CDFA Fertilizer Research and Education Program, Annual Report

Project Title: **Adapting CropManage Irrigation and Nitrogen Management Decision Support Tool for Central Valley Crops. (Agreement 06-0710-SA)**

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B. Objectives

The general objective was to expand the CropManage (CM) online decision support tool for Central Valley crops, including tree commodities, forage crops, and warm season vegetables. Specific objectives include:

1. Adding algorithms and user interface modules that accommodate warm season vegetables, forage, and tree crop commodities.

2. Supporting the addition of almonds, processing tomatoes, and alfalfa to CM

3. Improve the user-interface so that users can intuitively and quickly navigate within software tool, and data is presented in an easily understandable format.

4. Conduct outreach to the agricultural industry through workshops, presentations at grower meetings, and newsletter, blog, and trade journal articles.

C. Abstract

Central Valley farmers are under regulatory pressure to use fertilizer nitrogen efficiently and demonstrate that they are following best management practices. Because nitrate can readily leach, a combination of practices that help growers follow the 4Rs (right source, right amount, right time, right place) and optimize water management is required to achieve improved N use efficiency. UC research, much of which has been funded by CDFA Fertilizer Research and Education Program (FREP), has greatly increased the understanding of the nitrogen needs of many commodities farmed in California. However, adapting this information for the site-specific soil, weather, and cultural practices can be challenging for growers. In addition to nutrient management, water scarcity during the latest drought has increased the urgency for easy-to-use tools that can assist growers in using limited supplies of water as efficiently as possible to maximize production. The California Irrigation Management and Information System (CIMIS) operates more than 140 weather stations that collect reference evapotranspiration (ETo) data in most agricultural production regions of California. To determine how long to irrigate using ETo data, growers need to complete a series of calculations that can be quite time consuming.

CropManage (CM) is an online tool for assisting growers with efficiently managing water and nitrogen fertilizer to match the specific needs of their crops. With financial support of CDFA-FREP, CM was originally developed to help farmers estimate irrigation schedules in lettuce using CIMIS ETo data and determine fertilizer N needs using the soil nitrate quick test and models of N uptake. Since the first version was released in 2011, CM was expanded to include other coastal crops, including baby salad greens, spinach, celery, broccoli, cabbage, cauliflower, and strawberries. CM also allows growers to track fertilizer and water applications on each of their fields. This record keeping capability of the software allows multiple users to share and review water and N applications on each field of their ranch, and for growers to maintain data required to comply with water quality regulations. There is much interest to expand CM to include Central Valley Crops such as almonds, walnuts, pistachio, alfalfa, and processing tomatoes. However, these commodities require algorithms and user interfaces that are significantly different than the current version of CM. The funding requested in this proposal was for updating the software to allow the addition of Central Valley crops and improve the user-interface so that it is more intuitive for clientele to use.

The initial step to accomplish the objectives of this project was to organize meetings with key farm advisors, specialists, professors, and growers involved with the production of alfalfa, processing tomato, and tree commodities (almonds, pistachio, pears, prunes, and walnuts) to understand the requirements needed for an online irrigation and nutrient management decision support tool. In addition, current CM users provided feedback on how to improve the user interface. Over the following two years several iterations of the new commodity models were developed and tested. Errors were identified and addressed, and the software was retested before being released to a publicly accessible computer server. Public outreach and training were accomplished through presentations at industry meetings, hands-on training workshops, webinar trainings, and updates to the user help support that has been integrated into the software. A significant outcome of this project is more than a 30% increase in subscribed users and an increase in irrigation and fertilizer recommendations of more than 80% to more than 2000 per month during the growing season (March through October). Preliminary testing of the processing tomato irrigation scheduling algorithm was conducted near Dixon CA during the 2019 season. Results indicated that the software may overestimate irrigation requirements based

on evapotranspiration demand due to deep soil moisture that may be present in the soil before planting.

Introduction

Central Valley farmers are under regulatory pressure to demonstrate that they are using nitrogen fertilizer efficiently and are following best management practices to minimize environmental impacts of N fertilizer. Because nitrate can readily leach in soil, a combination of practices that help growers follow the 4Rs (right source, right amount, right time, right place) and optimize water management is required to achieve improved N use efficiency.

During the past 40 years UC research has greatly increased the understanding of crop N needs and resulted in several spreadsheet and online tools that growers can use to determine appropriate amounts of fertilizer to apply to their crops. Work on almonds and pistachios has resulted in guidelines and spreadsheet models for managing N (Brown et al. 2013a, 2013b, Saa et al. 2014a, 2014b, Siddiqui and Brown 2013). Hartz and Bottoms (2009) and Hartz et al. (1998) have outlined guidelines for N management in processing tomatoes, which Geisseler (2015) is currently formulated into a N recommendation model. The objective of these guidelines and models is to assist growers in developing appropriate N budgets for their crops that are based on realistic yield goals, with adjustments for N contributions from irrigation water, soil mineral N, and N potentially mineralized from soil organic matter and crop residues. Additionally, for tree crops, early season leaf sampling can provide an estimate of N status in the tree tissue that can be used to make adjustments in the timing and amount of fertilizer. Similarly, in vegetables, the soil nitrate quick test (SNQT) can provide growers with an estimate of the mineral N status of the soil which can offset a portion of the total N needs of a crop. By accounting for all reasonable sources of N that could benefit a crop, growers can make better decisions on the right amount of N to applied to their fields.

In the context of nutrient management, good water management is also critical to prevent nitrate losses by leaching. Large scale trials in lettuce, for example, have shown that the combination of monitoring soil mineral N status and using evapotranspiration (ET) based irrigation scheduling could significantly reduce N fertilizer needs without sacrificing yield or quality (Cahn et al. 2010). Water scarcity during the latest drought has also increased the urgency for easy-to-use tools that can assist growers in using limited supplies of water as efficiently as possible to maximize production. Commodities such as almonds and alfalfa came under increased scrutiny during the last drought because of the large amounts of water applied to these crops. The rapid conversion of processing tomatoes from overhead sprinkler and furrow systems to drip irrigation during the last 10 years has increased the need for growers to have simple-to-use tools to determine how much water is needed to maximize fruit yield and quality. ET-based scheduling combined with soil moisture monitoring can assist growers in determining when and how much water to apply to crops such as alfalfa, almonds, and tomatoes, reducing the risk to leach nitrate from the root zone.

The California Irrigation Management and Information System (CIMIS) operates more than 140 weather stations that collect reference evapotranspiration (ETo) data in most agricultural production regions of California. Reference ET data is key to determining crop water requirements, but only a relatively small proportion of farmers use these data to guide irrigation scheduling. Using CIMIS data for irrigation management requires several calculations to account for site-specific effects of crop development stage, soil physical properties, soil and

water salinity, and irrigation system performance. The effort can be time consuming and confusing for growers and consultants to integrate into an irrigation schedule.
Although UC advisors and specialists have developed many guidelines and spreadsheet models for nutrient and irrigation that can be quite useful for growers, they are not easily integrated into commercial farming operations. Growers must seek out each commodity specific online tool or spreadsheet from different sources. Often these tools only address a few commodities or are specific for nutrient or irrigation management. Most growers simultaneously manage multiple fields and commodities, and water and nutrient management are only two of many responsibilities that they must address in their farming operations.

In collaboration with ANR communication services and financial support from CDFA-FREP, Cahn et al. (2011) developed a preliminary version of CropManage (CM), an online irrigation scheduling and nutrient management tool for vegetables (cropmanage.ucanr.edu). CropManage is a database-driven web application that assists growers and farm managers in determining watering and fertilizer N schedules on a field-by-field basis. The software automates all steps required to calculate crop water requirements, including retrieving the CIMIS ETo and precipitation data from the closest weather station, estimating the crop coefficient, and determining the appropriate irrigation time and interval based on soil type and models of crop development. N recommendations for vegetables are based on soil nitrate quick test values, models of crop N uptake and credits for nitrate in irrigation water and previous crop residues.

The web application also helps growers track irrigation and fertilizer schedules on multiple fields and ranches and allows users from the same farming operations to view and share their data. This record keeping capability of the software allows growers to review water and N applications on each field of their ranch, and to maintain data required to comply with water quality regulations.

As a web-based tool, CM can be configured to integrate with other existing web applications and data sources to improve the accuracy of the irrigation and fertilizer models. For example, CM retrieves soil property data from the UCD SoilWeb tool. CM can also be configured to automatically import flowmeter and soil moisture data directly from sensors in grower fields using cell phone modems with IP addresses. A Web application protocol interface (API), added to CM in 2015 facilitates exchange of data with proprietary and 3rd party software.

Since the first version was released, CM was expanded to include other coastal crops, including baby salad greens, spinach, celery, broccoli, cabbage, cauliflower, and strawberries. UC extension specialists and advisors, as well growers and commodity boards, expressed interest to expand CM to include Central Valley Crops such as almonds, walnuts, pistachio, alfalfa, and processing tomatoes. By incorporating nutrient and irrigation models available from UC researchers into CM, growers would be able to use one software tool to manage many different commodities. Also, by integrating models for multiple commodities, the overall cost of developing and maintaining a user-friendly decision support tool could be minimized. However, the integration of central valley commodities requires the introduction of algorithms and changes to the user interface that are significantly different than the current version of CM. Funding requested for this project was primarily for software development for integrating CM with Central Valley tree, forage, and warm season vegetable crops.

Work Description

Year 1.

Task 1. Develop and test preliminary algorithms and user interface for processing tomatoes. Completed May 2018. Breyta programmers added algorithms to CM that estimate crop ET based on reference ET, canopy cover and development stage of processing tomato. The interface was modified so that the user can specify the degree of water stress desired during fruit maturity to optimize fruit quality. Irrigation interval is recommended based on soil water holding capacity, rooting depth, and crop ET. The N requirement algorithm is based on N uptake data for processing tomato, soil nitrate test values, nitrogen in irrigation water, and soil and crop residue mineralization. Data to support models of canopy cover development, root development, and N uptake for processing tomatoes were developed in a parallel FREP grant (Geisseler et al. 2015 CDFA-FREP Award 15-0410SA). A working version of processing tomatoes is now available on CM.

Task 2. Develop and test preliminary algorithms and user interface for almonds
Completed March 2019. This task involved adding models to estimate water and nitrogen requirements of almonds to CM. Similar to the interface for processing tomatoes, users are able to enter the degree of water stress desired after the hull split stage. The N requirement algorithm for almonds is based on the model of Saa et. al. (2014). The model allows users to estimate N requirements based on projected yield, leaf N values, age of the orchard, and soil amendments. The algorithms were developed and tested in a spreadsheet format and subsequently coded and tested in the development version of CropManage. Almond is now available on the production version of CropManage.

Task 3. Develop and test preliminary algorithms and user interface for alfalfa
Completed August 2018. The irrigation model for alfalfa was adapted from the Basic Irrigation Scheduling spreadsheet program for alfalfa, developed by Snyder and Bali. An average crop coefficient is estimated based on a crop development model for young, established, and mature alfalfa fields. The user interface was modified to allow users to enter cut dates. Alfalfa is now available on the production version of CropManage.

Task 4. Update CropManage user interface to improve navigation and data presentation
Completed December 2017. UCANR and Breyta Inc. programmers collaborated to update the CropManage user interface which greatly improved navigation and presentation of information. The user interface was also redesigned to be easy to view and navigate on a smart phone screen. However, the new version of the interface loaded slower than the original version, so a later effort was made at the end of 2018 to modify the interface to improve the loading speed. The latest version of CM is now hosted on the Amazon Web Service cloud server which increases the reliability of the application and security of user data.

Task 5. Update user help support
Completed December 2019. Information icons were added to the CM to explain irrigation and nutrient management terms. WordPress software was integrated into CropManage to provide online help and user support. Through a link in the CM menu users can now search for help, look up terms in a glossary, and read tutorials.

Year 2.

Task 1. Finalize algorithms and user interface for processing tomatoes, almonds, and alfalfa. Completed March 2019. Algorithms and user interfaces for almond, alfalfa, processing tomato were tested and modified to address errors in calculations and to improve the user experience. The user interface for trees (almond) was modified so that users can enter leaf tissue sample values. Calculators were also added to assist users in estimating seasonal N contribution from compost and manure amendments, as well as legume cover crops. The irrigation application rate calculator was updated for micro-sprinklers commonly used in orchards.

Task 2. Add module to import soil moisture data from commercial companies and other 3rd party providers.
Completed November 2018. The soil moisture importation module was simplified so that users can easily link their soil moisture data files to CM. The module has been tested in field trials. An application protocol interface (API) was developed so that CM can be interfaced with other software products so that it can display soil moisture data provided by commercial companies.

Task 3. Improve visualization of data
Completed November 2018. The graphical display of soil moisture data was improved to allow users to quickly zoom to specific ranges of dates and values, and easily distinguish among multiple curves on the same graph.

Task 4. Survey users for feedback on new user interface
Completed November 2019. CM users were surveyed about modifications made to the interface during CropManage workshops in 2018 and 2019. An additional survey on CropManage was conducted in collaboration with CDFA-FREP staff during 2019. A user feedback link was added to the menu so that errors and suggestions for improvement can be quickly reported to the software engineer.

Task 5. Write interim and annual reports
Completed. Both interim and annual reports were submitted for year 2

Work plan for Year 3.

Task 1. Add module to allow users and 3rd party sources to input canopy cover data
Completed March 2019. User interface was updated so that measurements of canopy cover can be entered and compare with modeled estimates. Additionally, satellite estimates of canopy cover from the NASA Satellite Irrigation Management System are automatically imported and displayed on the same canopy graph. Sliders below the graph were added so that users can readjust the CM canopy model to match observed measurements.

Task 2. Enhance the N mineralization model
10% completed. Although we hoped to improve the existing N mineralization model used in CM based on results and outcomes from an ongoing FREP project lead by Smith et al. there has not been enough time to analyze data from this project to develop a substitute model. In

addition, a recently funded FREP project led by Joji Muramoto will further investigate soil and organic amendment mineralization. We are therefore waiting for this information to be developed before changing the present N mineralization model in CM. Our hypothesis is that C:N ratio, soil temperature, and soil moisture will be the main factors for estimating mineralization from organic fertilizers and amendments.

Task 3. Conduct training workshops for alfalfa, processing tomato, and almond growers
Completed November 2019. Initial workshops focused on training farm advisors and specialists that work with central valley crops. Cropmanage hands-on training workshops were conducted for advisors and specialists working with processing tomato 1/18/19. A workshop was conducted at the water management workgroup meeting held in Davis on 3/6/19 covering alfalfa, trees, and processing tomato. Other trainings specifically for trees were conducted at the tree crop work group meeting held in Davis CA on 3/28/19 and in a breakout session at the Annual FREP conference held in 2019. Feedback from the participants was used to modify the user interface and algorithms in CropManage. Periodic trainings on using CM for alfalfa, almonds, and processing tomato will continue to be offered after the grant has ended.

Task 4. Survey users on modules for almond, processing tomato, and alfalfa.
Completed November 2019. CM users were surveyed for feedback on modules for alfalfa, almond, and processing tomato Users participating in the workshops outlined above (Task 3) were asked to provide feedback during and at the end of the trainings. Follow up discussions with individual users were pursued to better understand how to improve the software.

Task 5. Write interim and final reports
Completed. The interim and final reports have been completed.

Results and Discussion

User Interface

The first version of the upgraded user interface for CM (Year 1, Task 4) was developed and implemented during the first 6 months of the project. UCANR information technology staff assisted Breyta Inc. in moving the existing CM software to Amazon Web Cloud Service, as well as to adapt the CM code to Angular 2.0 and more recently to Angular 3.0. Angular is a framework software that automates configuring CM to different web browsers. Breyta then redesigned each user interface module in CM, which was tested, debugged, and retested through several iterations. This task required much more time than anticipated but was finally free of errors by late October 2017. After several months of testing, the new interface was announced to the public as version 3.0 at the end of December 2017. After the first year of transforming CM to the new version users complained that the interface, though easier to navigate, was loading slower than the original version. Hence the interface had to be redesigned a second time, to accommodate faster loading.

The current interface for CM improves the user experience by simplifying how users navigate to their plantings and ranches (Figures 1 and 2). The user can filter by the first letter or complete name of a ranch, and by name, lot name, crop type, or year of a planting. Users can also click on a star to designate ranches or plantings to a favorite list that displays only the plantings and/or ranches which are of immediate interest to the user.

The planting summary tile (Figure 3) allows the user to quickly review upcoming and past events and tasks. The tile shape of the planting summary displays efficiently on a smart phone or tablet computer screen. The most recent or upcoming events are listed first, and the user can scroll to view events that are further in the future or past. An icon is displayed next to a past event when it has been confirmed to be completed. Users can also add an irrigation, fertilizer, and soil tissue sample events from the planting tile. Clicking on the icon in the lower right corner opens a summary table (Figure 4) of all events entered in the planting. The tabs on the top of the table allow the user to view only irrigation, fertilizer, and soil sample events. Totals of fertilizer and water applied to the planting are displayed in the footer at the bottom of the table. Details of entered water, fertilizer, soil samples can be reviewed by opening an event. The username, date, and time of an entry are also displayed.

Processing tomato

The processing tomato module required redesigning the existing interface for lettuce and other cool season vegetables. It includes a calculator for estimating total crop N uptake from expected fruit yield, and a form to enter crop water stress parameters to optimize quality during the ripening phase (Figure 5). The crop coefficient model was also modified for processing tomatoes to account for the decrease in evapotranspiration that usually occurs during the fruit maturing stage. The algorithm for recommending nitrogen fertilizer in processing tomato was modified to accommodate growers that do not test or infrequently test their soil for residual nitrate. In this situation, the user would receive a recommendation based on the crop N uptake and soil mineralization estimates. Nitrate in the irrigation water is subtracted off from the fertilizer recommendation.

Preliminary field testing of CM for processing tomato was conducted in two commercial fields in Dixon CA during the 2019 season. Flowmeters were installed in each field and interfaced with a datalogger so that applied water data could be automatically recorded on CM. Recommended water for fields 1 and 2 were 28.5 and 22.9 inches, respectively. The grower applied 18.2 and 17.7 inches to fields 1 and 2, respectively, which is substantially less than the CM recommendations. As the purpose of this testing was to observe if the grower irrigations were close to the CM estimates, we can only speculate on a few possible reasons for why the grower applications were less than the CM recommendations. A wet spring provided a substantial amount of moisture in the soil profile. Hence there was no need to irrigate to full crop ET until later in the season. However, the canopy cover in both fields declined substantially later in the season indicating either a disease issue or that the crop may have been water stressed (Figure 6)

Alfalfa

The addition of alfalfa to CropManage was completed in August of 2018. Included algorithms are similar to the Basic Irrigation Scheduling (BIS) software developed by Snyder and Bali. The user must enter cutting dates which defines the canopy development curve and Kc values (Figure 7 and 8). Since alfalfa fixes nitrogen, no fertilizer N recommendation is provided; however, users can enter soil test values and fertilizer events. Alfalfa as well as other deep-rooted crops such as processing tomato and almonds, required changes to the root development algorithm and soil database to include depths of 0 to 4 ft. This addition required major updates to the CropManage database and soil module. Users can also input the depth of impermeable layers that limit the root growth of their crop.

Almonds

The addition of almonds to CropManage required major changes to the user interface and algorithms. The irrigation algorithm is similar to processing tomato, where the Kc values are estimated based on a canopy development curve (Figure 9) and users can define periods when water stress should be imposed on the crop. The nitrogen recommendation algorithm is based on an estimate of seasonal crop N requirements, defined from a yield goal, spring leaf tissue values, and potential N mineralization from applied manure, soil amendments, and incorporated cover crops (Figure 10). A nitrogen uptake curve is used to estimate the crop N requirement between fertilization events. Nitrate-N applied in irrigation water is subtracted out from the N recommendation. Because water and nitrogen requirements of trees changes as they age, the parameters for the irrigation and nitrogen models are defined for orchards of different ages: for example, almond 1-2 years, almond 3-4 years, etc. The user must indicate the age of the orchard each year as well as the date when the leaves emerge in the spring. In collaboration with the Almond Board of California (ABC) we developed an interface between CropManage and the California Almond Sustainability Program (CASP) so that almond growers have an option to export data entered into CM to the CASP website. This module was funded by ABC.

Soil moisture display

The soil moisture display was tested for several field sites using tensiometers that were interfaced with Campbell dataloggers. Linking the datafile to a CM planting was facilitated with an improved user interface (Figure 11). The graphical chart allows users to display the sensors and locations of interest and adjust the scaling (Figure 12).

User support improvements

User support was enhanced by adding information icons to explain irrigation and nutrient management terms throughout the software. WordPress software was integrated into CropManage to provide online help and user support. Through a link in the CM menu users can now search for help, look up terms in a glossary, and read tutorials (Figure 13). Finally, a link was added so that users can send feedback to the CM administrators (Figure 14).

Project Impacts

This project has greatly increased the usability of the online irrigation and nitrogen management decision support tool, CropManage, and expanded the capabilities of the software for central valley crops including alfalfa, almond, and processing tomato. The user interface is much more intuitive and responsive than before this project began. The software also is much easier to navigate in the field using a smartphone or tablet computer. The project was also able to educate more than 1800 clientele about nutrient and water management tools for improving fertilizer use efficiency. Evidence of success is the documented increase in usage of CropManage. User enrollment increased from about 1300 before 2016 to more than 2000 at the end of 2019. CropManage recommendations during the growing season increased from less than 1000 per month before 2016 to more than 2300 per month during 2019. Because almond, alfalfa, and processing tomato were recently added to CM, central valley growers are just becoming familiar with the software. We expect adoption by these growers to increase as we conduct more workshops and trainings in the central valley during the upcoming season.

Outreach activities

Presentations and workshops on CropManaage are summarized in Table 1. A total of 52 presentations were given during the period of the grant, and more than 1800 participants attended these presentations. Some presentations were introductions to the software while others were 2 to 3 hours workshops where participants received hands-on instruction using their laptop or tablet computer. Presentations were made throughout California, including the central valley, central and south coast, as well in other states, including Hawaii, Oregon, and Arizona. No FREP funding was used for travel for these out-of-state presentations. Beginning in 2018 presentations in the central valley emphasized processing tomato, almonds, and alfalfa (6 presentations).

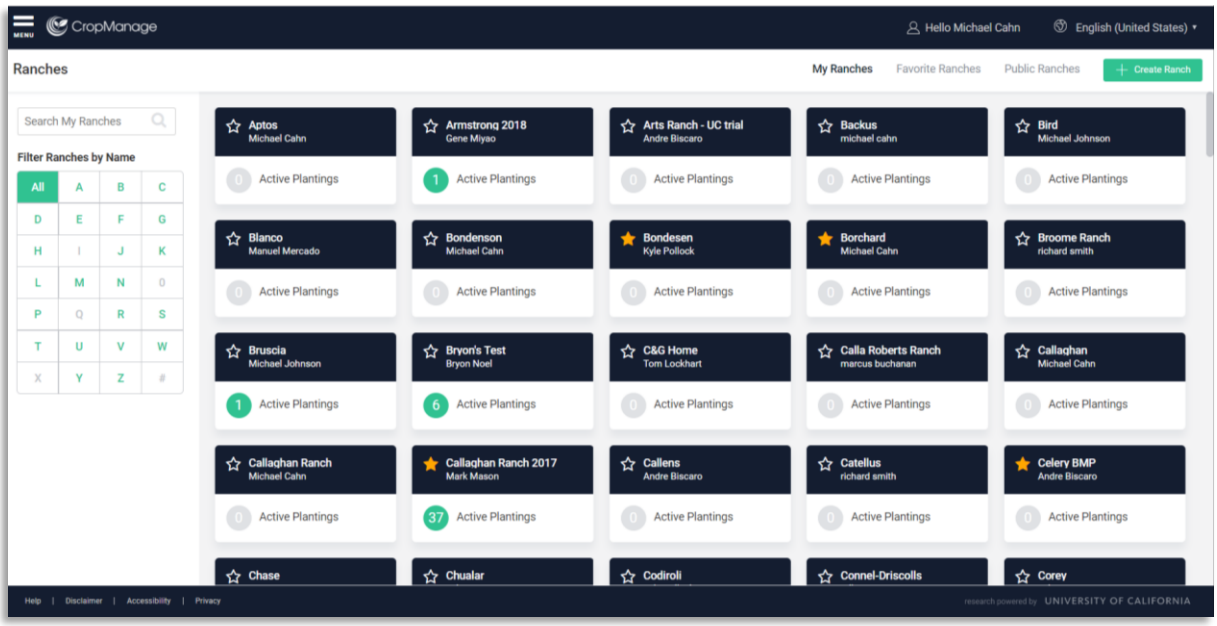

Figure 1. Updated user interface in CropManage displays ranches available for the user to view. User can filter by first letter or complete name of the ranch.

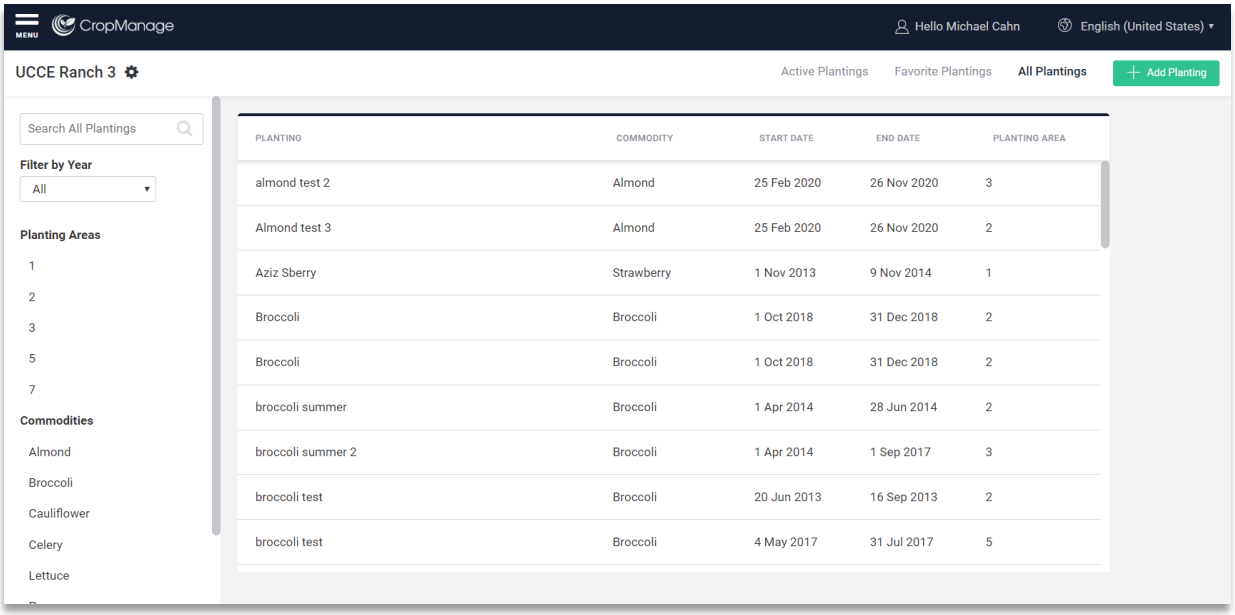

Figure 2. Updated user interface in CropManage displays current and past plantings for a variety of commodities. Users can filter plantings by field (planting area), planting name, commodity, or year.

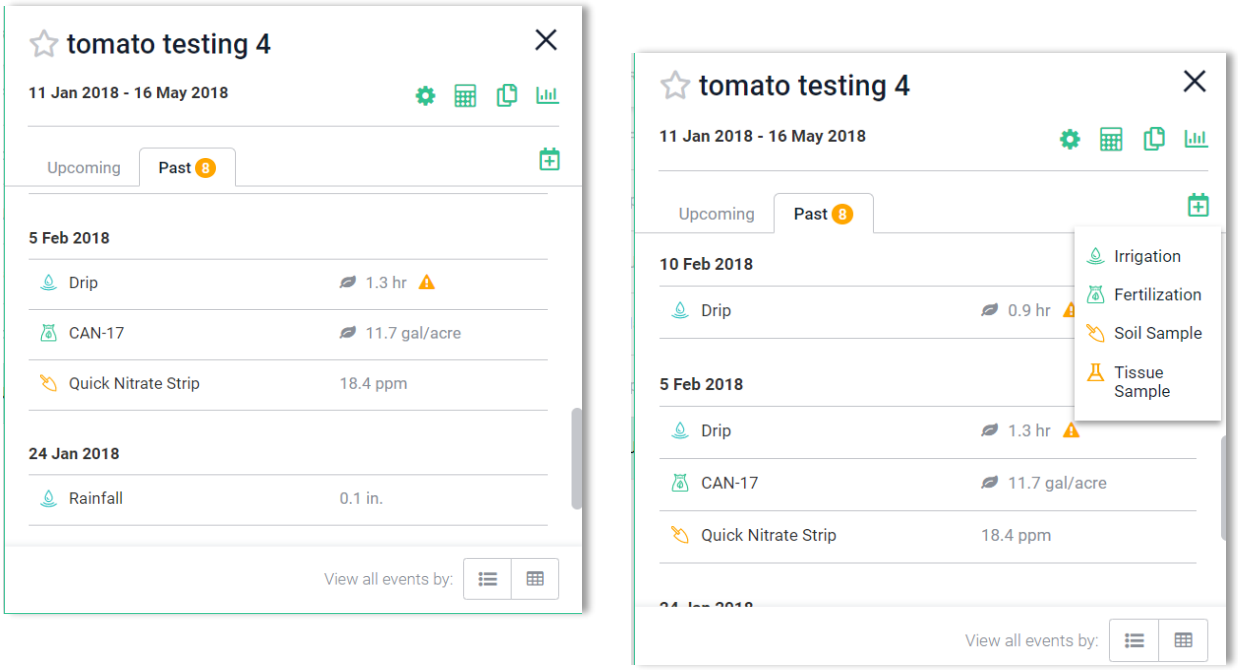

Figure 3. Updated user interface in CropManage displaying events for a processing tomato crop. The interface is designed to display efficiently on smartphones and divides events into "upcoming" and "past" activities. The icons on the right-side of the planting modal allow users to quickly add water, fertilizer, and soil sample events.

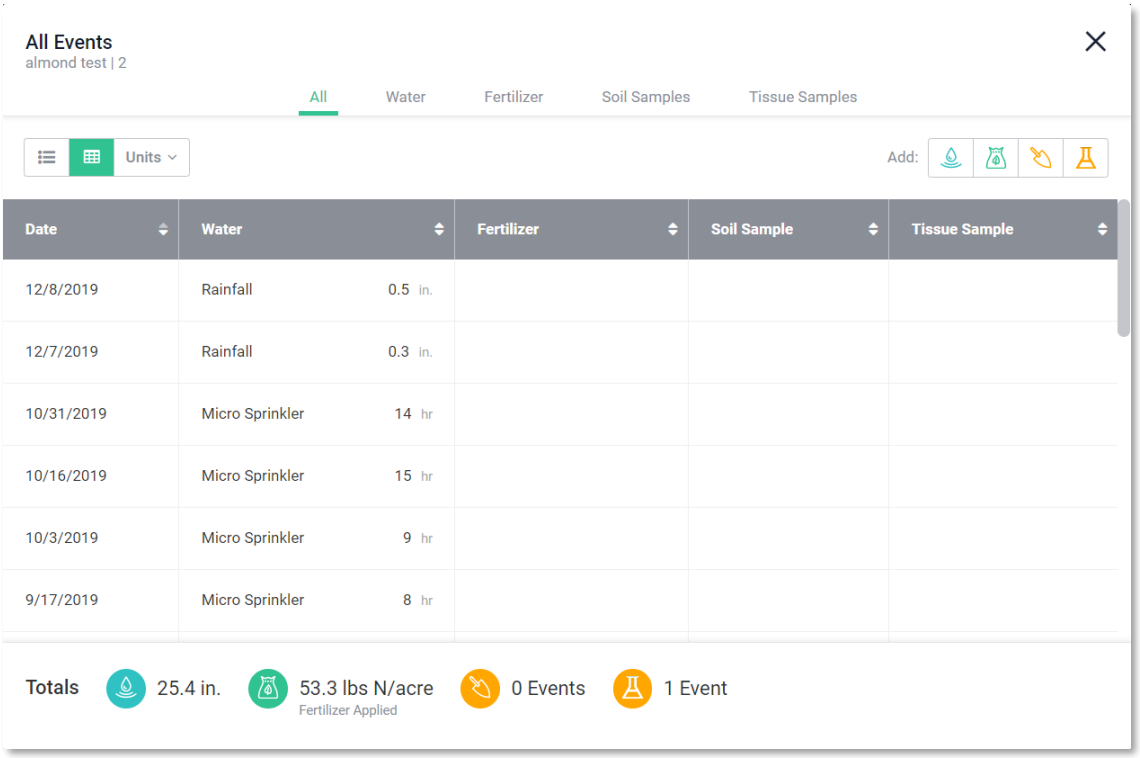

Figure 4. Updated user interface in CropManage displaying a table summarizing all events entered into an individual planting. Totals of applied water and fertilizer are displayed below the table. Clicking on an event displays who entered the event and the time of entry.

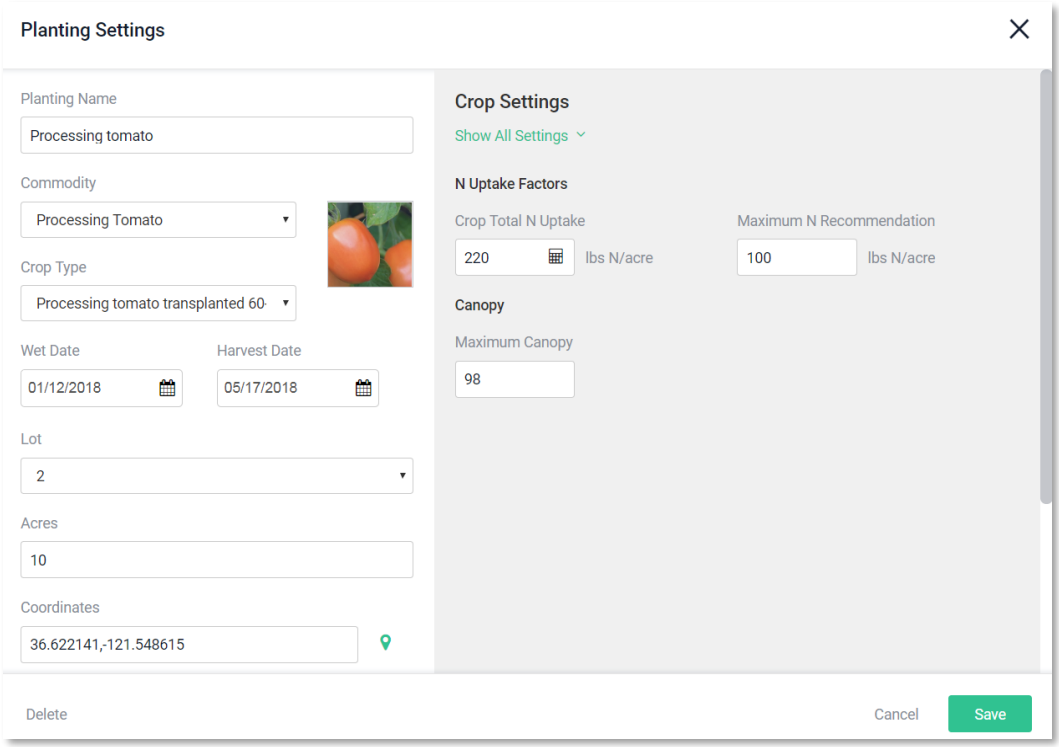

Figure 5. Updated user interface in CropManage displaying crop settings for processing tomato. A calculator is included in the user interface for estimating the total crop N uptake based on expected fruit yield.

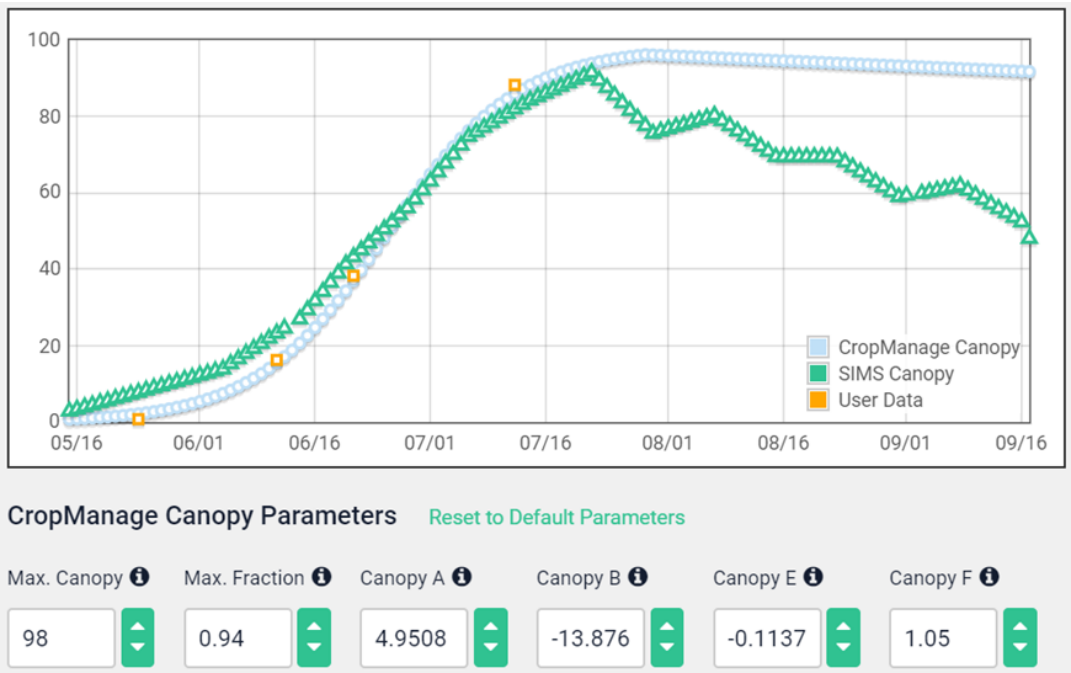

Figure 6. Comparisons of CM, satellite estimates and ground measurements of canopy cover in a commercial processing tomato field.

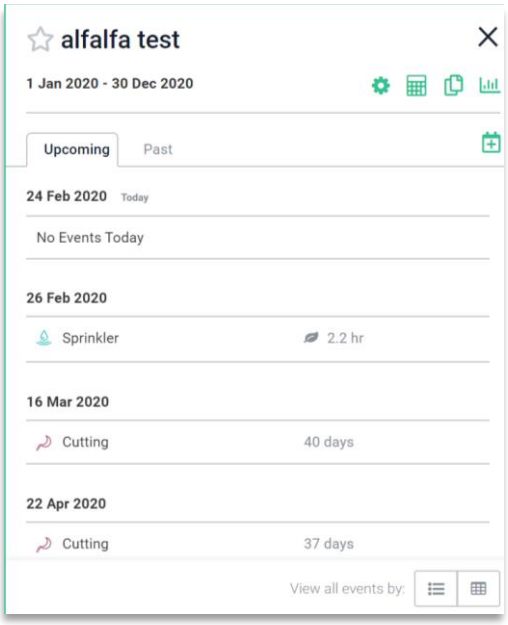

Figure 7. Updated user interface in CropManage for alfalfa allows users to enter dates when they cut their fields.

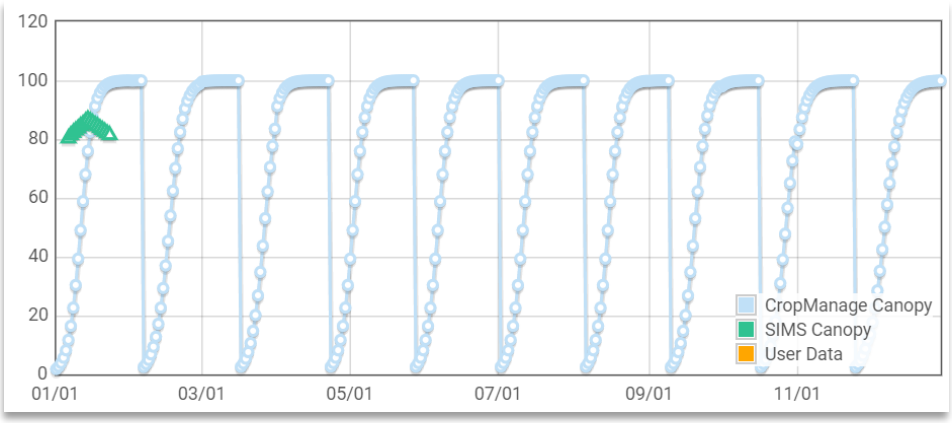

Figure 8. User entered cutting events define the canopy curve and the crop coefficient development over the season.

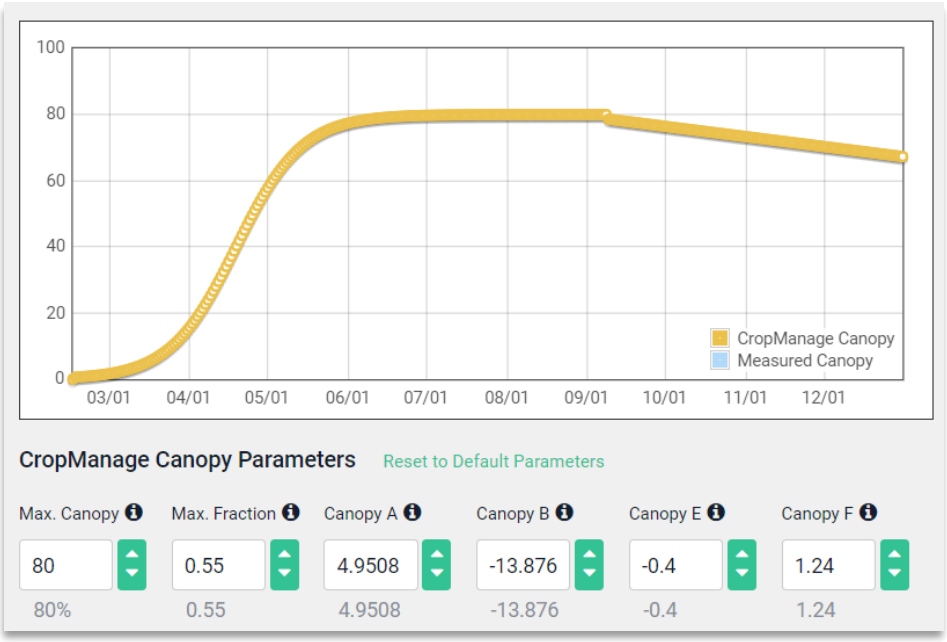

Figure 9. Canopy curve of almonds is used for estimating the crop coefficient (Kc) for the irrigation recommendation. Users can view and adjust the canopy curve to match the specific conditions of their orchards.

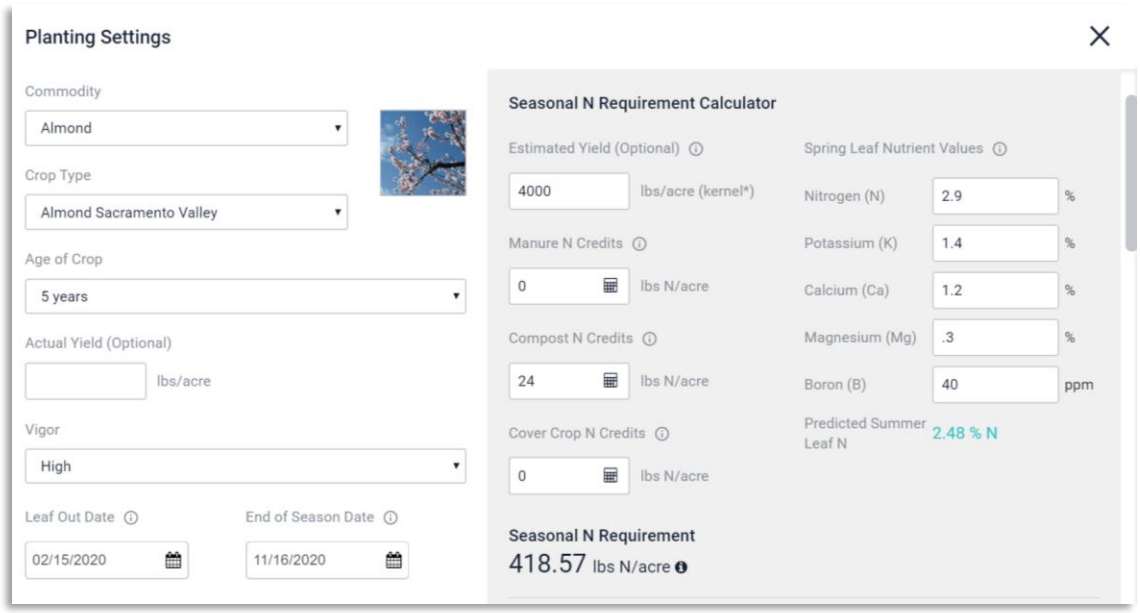

Figure 10. A seasonal nitrogen requirement calculator, based on the spreadsheet model of Brown et al. 2013, was added to the plantings settings of the almond module.

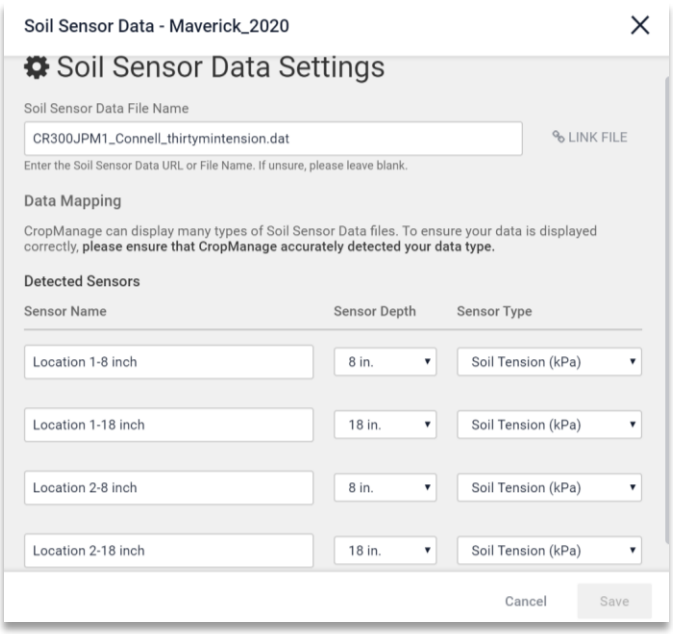

Figure 11. A user interface was developed to facilitate interfacing soil moisture data files with the graphical display.

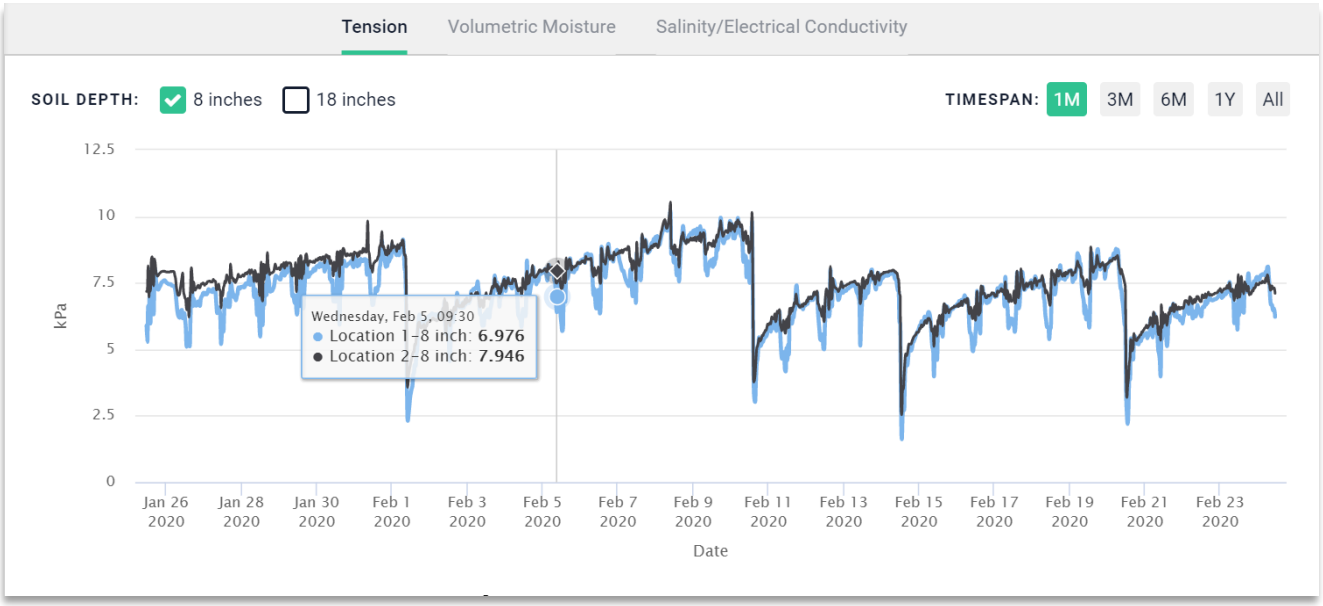

Figure 12. Graphical display of soil moisture data within CM.

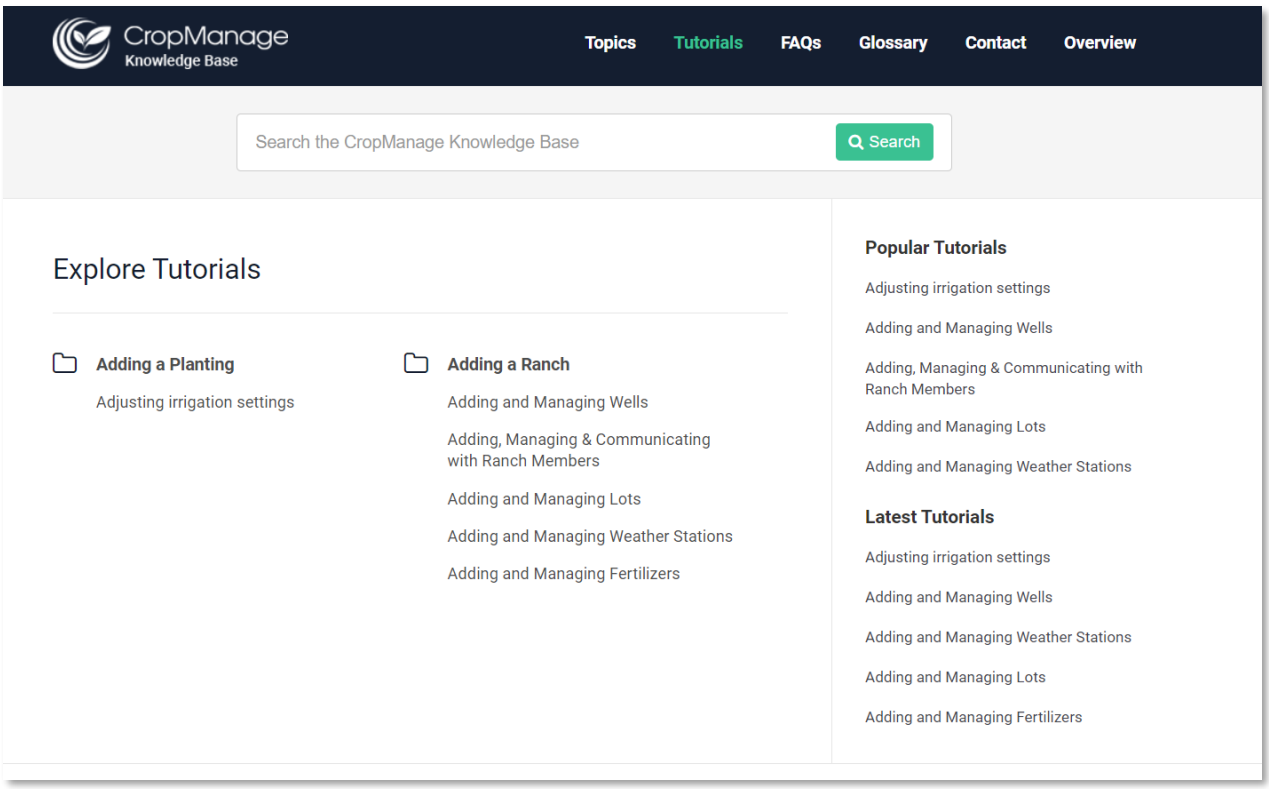

Figure 13. Online help support, designed using WordPress software, was integrated into CropManage and provides tutorials, glossary of terms, and other topics to assist users.

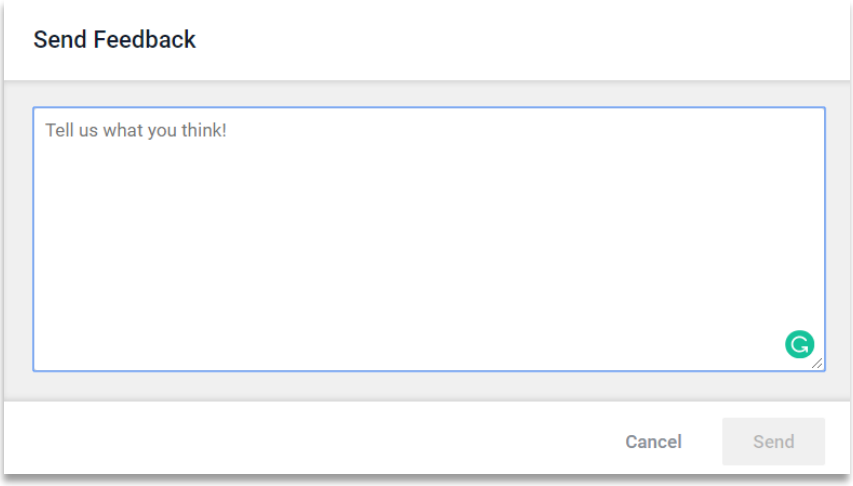

Figure 14. Users can send messages about errors directly to the software engineer and site administrator using the feedback feature.

Table 1. Summary of outreach activities on CropManage.

#	Date	Meeting name	Presentation Topic	Sponsors/Co-Sponsors	Location	Attendance
1	2/3/2017	UC Strawberry Meeting	CropManage for management of water and nitrogen in strawberry	UCCE Santa Cruz	Watsonville CA	145
2	2/23/2017	UC Irrigation and Nutrient Meeting	CropManage Update	UCCE Monterey	Salinas CA	80
3	3/29/2017	CropManage Workshop	Hands-on training with CropManage	PVWMA	Watsonville CA	30
4	4/13/2017	CropManage Workshop	Hands-on training with CropManage	UCCE Monterey	Salinas CA	35
5	4/28/2017	Irrigation course	CropManage Training	Cabrillo College	Aptos CA	20
6	5/5/2017	Plant production course	CropManage Training	Hartnell College	Salinas CA	25
7	5/11/2017	CropManage Workshop	Hands-on training with CropManage	UCCE Ventura Co.	Ventura CA	20
8	5/22/2017	AgTech Meeting	CropManage: Irrigation and nutrient management decision support tool	UCANR	UC Davis	18
9	6/6/2017	Chilean wine grape tour	CropManage: Irrigation and nutrient	UC Davis LAWR	Davis CA	15

			management decision support tool			
10	8/16/2017	UCCE Ventura water and nutrient management meeting	CropManage 3.0: field-ready water and nitrogen management decision support	UCCE Ventura	Oxnard CA	50
11	9/21/2017	American Society of Horticulture Science Annual Meeting	Cropmanage Online Decision Support Tool for Irrigation and Nutrient Management of Vegetables and Strawberries	ASHS	Kona HI	poster
12	9/22/2017	Univ of Hawaii, Noon Seminar Series	Developing an Online Decision Support Tool for Irrigation and Nutrient Management of Vegetables and Strawberries on the Central Coast of California	University of Hawaii	Manoa, HI	12
13	11/27/2017	Santa Maria Vegetable and Strawberry Meeting	CropManage 3.0: bringing water and nitrogen management decision support to the field	UCCE San Luis Obispo	Santa Maria CA	60
14	2/28/2018	AgTech Meetup	CropManage: Bringing water and nitrogen management decision support to the field	Santa Cruz County AgTech Meetup	Watsonville CA	25
15	3/6/2018	Fresno State Vegetable Production Lab	CropManage Hands-on Training	CSU Fresno	Zoom meeting	25
16	3/14/2018	Hartnell College vegetable production seminar series	CropManage Hands-on Training	Hartnell College	Salinas CA	25
17	3/16/2018	CropManage development meeting	CropManage - Alfalfa Crop Review	UC Davis	Davis CA	8
18	3/20/2018	Oregon vegetable grower tour	CropManage: Bringing water and nitrogen management	UCCE Monterey	Salinas CA	15

			decision support to the field			
19	3/22/2018	CropManage Workshop	CropManage Hands-on Training	PVWMA/UCCE Santa Cruz Co	Watsonville CA	25
20	3/28/2018	AgTech Summit	CropManage: Bringing water and nitrogen management decision support to the field	Hartnell College	Salinas CA	30
21	3/29/2018	D'Arrigo Project Review	CropManage with broccoli	CSUMB/D'arrigo	Salinas CA	10
22	10/12/2018	Annual meeting of the USDA NRI SCRI project:	Validation and demonstration of decision support tools for improving water and nitrogen use efficiency in lettuce	Plant Science Dept, UCD	UC Davis	15
23	10/16/2018	DWR Seminar	CropManage: bringing irrigation and N management decision support to the field	Cal DWR	Sacramento CA	18
24	10/16/2018	UCD Vegetable production course (PLS110)	CropManage Training	UCD Plant Sciences Dept	Davis CA	40
25	10/18/2018	Celery Irrigation Field Day	Irrigation management of celery	USDA-ARS, NASA	Salinas CA	24
26	10/22/2018	FREP pre conference tour	Irrigation and water management on the central coast	CDFA-FREP	Seaside CA	55
27	10/24/2018	FREP conference	Speed update on CropManage	CDFA-FREP	Seaside CA	130
28	11/1/2018	Western Plant Health Association 2018 Nutrient Seminar	CropManage: bringing irrigation and N management decision support to the field	WPHA	Modesto CA	35
29	11/26/2018	Vegetable crop continuing conference	CropManage Update	UC ANR	Davis CA	40
30	1/18/2019	CropManage Hands-on training workshop	Hands-on training with CropManage for farm advisors and specialists	UCCE Monterey and UC Davis	Davis CA	14

31	1/31/2019	Oregon State University Dept Seminar	CropManage decision support tool for irrigation and nutrient management	Oregon State University	Corvallis OR	35
32	2/1/2019	Oregon Processed Vegetable Commission Grower Meeting	CropManage decision support	Oregon Processed Vegetable Commission	Albany OR	75
33	2/6/2019	Plant and Soil Conference	Using CropManage Decision Support Tool for Improving Irrigation Efficiency of Coastal Vegetables	California Chapter of Agronomy Society of America	Fresno CA	45
34	2/26/2019	2019 UCCE Irrigation and Nutrient Meeting	Optimizing Water Management in Celery using Weather Based Scheduling	UCCE Monterey	Salinas CA	70
35	3/6/2019	Water Program Team Meeting	CropManage training for ANR members	UCANR	Davis CA	25
36	3/12/2019	Fresno State Vegetable Production Lab	CropManage lab training	Fresno State	Zoom meeting	40
37	3/28/2019	Pomology Program team meeting	Adapting CropManage for Irrigation and Nutrient Management for Trees	UCANR Pomology Workgroup	Davis CA	40
38	4/3/2019	California Crop Coefficient Committee Launching Meeting	Using CropManage for ET based irrigation scheduling	UCANR/DWR	Sacramento CA	60
39	5/3/2019	CropManage Workshop	Introduction to using CropManage	Cabrillo College	Aptos CA	35
40	5/22/2019	CropManage Workshop	Introduction to using CropManage	UCCE Ventura	Ventura CA	30
41	5/24/2019	Visitors from Tashkent Institute of Irrigation and Mechanization Engineers	Introduction to CropManage and irrigation challenges on the central coast	UC Davis	Davis CA	3
42	6/7/2019	CropManage tutorial	Introduction to using CropManage	Scheid Vineyards	Greenfield CA	5
43	7/10/2019	Cauliflower irrigation trial meeting	Using weather-based approaches to scheduling irrigation in cauliflower	UCCE Monterey, USDA-ARS, NASA	Salinas	34

44	10/1/2019	Multi-processor Grower Workshop for Water Stewardship	Technical Assistance for Improving Water and Nutrient Management	Taylor Farms/Fresh Express	Salinas CA	70
45	10/16/2019	Hartnell College	CropManage Hands-on Training	Computers in AG course	Salinas CA	32
46	10/30/2019	Fertilizer Research and Education Progarm Annual Conference	CropManage Decision Support Tool: Inputs, Outputs, and Users	CDFA Fertilizer Research and Education Program	Fresno CA	125
47	10/30/2019	Fertilizer Research and Education Progarm Annual Conference	CropManage demonstration for tree crops	CDFA Fertilizer Research and Education Program	Fresno CA	45
48	11/15/2019	Lettuce SCRI project annual meeting	Validation and demonstration of decision support tools for improving water and nitrogen use efficiency in lettuce	UC Davis	Davis CA	15
49	11/19/2019	Hartnell College soil fertility class	CropManage training	Hartnell College	Salinas CA	30
50	11/20/2019	CropManage Hands-on training workshop	CropManage training	RCD Santa Cruz County	Watsonville CA	23
51	1/14/2020	CropManage zoom training for Arizona State Univ	Introduction to CropManage	UCCE Monterey	Zoom meeting	2
52	1/27/2020	Soil Fertility graduate course	Introduction to CropManage	CSU Cal Poly	San Luis Obispo	10

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Project Title: **Adapting CropManage Irrigation and Nitrogen Management Decision Support Tool for Central Valley Crops. (Agreement 06-0710-SA)**

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Start year: 2016 End year: 2019

Location: Monterey County, Yolo County, San Joaquin

Highlights

- Adapted and existing irrigation and nitrogen management decision support platform for central valley crops.
- CropManage decision support tool assists grower in determining the right amount of water and fertilizer nitrogen to apply to their fields.
- Ease-of-use of the software and compatibility with smartphones was greatly improved.
- Use of CropManage increased more than 2-fold during the span of the project.

Introduction

Central Valley farmers are under regulatory pressure to use fertilizer nitrogen efficiently and demonstrate that they are following best management practices. Because nitrate can readily leach, a combination of practices that help growers follow the 4Rs (right source, right amount, right time, right place) and optimize water management is required to achieve improved N use efficiency. UC research, much of which has been funded by CDFA Fertilizer Research and Education Program (FREP), has greatly increased the understanding of the nitrogen needs of many commodities farmed in California. However, adapting this information for the site-specific soil, weather, and cultural practices can be challenging for growers. In addition to nutrient management, water scarcity during the latest drought has increased the urgency for easy-to-use tools that can assist growers in using limited supplies of water as efficiently as possible to maximize production. The California Irrigation Management and Information System (CIMIS) operates more than 140 weather stations that collect reference evapotranspiration (ETo) data in

most agricultural production regions of California. To determine how long to irrigate using ETo data, growers need to complete a series of calculations that can be quite time consuming. CropManage (CM) is an online tool for assisting growers with efficiently managing water and nitrogen fertilizer to match the specific needs of their crops. CM also allows growers to track fertilizer and water applications on each of their fields. This record keeping capability of the software allows multiple users to share and review water and N applications on each field of their ranch, and for growers to maintain data required to comply with water quality regulations. Although originally developed for central coast crops such as cool season vegetables and berries, there is much interest to expand CM to include Central Valley Crops such as almonds, walnuts, pistachio, alfalfa, and processing tomatoes. The objective of this project was to expand the capabilities of the software for central valley commodities including tree and forage crops, and simultaneously improve the user interface so that software is easy for growers to use in the field and compatible with most smartphones.

Outcomes

The new version of CM is much easier to use and navigate than the original version and is compatible with most smartphone browsers (Figure 1). The response time for growers to receive water and nutrient recommendations was reduced from 5 to 20 seconds to consistently less than 2 to 3 seconds. The software is now compatible to use with almond, alfalfa, and processing tomato, which represent a substantial portion of the agricultural land in the central valley. The decision support platform could potentially help many growers in California better manage fertilizer nitrogen and optimize water for yield while minimizing leaching of nitrate. The CIMIS reference ET can now be applied more easily and accurately for irrigation scheduling. The record capabilities of the online tool can assist growers with tracking their fertilizer and water use as well as lessening the reporting burden for complying with water quality regulations.

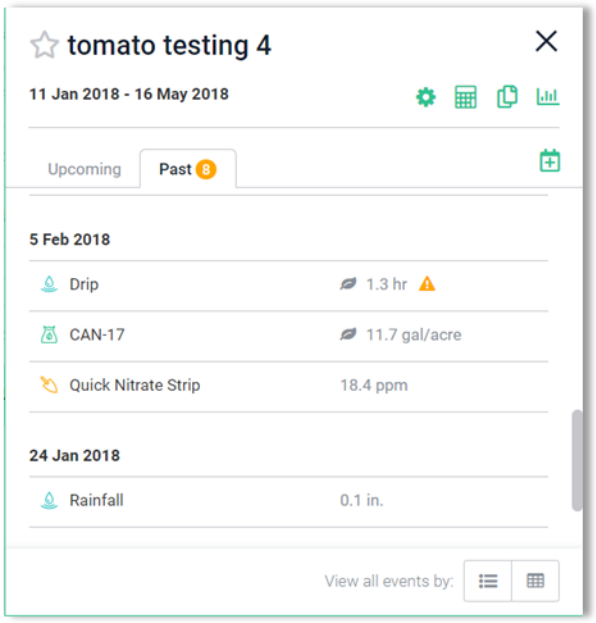

Figure 1. CropManage user interface is compatible with most smartphones