water use (flowmeter data), to generate recommendations based on crop demand at any given time. The adoption of CropManage has great potential for improving water and nitrogen application efficiency, particularly in vegetable and berry production, by reducing over-irrigation and thus leaching of nitrogen to the groundwater and by producing nitrogen application recommendations based on soil sampling. While the software allows for manual data entry, the most efficient and practical way to optimize its value for irrigation water use tracking and recommendations is using flowmeters with telemetry (dataloggers and cellular communication) to automate data input. Technical assistance providers from UCANR, RCDs, NRCS and private sector can help growers by installing, managing, and troubleshooting equipment for data collection to be used in CropManage. The system was originally designed to work with research-grade Campbell Scientific data loggers and modems, which poses a barrier for broader grower adoption (independently), as the equipment can be expensive, and it requires a certain level of computer literacy and technical skills. Lowering the cost, simplifying the technical requirements, and providing 1:1 technical assistance to access these tools is important, but there are other barriers to the adoption of CropManage that still need to be addressed. Fostering trust in new management ideas/tools and willingness to revise persistent cultural practices is a big barrier. During the growing season growers are not always willing or able to physically meet to discuss the irrigation data collected by the data loggers and the recommendations obtained in CropManage. Also, depending on the size and internal decision-making process of the operation, it is crucial to identify and work with the right players (grower, ranch managers, irrigators).

D. Objectives:

1. Increase understanding and trust in weather-based irrigation scheduling decision support tools among Spanish-speaking growers and irrigators.
2. Increase adoption of CropManage and implementation of recommendations among Spanish-speaking growers and irrigators.
3. Assess effectiveness and impact of CropManage adoption among participating growers and irrigators.

E. Methods:

Objective 1. Increase understanding and trust in weather-based irrigation scheduling decision support tools among Spanish-speaking growers and irrigators.

Tasks:

1. Identify and enroll participating growers and irrigators that would receive technical assistance and one-on-one training on weather-based irrigation scheduling.
2. Assess baseline practices and decision-making tools and process regarding irrigation scheduling among participating growers and irrigators.
3. Provide one-on-one training and practical demonstration of weather-based irrigation scheduling tools and concepts.

Summary: Participant outreach and enrollment started in late 2020 and continued during years 2021 and 2022. Direct technical assistance, field work and collaboration with 20 growers took place during two entire irrigation seasons (March to October) in 2021 and 2022. Upon enrollment, RCD staff completed an informal assessment of baseline practices and decision-making tools and process regarding irrigation scheduling and nutrient management through conversation and unstructured interviews with all participating growers. Most growers relied on direct observations of plant vigor and soil moisture, and their practical experience to inform their irrigation scheduling. Only one of the twenty participating growers had used CropManage before. RCD staff worked one-on-one with ranch managers and growers to discuss irrigation scheduling decision-making tools and concepts and conducted one-on-one visits with irrigators to discuss the data of irrigation applied collected by the flowmeter in comparison with the irrigation recommended by CropManage. These services were offered to participating growers during two consecutive irrigation seasons. 11 of the 20 participating growers enrolled in year 1 and re-enrolled along with 9 new growers in year 2. All 20 growers have now re-enrolled and will continue to participate in this program with new grant funding awarded to the RCD. Education and outreach were provided in Spanish and English, as needed. Some of the barriers to the adoption of CropManage were overcome by loaning data loggers to participating growers and allowing them to test and benefit from the recommendations without making a large initial investment in equipment.

Objective 2. Increase adoption and implementation of CropManage recommendations among Spanish-speaking growers and irrigators.

Tasks:

1. Work with project partners (Pajaro Valley Water Management Agency, UCANR and private industry) to identify interested growers and select monitoring fields.
2. Install flowmeters and data loggers in the field in collaboration with farm staff.
3. Follow-up visits to report and explain recommendations from CropManage and provide maintenance to flowmeters and data loggers.

Summary: RCD staff installed flowmeters and telemetry stations (Figure 1) at participating fields in February/March for berry crops, and at planting dates (generally between April and August) for vegetable crops. For each participating operation a new CropManage account was created, and RCD staff assisted new users with setting up the ranches and plantings that would be actively monitored and guided using CropManage (Figures 2 and 3). Participating growers received periodic reports generated from monitoring data and crop uptake models in CM, consisting of a simple graph to compare their cumulative water use against CM's cumulative recommended amount (Figure 4). Along with the applied vs. recommended graph, growers received a table showing the total inches applied, duration of irrigations applied and application rate variability during the previous weeks (Figure 5a) and this information was interpreted and discussed to guide potential adjustments. Any concerns or hesitations from the growers/irrigators about following CropManage recommendations were also discussed and addressed. Receiving frequent feedback during the growing season enabled growers to assess and adjust their irrigation scheduling to minimize over or under irrigation (Figure 5b). Participating growers also received individual assistance and training to use the soil nitrate quick test and CM software to help inform their decisions related to nitrogen management throughout the growing season (Figure 6). All participating growers had access to recommendations and recorded irrigation and fertilizer application events in their CropManage accounts (Figure 7). Growers were invited to attend annual CropManage trainings organized by UCANR and RCD through the PV Water conservation program. RCD staff conducted daily monitoring and quality control of the automated data collection system from all stations deployed in the field into a server that regularly fed data to CropManage. Whenever an issue was detected at any of the stations, RCD staff promptly went to the field to troubleshoot and resolve it, to maintain uninterrupted data collection and reporting to growers (Figure 8).

Figure 1. *Flowmeter and solar powered telemetry stations (datalogger + modem) installed on selected planting blocks along sub-main irrigation lines.*

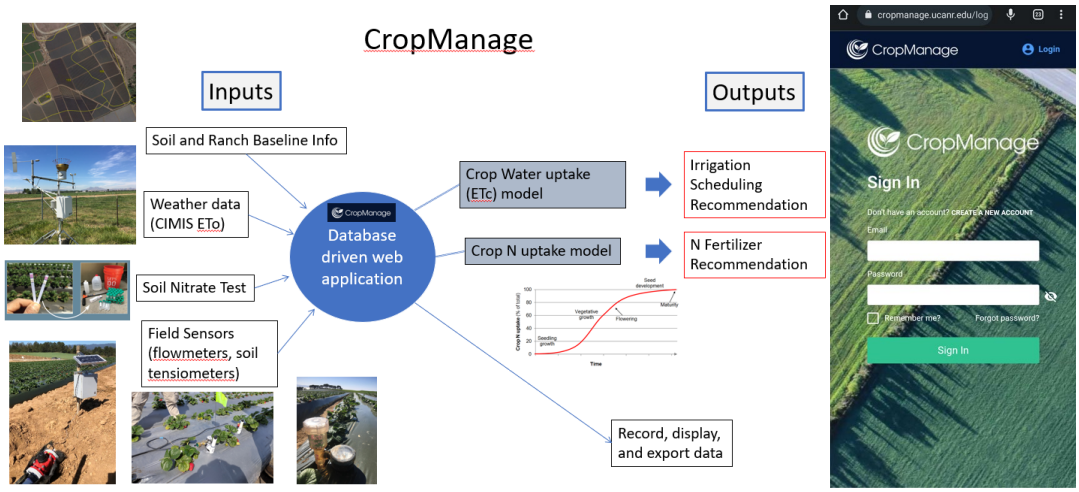

Figure 2. *Inputs and outputs of CropManage, a public web-based decision support tool developed by UCANR to help guide irrigation and nutrient management on farms.*

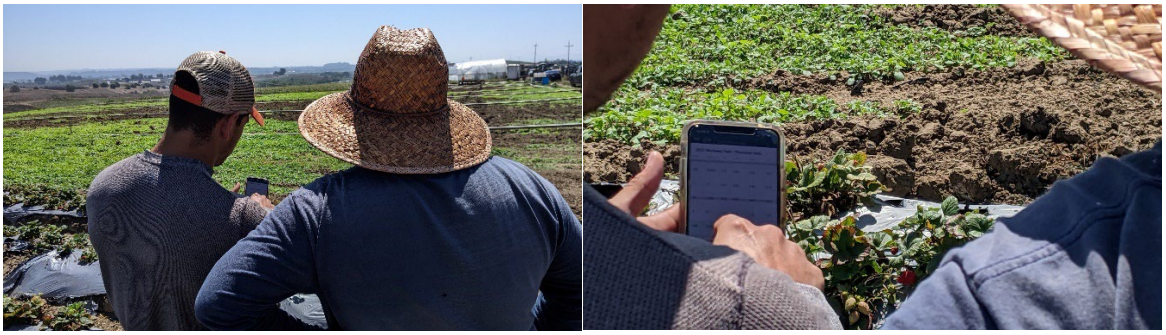

Figure 3. *Field technician Alfredo Cortes demonstrating how to enter and access information in CropManage using a mobile phone in the field.*

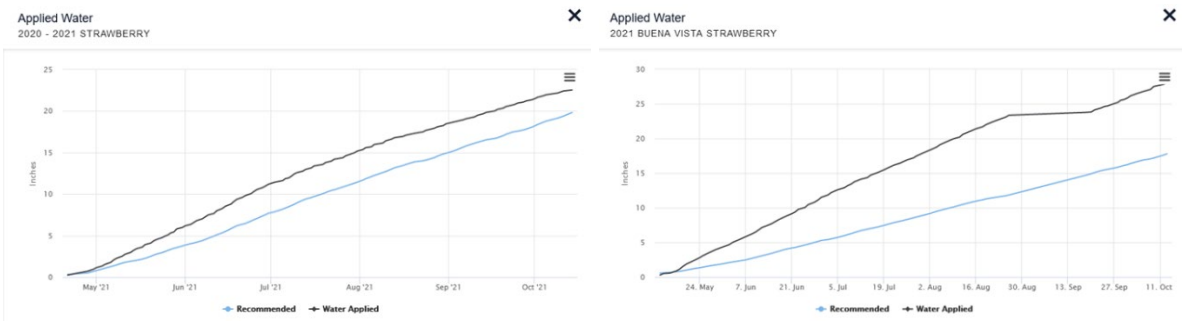

Figure 4. *Examples of irrigation monitoring data visualization in CropManage showing a comparison between cumulative applied vs. cumulative recommended amounts to assess past performance and guide future management.*

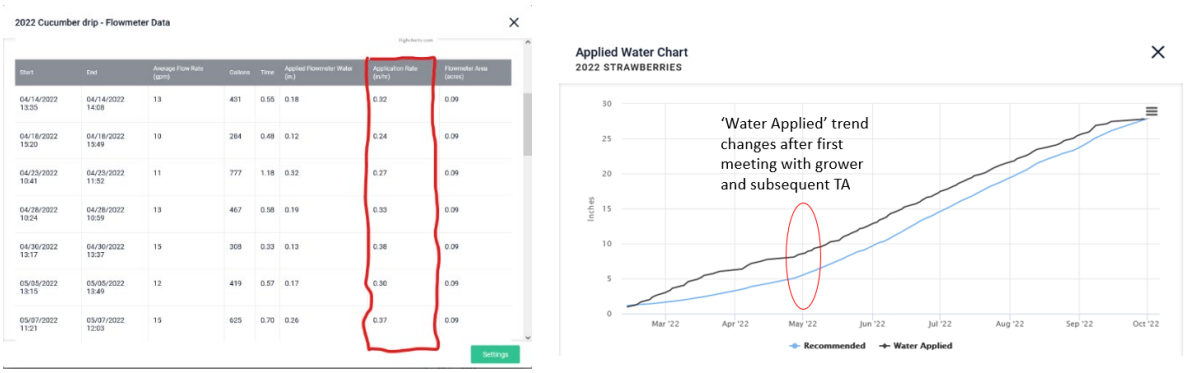

Figure 5. a) *Example of summary table in CropManage showing detailed records for each irrigation event, including flowrate, number of inches applied, duration in hours and application rate (in/hr).* ***b)*** *Example of CropManage applied vs. recommended irrigation graph suggesting evidence of grower management adjustment in response to monitoring feedback and technical assistance.*

Figure 6. *RCD staff training growers on the use of the soil nitrate quick test to guide nitrogen fertilizer application using CropManage.*

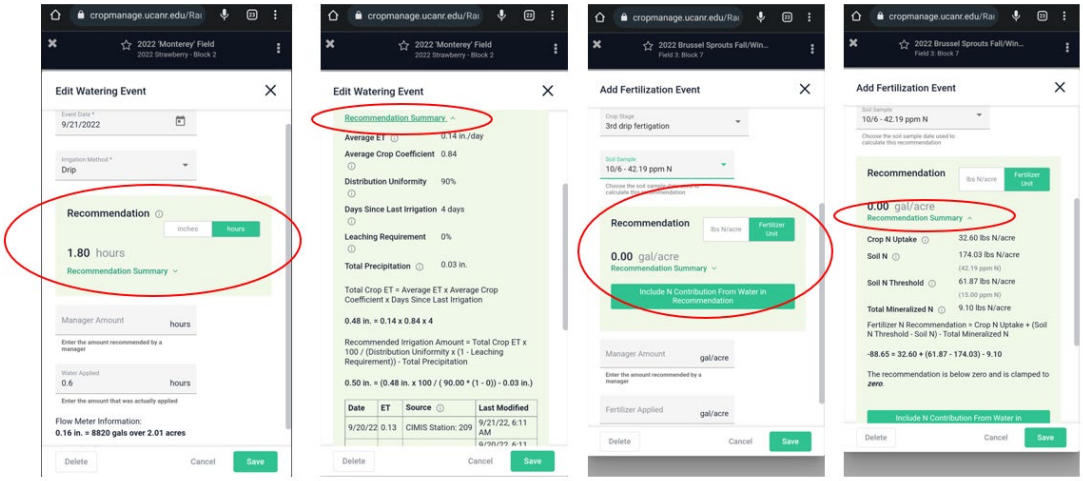

Figure 7. *Examples of recommendation visualization and detailed summary for irrigation and fertilizer application events in CropManage.*

Figure 8. *Installation, troubleshooting and repair of monitoring equipment in the field is an integral part of the technical assistance provided through this program.*

<u>Objective 3.</u> Assess effectiveness and impact of CropManage adoption among participating growers and irrigators.

Tasks:

1. Perform end-of-season interviews with irrigators, ranch managers and growers to evaluate effectiveness of CropManage recommendations.

Summary: RCD staff conducted monthly visits during the growing season and end-of-season interviews with each participating grower to review data, recommendations and assess participant's response and reactions to the information and assistance provided. These meetings with participating growers offered insights to evaluate their reaction and confidence toward CropManage recommendations and provided feedback on the use of weather-based irrigation scheduling monitoring tools and concepts.

<u>Outreach and education methods</u> – program promotion, reaching target audience and overcoming barriers:

The project used three primary mechanisms for education and outreach:

- 1:1 training and technical assistance in the field to participating growers
- Field trainings in Spanish for groups of irrigators and ranch managers
- Hands-on classroom trainings on the use of CropManage

Program promotion was accomplished by leveraging an existing network of growers, technical partners, and advisors with whom the project team had an established working relationship. Outreach was primarily conducted by direct one-on-one communication via phone, e-mail or in-person visits in the field. Most of the growers in this network represent the limited resource, Spanish speaking growers who were the target audience of this project, which made reaching this target audience relatively effortless. The project team also relied on referrals from partner organizations who offer different types of assistance to the same target audience. Strategies to overcome grower engagement barriers included: loaning monitoring equipment to all program participants and providing reliable troubleshooting and maintenance at no cost to the growers; communicating in the language that felt most comfortable to each participant (Spanish in most cases), in a culturally relatable manner and taking time to foster mutual understanding and trust; use a gradual approach to education and capacity building that recognized knowledge gaps and followed a scaffolding process to support growers in mastering new concepts, tools and gaining confidence; being consistent and regularly present in the field to review and affirm previous learning and foster trust; listening and being open to grower's experience and perceptions, and seek common ground to facilitate communication and learning.

The measure of success for this project would be an evidenced or self-reported gain in understanding and confidence that resulted in adoption and effective use of the CropManage tool to improve irrigation and nutrient management among participating growers. The extent to which this measure was achieved was evaluated in three different ways:

- Through conversation and interaction with participating growers during regular field visits over two years.
- By assessing management performance and adjustments relative to technical recommendations, evidenced in CropManage monitoring reports.
- Through end-of-season interviews and surveys to assess program efficacy from the grower's perspective.

F. Data/Results:

Material deliverables:

1. Monitoring reports for participating growers.

During the 2021 and 2022 growing seasons, RCD staff provided direct individual assistance to twenty (20) growers (11 growers during both years and 9 growers only in 2022) by installing and operating automated field monitoring equipment to evaluate and interpret (using CropManage) their irrigation water use relative to concurrent weather-based crop demand (crop ET) throughout the crop cycle. Participating growers received periodic reports consisting of a simple graph to compare their cumulative water use (from field monitoring data) against CropManage's cumulative recommended amount based on CIMIS weather data and

CM's built-in crop uptake models (Figures 9 and 10). Receiving this type of feedback as frequently as once or twice a month during the growing season enabled growers to assess and, in some cases, adjust their irrigation scheduling in time to correct potential over or under irrigation.

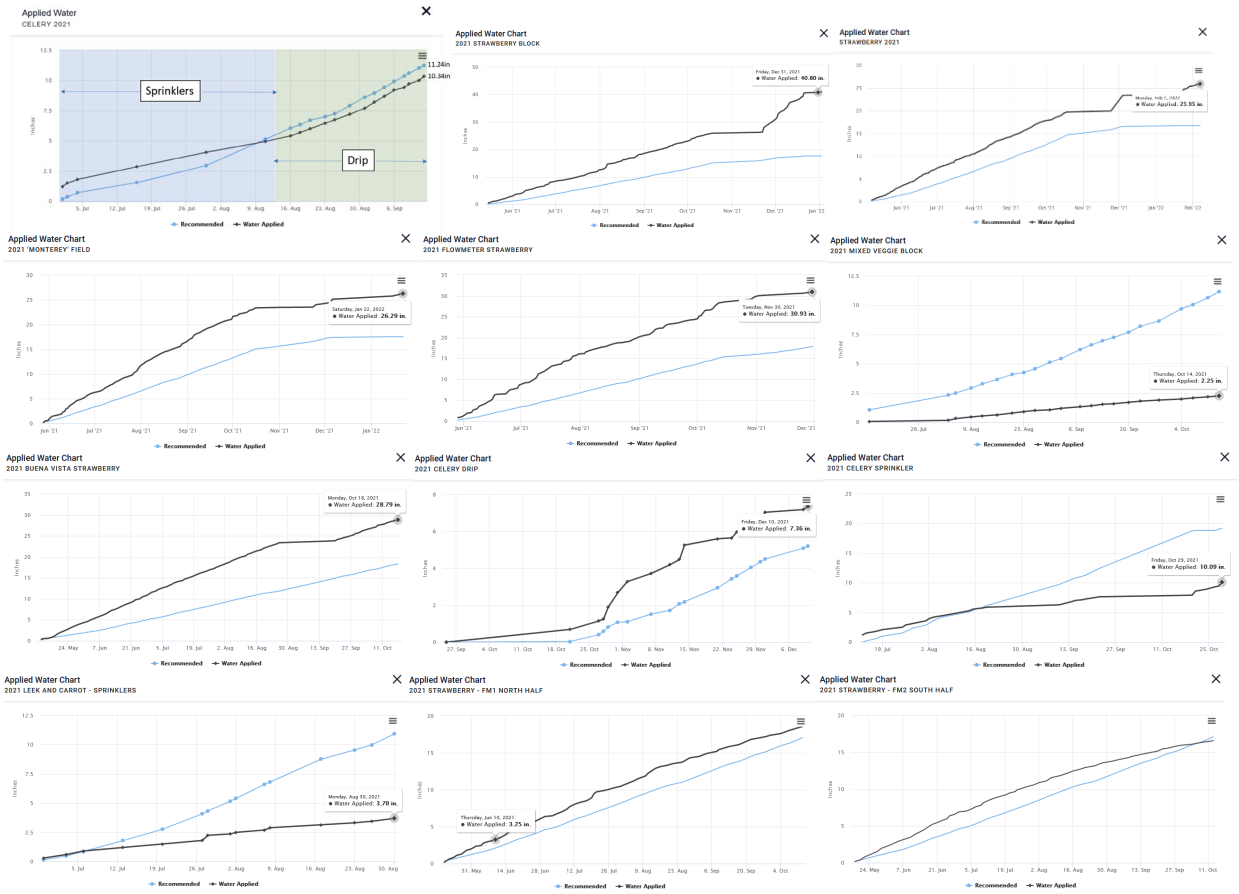

Figure 9. *Monitoring data visualization of cumulative amounts of irrigation water (applied vs. recommended) for individual plantings at participating fields in 2021. The black line represents cumulative applied water, and the blue line represents cumulative recommended water.*

Education and Outreach Events:

*Six (6) events, described in **section J** below (Outreach Activities Summary) *

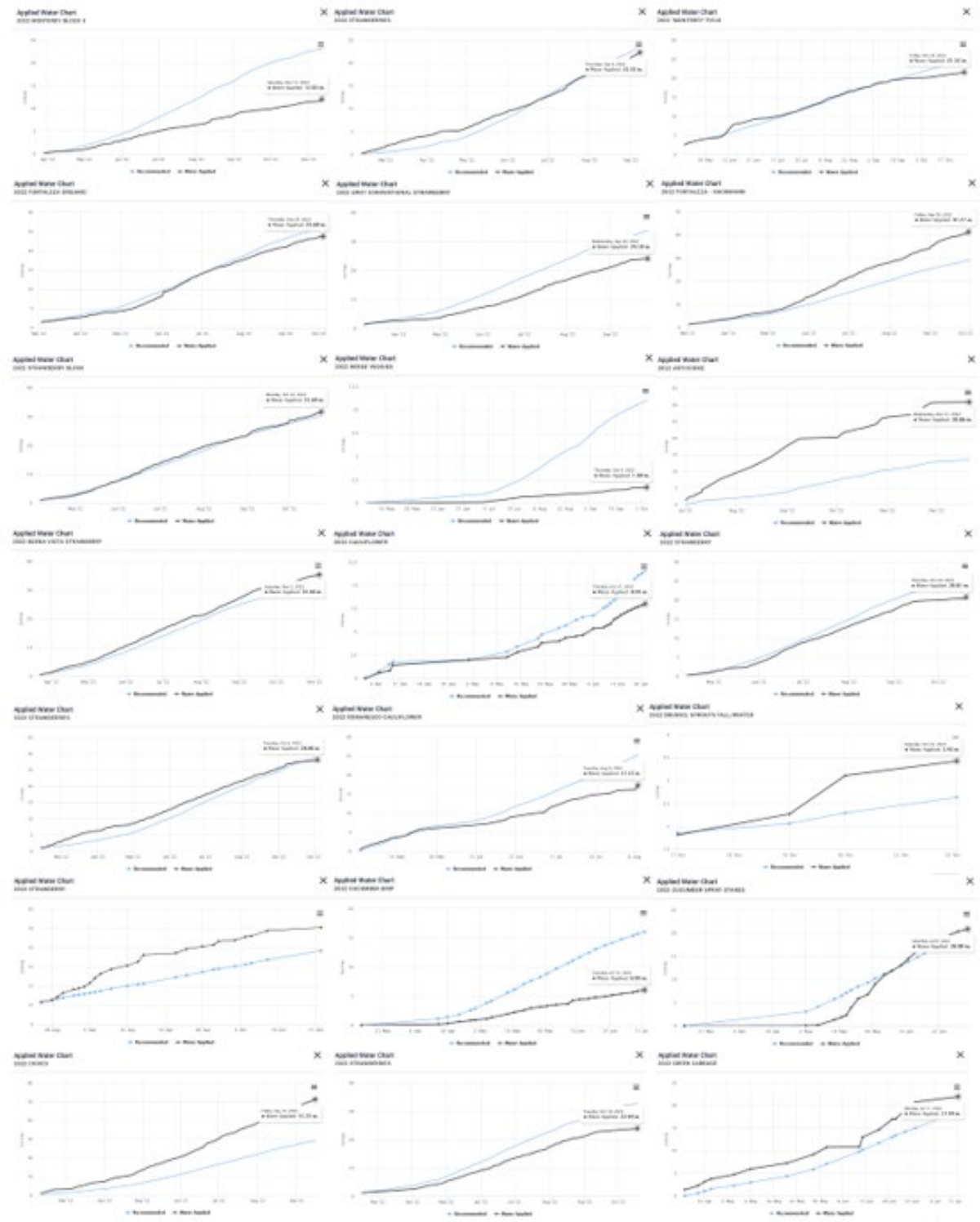

Figure 10. *Monitoring data visualization of cumulative amounts of irrigation water (applied vs. recommended) for individual plantings at participating fields in 2022. The black line represents cumulative applied water, and the blue line represents cumulative recommended water.*

Impact Measures

1. Evaluation tools:

- 1:1 conversation and interaction with participating growers during regular field visits over two years.
- Objective assessment of management performance and adjustments relative to technical recommendations, evidenced in CropManage monitoring reports.
- End-of-season interviews and surveys to assess program efficacy from the grower's perspective.

2. Evaluation findings and improvements made based on feedback:

Thirty (30) different plantings (9 in 2021 and 21 in 2022) were set up and monitored using CropManage during this project. An objective assessment of participant's irrigation performance and adjustments relative to CropManage recommendations, (evidenced in monitoring data visualization of cumulative irrigation applied vs. recommended charts) show that in 2021 most participants ended up applying more water throughout the season than it was recommended based on weather and crop uptake demand (Figure 9); while in 2022, the cumulative amount of water applied for most growers (particularly those who were returning from year 2021) followed very closely the cumulative recommended amount (Figure 10). Now, when examining these graphs, besides looking at the end cumulative difference between applied and recommended, it's very important to look at the overall trend (slope) of both curves as time progressed and look for inflexion points that might demonstrate a change in trajectory resulting from management adjustments. When the two lines run parallel, even if one is higher than the other, it means they are following the same trajectory, or in other words the application is consistent with the recommendation. However, the two curves can run parallel for most of the season and have a large difference at the end because there was a diversion (under or over irrigation) early in the season (even for a short period of time). Inflexion points were observed in several cases, suggesting active adjustments in response to the monitoring feedback.

1:1 conversations and informal feedback during field visits over two years demonstrated increasing confidence and ability to use weather-based irrigation scheduling monitoring tools and concepts; this was especially true among growers who participated since 2021 and returned in 2022, and it shows the importance of continued hand-holding and one-on-one assistance. Most participating growers did pay attention to (and understood) the periodic reports from CropManage provided by the RCD team and adjusted subsequent irrigation scheduling accordingly. Some growers took the next step and actively used the software to generate and interpret recommendations to guide their irrigation scheduling. Either way, in most cases the combined use of field monitoring equipment (flowmeters, telemetry, and soil tensiometers in some cases), CropManage recommendations, and guided technical assistance resulted in a close match between applied and recommended water use among participating ranches. Growers who received assistance with nitrogen management and soil nitrate testing also gradually

improved their understanding and confidence to calculate how much fertilizer N they need to apply based on current soil N levels and crop growth stage. All of this suggests a positive change in management practices for water and nitrogen use because of having access to CropManage and direct 1:1 technical assistance.

According to the end-of season surveys all participating growers found the program to be very helpful and identified concrete benefits from monitoring their plantings and using CropManage to inform their irrigation and nitrogen management. Some growers expressed and demonstrated confidence in autonomously using CropManage, but most of them indicated a preference for continued technical assistance and regular external support over a fully independent adoption of the proposed tools. Lack of time to learn and keep track of new tools was the main barrier for a more independent adoption. Most growers found the periodic reports and recommendations generated from CropManage, on-going field monitoring and technical assistance provided by the RCD team to be insightful, practical, and in line with their own observations and intuition regarding crop needs. Some growers expressed a willingness to invest in their own equipment (flowmeters and telemetry) and continue to use CropManage in the future. And some growers offered specific feedback on potential improvements to the CropManage software and its user friendliness.

G. Discussion and Conclusions:

The project's education, outreach and direct technical assistance activities serving individual growers and groups in the field helped to remove some of the existing barriers for adoption of smart and automated tools to inform and improve irrigation and nitrogen application scheduling, specifically CropManage and associated monitoring tools and practices. Project participants found the monitoring and periodic reports and recommendations generated from CropManage to be insightful and they used them to guide and/or adjust their irrigation and nitrogen scheduling. In this sense, the project objectives were achieved. Most of the participants who showed over-irrigation trends at some point during their crop cycles stated that they were able to adjust their irrigation scheduling (reduce water applied) based on the periodic reports, and this shift was evidenced in CropManage cumulative applied vs. recommended charts. At the end of the first year, most participants were still confused about (or could not clearly articulate) basic concepts related to weather-based irrigation scheduling and did not feel confident enough to use CropManage and interpret its recommendations without continued assistance from RCD staff. This highlights a combined challenge of preferred modes of learning, level of formal education and lack of time, which are difficult to overcome through traditional education and outreach strategies and hinder an entirely independent adoption of the tools promoted with this project. However, by the end of the second year more growers felt confident and were able to explain why weather-based irrigation scheduling is an important and useful practice. In terms of long-term adoption, this project reaffirmed that the deployment, retrieval and management of flowmeter and data logger units in the field still requires external assistance by an agency or a third party. The simplicity and clarity of the periodic reports and technical assistance provided by the RCD team (who was also in charge of making sure all the monitoring equipment kept running smoothly and without interruption) made it less appealing for participants to

want to fully learn and master the CropManage software and continue to use it on their own. Nevertheless, about half of the participating growers indicated their interest in learning the program with the hope that they can easily use it from their cellphones soon. CropManage is a powerful and relatively easy-to-use decision-support tool, but for it to be effective, irrigators and ranch managers must invest time to familiarize with and develop trust for it. Lack of time, distrust for new ideas and hesitation to revise persistent cultural practices and tools to guide their management remain some of the largest barriers to adoption among growers. Developing confidence and capacity for adopting these decision and management support tools can be a slow process, particularly among the demographic group this project targeted. It requires sustained individual assistance and guidance in a linguistically and culturally appropriate manner not only to ensure adequate data input, tracking, interpretation and application of tools and recommendations, but also to support growers until they feel ready.

H. Challenges

The original scope of this project to promote and facilitate the adoption of CropManage among berry and vegetable growers was to develop and test a fully functional low-cost and user-friendly datalogger that could be easily adopted due to its affordability and without requiring extensive knowledge of research-grade dataloggers. During the first year, the original project lead (Dr. Gerry Spinelli) built and tested 8 prototype Arduino dataloggers (in the lab and the field), identified and field tested a preferred flowmeter capable of pulse output, and worked with a consultant programmer to develop and improve the datalogger software and adapt it to changing cellular communication (shift from 2G to 4G networks). In August of 2020, Dr. Spinelli took a new job and left the RCD. Since the Arduino datalogger was his brainchild and the RCD no longer had the technical capacity to see it through, the project scope was revised to fit the strengths of the remaining staff, while still fulfilling the project objectives. The project emphasis shifted to removing adoption barriers through education and outreach, and direct work with growers to promote and facilitate the use of CropManage with existing technology.

I. Project Impacts:

This project contributed to significant capacity building and broader adoption of CropManage for improved irrigation and nitrogen management among historically disadvantaged growers. Multi-year re-enrollment, repeated 1:1 visits and continued support was an essential component of the program, which fostered trust and gradually built grower capacity to adopt and get the most out of these management tools and recommendations. RCD staff will continue to work with returning participants beyond the end of this grant to maintain continuity and try to reach further into their learning process. Understanding the unique decision-making process and roles within each operation and identifying the right person or step in the process where an influence can be made to improve management is essential, and something this project actively worked to achieve. Larger production companies, processors or coolers may be able to hire, and train dedicated staff to perform this task, integrating irrigation monitoring in their operations as part of the company’s sustainability and compliance effort. RCDSCC is actively strengthening partnerships with large vegetable and berry producers to

promote and facilitate adoption of these tools within their companies. Continued support after the FREP-funded portion of this project will be ensured by the existing partnership between the RCD of Santa Cruz County, the UCCE of Santa Cruz and Monterey County and the Pajaro Valley Water Management Agency (PV Water) through the water conservation program. The PV Water conservation program has invested heavily on promoting the adoption of CropManage as an irrigation management tool for growers and it is expected to continue funding this effort. Lessons learned from this project can help other RCDs, technical service providers and groundwater management agencies or irrigation districts statewide.

J. Outreach Activities Summary:

Six (6) education and outreach events were delivered during this project.

1. 2021 CropManage Training (Virtual webinar, May 2021, 78 attendees) – UCANR and RCD co-hosted this event. RCD staff provided simultaneous Spanish interpretation. The training had 78 attendees (mostly growers), 22 were Spanish speakers. CCA CEUs/Grower CEUs offered. (Figure 13).
2. JSM Irrigator Training (JSM Farms, Royal Oaks, June 2021, 10 attendees) – RCD and UCANR co-hosted an irrigator training in Spanish for 10 growers and irrigators at JSM Triple M ranch. The training provided an overview of soil and weather-based irrigation scheduling concepts and tools. (Figure 11).
3. 2022 CropManage Training (Watsonville Public Library, May 2022, 15 attendees) – UCANR and RCD co-hosted a CropManage Hands-On Training in person for growers. RCD staff provided simultaneous Spanish interpretation. The training had 15 attendees (mostly growers), 5 were Spanish speakers. CCA CEUs /Grower CEUs offered. (Figure 13).
4. Jacobs Farm Irrigator Training (Watsonville, Oct 2022, 24 attendees) – RCD and UCANR co-hosted an irrigator training in Spanish for 24 irrigators at one of Jacobs Farms' facilities in Watsonville CA. The training provided an overview of plant-soil-water interactions and concepts and tools for soil and weather-based irrigation scheduling (Figure 12).
5. 2022 Annual FREP-WHP Nutrient Management Conference (Visalia, October 2022) – RCD staff gave a presentation titled: "Promoting the adoption of CropManage to optimize nitrogen and irrigation use through technical assistance with dataloggers and cellular modems for Spanish speaking growers in Santa Cruz and Monterey Counties".
6. 2023 CropManage Training (Watsonville Public Library, January 2023, 32 attendees) – UCANR and RCD co-hosted a CropManage Hands-On Training in person for growers. RCD staff provided simultaneous Spanish interpretation. The training had 32 attendees (mostly growers), 11 were Spanish speakers. CCA CEUs/Grower CEUs offered. (Figure 13).

Figure 11. *Irrigator training in Spanish hosted at JSM Organic Farms Triple M Ranch (Jun 2021), with theory and hands-on practical activities to demonstrate key concepts for irrigation management and water conservation.*

Figure 12. *Irrigator training in Spanish hosted at Jacobs Farms (Oct 2022), with theory and hands-on practical activities to demonstrate key concepts for irrigation management and water conservation.*

Figure 13. *Practical (interactive) trainings on the use of CropManage, hosted once a year throughout the duration of the project.*

K. References:

Cahn, M., Hartz, T., Smith, R., Noel, B., Johnson, L., & Melton, F. 2015. Crop Manage: An online decision support tool for irrigation and nutrient management. In Proc Western Nutrient Manage Conf (pp. 9-14).

Cahn, M., English, M. J., & Hartz, T. 2011. Irrigation and nitrogen management web-based software for lettuce production. In Fertilizer Research and Education Program Conference (p. 19).

L. Appendix: include supplemental figures, tables, etc. cited in the report in this section. All supplemental materials in this section must be cited in the body of the report.

NA

M. Factsheet/Database Template:

See separate document

N. Copy of the Product/Result:

NA