2016 CDFA Fertilizer Research and Education Program

Project Title: Adapting CropManage Irrigation and Nitrogen Management Decision Support Tool for Central Valley Crops

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Supporters:
California Almond Research Board, California Tomato Research Institute, California Alfalfa and Forage Association, California Walnut Board, Western Growers, Grower Shipper Association of the Central California

CDFA Funding Request Amount:

Total Requested: $224,760 Year 1: $74,920 Year 2: $74,920 Year 3: $74,920
B. Executive Summary:

Problem: 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 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. 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.

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 1400 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 head lettuce using CIMIS ETo data and determine fertilizer N needs using the soil nitrate quick test and models of lettuce 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. Since CropManage was first released, use of the on-line tool has steadily increased on the Central Coast. CM currently has more than 1000 registered users, and provides more than 1000 recommendations per month to users for water and fertilizer during the production season.

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 is primarily needed for programming infrastructure to allow the addition of Central Valley crops and improve the user-interface.

Objectives: Expand CropManage online decision support tool for Central Valley crops, including trees, forage, and warm season vegetables. Specific objectives include:
1. Adding algorithms and user interface modules that accommodates warm season vegetables, forage, and tree crop commodities.

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

3. Improve CM user-interface so that navigation within software is more intuitive 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.

**General Approach and Evaluation:**

The Computer Services and Information Technology (CSIT) Staff at UC Agriculture and Natural Resources (ANR) will coordinate with project PI’s to expand CropManage for including warm season vegetables, forage, and tree crops. This task will require reorganizing the underlying architecture of the software so that the user-interface, algorithms, database, and other features of CM are customized for each commodity type. Because CM was recently reorganized into an object-oriented programming structure in 2015, the software can be customized more easily to accommodate different commodities.

This project will also support adding an initial tree, forage, and warm season vegetable commodity to CM. We will concentrate on Central Valley commodities already funded to develop and test algorithms for CropManage, including almonds, alfalfa, and processing tomato. We anticipate that the cost for including additional tree, forage, and warm season vegetable commodities to CM will be greatly reduced after these 3 initial commodities are added since the algorithms and interfaces should be similar within the same crop type. This was the case when CM was originally developed for lettuce. Minor changes were required to the underlying code of CM to accommodate the addition of spinach, broccoli, cauliflower, cabbage, and celery.

Additionally, we will coordinate with UC ANR CSIT staff to improve the CM user interface. CSIT staff will collaborate with the software development company, Breyta Inc. (www.breyta.com), to develop and implement the new interface. We will reorganize the user interface so that navigation within CM is more intuitive and so that data can be displayed more clearly in tables and graphs. Some strategies that we will be employed to simplify the user interface are to substitute text menus with icons, use tiles shapes to represent plantings and ranches, and include cursor activated hints and tips to explain terms and icons in more detail. We will also improve graphs and tables so that data displays clearly and are easy to customize to specific ranges of dates. Preliminary interfaces will be made available to users so that they can provide feedback on the features that they like and dislike.

Outreach workshops will also be conducted to introduce CM to growers and crop consultants, and demonstrate how to incorporate the online tool into their irrigation and fertilizer management decisions. These workshops also provide a forum to receive feedback from users on how to improve CM, and an opportunity to survey users on proposed improvements that will be made to the user interface.

**Target Audience:** Central Valley growers, farm managers, crop advisors
C. Justification

Problem:
Need for easy to use tools for guiding N and water management

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 (2007) 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 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 have come under increased scrutiny during the latest drought because of the large amounts of water applied to these crops.

More water is applied to alfalfa (approximately 18-20 percent of all the water used for irrigation) than any other irrigated crop in California. Hence alfalfa water use is under increased scrutiny and any improvement in irrigation efficiency could have a significant impact on water supplies in the state. Better water management in alfalfa can potentially help mitigate nitrate issues in regions of the Central Valley where dairy manures or high nitrate water are routinely applied to fields. Alfalfa has a high N demand, and although it can fix N, alfalfa will preferentially uptake mineral soil N when available. Dairy producers could potentially apply a portion of their manures to alfalfa, but good water management would be critical to prevent leaching losses of nitrate, especially in new plantings or after cuttings when N uptake rates are still low.

Because alfalfa is one of the more difficult crops to irrigate it has not received sufficient attention from producers. Most alfalfa fields in the Central Valley are surface irrigated which is more difficult to manage than with sprinklers. In addition, alfalfa is cut multiple times per year
(3 to 10 times) and irrigations must be scheduled around cuttings. Alfalfa crop coefficients (Kc) vary over the season in response to cuttings. Because of these complications, most alfalfa producers do not use a weather-based water budget approach to schedule irrigations and the few that do use a water budget, use an average Kc for the season rather than accounting for cutting effects. UC publications are available to help growers improve irrigation scheduling of alfalfa (Sanden et al. 2011) including a spreadsheet calculation program that estimates ET based demand for alfalfa (Snyder et al. 2007).

Almonds are another crop that has been scrutinized for high water use during the drought, most likely due to the increase in acres of this commodity during the last 15 years. Though many almond growers using efficient irrigation methods such as drip and micro-sprinklers, they still need to determine the ET requirements of their crops to conserve as much water as possible and to prevent leaching losses of nitrate.

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. Field studies by Cahn et al. (2001, 2004), and Hartz and Hanson (2009) have shown that some cut back in water is needed during fruit maturity to optimize soluble solids levels of fruits. ET based scheduling combined with soil moisture monitoring can assist growers in determining when and how much water to apply to 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 a number of 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. Additionally, most growers simultaneously manage multiple fields and commodities, and water management is only one of many responsibilities that they must address in their farming operations.

Easy to use tools that support decisions on fertilizer N and water, allow tracking of water and fertilizer applications, and facilitate multiple users within the same farming operation to share information, is needed to implement many of the best management practices recommended by UC research.

Existing online water and N management tools

Several online tools have been developed to assist growers in managing water and N fertilizer of their crops. Wateright (www.wateright.org), developed by the Center for Irrigation Technology at California State University, Fresno, is suitable for many of the needs of growers, permitting access via the internet, and for multiple fields to be managed. However, it does not accurately model crop coefficients of major commodities such as tree crops and alfalfa. For example, it does not adjust the crop coefficient for alfalfa based on cutting cycles, or estimate soil evaporation losses during the establishment phase with overhead sprinklers. The software also does not have full database capabilities, requiring users to reenter information for each planned irrigation event.
Basic Irrigation Scheduling program developed by Snyder et al. (2007) has sophisticated algorithms to model crop Kc values during the development of different commodities, but is in a spreadsheet format and cannot be interfaced with a database. The California Almond Research Board has also sponsored the development of an irrigation scheduling program that will be available on their website. However, this program is best suited for irrigation planning rather than day-to-day scheduling and is specific for one commodity.

Online N management tools are less common than irrigation scheduling programs and exist for only a few commodities produced in the Central Valley. The California Almond Research Board sponsored the adoption of the Brown et al (2013) N budgeting model through the assistance of SureHarvest, Inc. Almond growers can access this online tool from the California Almond Sustainability Program website. Growers can also download the spreadsheet version of the model from the UCANR website. There is much interest to produce similar N budget models for other tree crop commodities. However, it would be cumbersome for growers to rely on different web apps for each commodity and access these tools from different websites.

The various irrigation scheduling and N budgeting programs described above are useful tools for helping growers make decisions on water or fertilizer management, but none provide all of the operational features needed for the particular challenges of managing multiple commodities across large crop acreage in California. Ideally, a more comprehensive online tool with capabilities for managing multiple fields, automating irrigation scheduling calculations using CIMIS weather data, and providing N recommendations based on nutrient budgets, would greatly help growers implement best practices for water and N management, and comply with water quality regulations.

**UC online irrigation and nutrient management decision support tool**

In collaboration with ANR communication services and financial support from CDFA-FREP, Cahn et al. (2011) developed a preliminary version of CropManage, an online irrigation scheduling and nutrient management tool for vegetables (https://cropmanage.ucanr.edu). CropManage is a database-driven 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 and models of crop N uptake requirements.

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 (Figure 1). 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 make use of 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, have expressed 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 is primarily needed to support programming that will be required to add Central Valley crops.

For this project, we will concentrate on adding Central Valley commodities already funded to develop and test algorithms for CropManage, including almonds, alfalfa, and processing tomato. An existing CDFA-FREP grant is currently funding the development of N management and irrigation models for processing tomatoes (Geisseler 2015) and a Department of Water Resources (DWR) grant is supporting the development of ET-based irrigation models specific for almonds, walnuts, and alfalfa. A majority of the funding for these projects is for developing and field testing the decision support algorithms rather than for software development. Also, DWR funding is only for adding the water management module to CM. Hence, additional funding is needed for adding an N management model for almond to CM. Although the N budget model for almonds of Brown (2013a) is available through the Almond Board and UCANR websites, adding it to CM will allow the users to also take advantage of other features offered in CM, such as the irrigation scheduling, and record keeping capabilities. We anticipate that after adding the almond N model to CM, other tree N budget models (pistachio) can then be added to CM for a fraction of the initial cost for almonds.

![Figure 1. Summary table of soil mineral N, and fertilizer and water applications for a lettuce field managed using the CropManage online tool.](image)

**FREP Mission and Research Priorities** Our project is well aligned with the FREP mission of promoting the research and education for the efficient use of fertilizers and protection of water quality. This project matches the FREP priority to “Develop Integrated Decision Support Tools.” By providing customized guidelines for both irrigation and N fertilizer management, CM addresses two main factors which lead to nitrate leaching losses: over-application of N fertilizer and excessive irrigation water.
Impacts and Grower Use: This project potentially will have major impacts on water and N management of Central Valley crops. Since 2011 when CM was launched, user registration and use of the online tool for coastal vegetable and berry production has steadily increased (Figure 2). Several major vegetable operations that use CM on the Central Coast have reported significant reductions in N applications as well as improved water management. The use of CM by Central Valley growers would likely follow a similar pattern after the addition of tree, forage, and warm season vegetable commodities. By providing research-based recommendations that can be customized to the specific conditions of a crop, growers will be able to make better decisions on how to adjust water and fertilizer amounts on a field-by-field basis.

Figure 2. Monthly use of the CropManage web-tool (2011-2016)

Long-Term Solutions and contribution to knowledge base

Improving N fertilizer management practices to meet the regulatory objectives of the State Water Resources Control Board and the Central Valley Regional Water Quality Control Board will likely require a substantial research effort as well as increased grower adoption of best management practices. UC researchers have a long tradition of extending their findings on crop nutrient management through reports, bulletins, trade journal articles, and powerpoint presentations. An online tool, such as CropManage, offers an additional outreach method, where farmers can customize research-based guidelines to the specific climatic conditions, soil type, and development stage of their crops. As more research on crop nutrient management is conducted in the future, CM algorithms can be updated to reflect changes in nutrient and water management guidelines. Finally, by adding almonds, alfalfa, and processing tomatoes to CM, as proposed for this project, additional tree, forage, and warm season vegetables can be added without the need for major changes in the software. Work is already underway to add walnuts and pistachios to CM after almonds are completed.

Supporting N and water management models for different commodities under one online site provides several advantages: 1. Users familiar with how to use CM for one commodity would be able to more quickly learn how to use N and water management tools for additional commodities. 2. Programming resources can be economized because updates needed as web
technology evolves can be applied across all the crops and models supported by CM. 3. The CM online tool should be sustainable because of increased involvement of UCANR farm advisors and specialists in conducting water and N management research and extension.

Although adapting CM for multiple commodities should economize programming costs, we recognize that continued funding will be needed to maintain the online tool, and update the software and services as technology evolves. Without resorting to advertising, we will be exploring several potential revenue streams that may sustain CM: 1. Charging an annual fee to frequent CM users. 2. Charging for special services to interface CM with 3rd party software. 3. Pursuing site-license revenue from institutions in other western states that would like to adapt CM for their commodities and clientele. 4. Pursuing site-license revenue from companies that are frequent users of CM and/or the CM web API. In addition to these revenues sources, we expect that small grants from commodity boards, non-profit and governmental agencies, as well as donations from the agriculture companies and growers can also contribute to sustaining CM.

D. Objectives

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

1. Adding algorithms and user interface modules that accommodates 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 both 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.

E. Work Plans and Methods

Programming approach: CropManage is written in C#.Net programming language using Microsoft visual studio and utilizes a SQL database. The software is organized into an object-oriented structure to provide quick response times and so that the software can be customized for different commodity types. External data from CIMIS is retrieved using HTTP/FTP requests. Scheduled tasks run in the background to bring in daily weather, flowmeter, and soil moisture data. The CropManage Web-API (Application protocol interface) is patterned on Twitter’s API (RESTful API) and allows data to be exported and imported from third party software. Bootstrap is used to create a responsive user interface that sizes correctly on any device (mobile phone, tablet or desktop computer).

The underlying architecture of the CropManage application, including user-interfaces, algorithms, database, and other features, will need to be customized for each commodity type that will be added in Objective 1. Because CM was recently reorganized into an object-oriented
programming structure in 2015, the software can be customized more easily to accommodate different commodities.

Programming tasks outlined in the work plan below will be carried out by UCANR and Breyta Inc. staff. PI’s and collaborators will provide the algorithms for the crop types to be added to CM, and test that the models accurately calculate water and N fertilizer recommendations. Visual Studio is used to track progress in accomplishing programming tasks, where each task is broken down into smaller “user stories” that have specific objectives and testing criteria. Completed stories are reviewed on 2 week iterations. Modifications to CropManage are first tested on the CropManage test site where clients (PI, co-PI’s, and Collaborators) can evaluate if the programmers have met the objectives of a user story and identify programming errors. After reviewing each completed user’s story (task), the PI and co-PIs can either determine that the story is completed or needs further modification. Completed stories are subsequently published on the production site of CM. This iterative process over a short time period assures that the programming staff work closely with the project PI’s and that tasks meet the intended objectives.

The rationale for involving Breyta Inc. (www.breyta.com) in the development of a new CM user-interface (UI) is that UCANR CSIT does not have staff that specialize in UI design, and UCANR has limited programming staff available whom could work on UI development. Figure 3 is an example of a UI that Breyta has proposed for improving the navigation within CropManage. Using tiles and icons, as well as more intuitive organization of the UI, users will be able to quickly navigate through the app.
Figure 3. Example of Breyta’s redesigned user-interface for CropManage (vegetable production).

Work Plan Year 1.

Task 1. Develop and test preliminary algorithms and user interface for processing tomatoes. This task will involve adding models to CM that estimate water and nitrogen requirements of processing tomatoes. UCANR programmers will add algorithms that estimate crop ET based on reference ET, canopy cover and development stage of processing tomato. Algorithms will also be added so that the user can specify the degree of water stress desired during fruit maturity. Irrigation interval will be recommended based on soil water holding capacity, rooting depth, and crop ET. The N requirement algorithm will be based on N uptake data for processing tomato, soil nitrate test values, and potentially whole leaf N values. Data to support models of canopy cover development, root development, and N uptake for processing tomatoes are being developed in an existing FREP grant (Geisseler et al. 2015 CDFA-FREP Award 15-0410SA).

Task 2. Develop and test preliminary algorithms and user interface for almonds
This task will involve adding models to estimate water and nitrogen requirements of almonds to CM. We will add an algorithm that estimates crop ET based on reference ET, canopy cover and development stage of almond. The algorithm will be modified so that users can enter the date of hull split to indicate when the crop Kc value begins to decline and also to enter the degree of water stress desired during maturation of fruits. A module will be added so that users can enter stem leaf water potential values to track water stress during fruit maturation. Irrigation interval will be recommended based on soil water holding capacity, estimated rooting depth, and crop ET. The irrigation model for almonds is currently being developed under a DWR and Cal State University ARI grants. The N requirement algorithm for almonds will be 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.

Task 3. Develop and test preliminary algorithms and user interface for alfalfa
UCANR programming staff will add algorithms to CM for estimating the water requirements of alfalfa. Since alfalfa does not require N fertilizer, a N recommendation module will not be needed, but users will still be able to record P, K, and micronutrients applications. Similar to the other commodities described in tasks 1 and 2, crop ET will be based on estimates of canopy cover. The currently funded DWR project is collecting data to describe canopy development in new and mature alfalfa crops, and the relationship between crop Kc values and canopy cover through surface renewal measurements of crop ET in commercial fields. Irrigation interval will be based on soil water holding characteristics, rooting depth, and estimated ET. The irrigation model will also estimate the first date after the winter to begin irrigating, and allow users to enter cut dates.

Task 4. Update CropManage user interface to improve navigation and data presentation
The joint effort of UCANR and Breyta programmers will update the CropManage user interface. Breyta will take lead on the design of the interface and develop the preliminary code. UCANR programmers will coordinate with Breyta to implement the new interface into CM and resolve
programming bugs that may arise. Tables will be improved to display data clearly and allow the user to easily modify ranges of dates.

**Task 5. Update user help support**
We will expand the help section in CropManage to support the addition of tree, warm season vegetable, and forage crops. Specifically, we will update step-by-step instructions on how to set up a ranch and plantings in CM, and to add soil samples, irrigation, and fertilizer events to specific plantings. Additionally, background and rationale for the guidelines and irrigation and fertilizer N recommendation models employed in cropmanage will be added to the help section.

**Task 6. Write interim and annual reports** We will submit a 6 month interim report and an annual report.

**Work Plan Year 2.**

**Task 1. Finalize algorithms and user interface for processing tomatoes, almonds, and alfalfa**
Program errors will be identified and corrected in the modules for processing tomatoes, almonds, and alfalfa. For each commodity, standard data-sets will be developed to test that algorithm calculations are accurate. Errors in data entry and display forms will be identified and corrected. Forms will be modified as needed to improve clarity, based on feedback from users.

**Task 2. Add module to import soil moisture data from commercial companies and other 3rd party providers.**
The CropManage API (api-cropmanage.ucanr.edu) will be expanded so that soil moisture data from commercial companies or 3rd party providers (grower/shipper operations, agencies, consultants) can be automatically imported and displayed graphically within CropManage. We will confirm that the API works by collaborating with at least one company/3rd party provider of soil moisture data.

**Task 3. Improve visualization of data**
UCANR and Breyta programmers will collaborate to improve the graphical display of data, including the visualization of flowmeter and soil moisture data. Graphs will allow user to quickly zoom to specific ranges of dates and values, and easily distinguish multiple curves on the same graph.

**Task 4. Survey users for feedback on new user interface**
CM users will be surveyed for feedback on modifications made to the interface. We will accomplish this task by conducting small focus groups that will be led by Breyta, Inc. and by developing an online survey that will be sent to registered CM users.

**Task 5. Write interim and annual reports**
We will submit a 6 month interim report and an annual report.

**Work plan for Year 3.**
Task 1. Add module to allow users and 3rd party sources to input canopy cover data
UC ANR programmers will add capacity for users to enter measurements of canopy cover and compare with modeled estimates. Modeled and observed measures of canopy cover will be statistically compared. We will also develop an interface so that users can adjust the CM canopy model to match measurements from their field.

Task 2. Enhance the N mineralization model
Improvements will be made to the existing N mineralization model used in CM based on results and outcomes from an ongoing FREP project lead by Smith. Factors such as soil temperature, OM content, soil texture, water soluble carbon, and other fractions of OM are being evaluated for predicting N mineralization.

Task 3. Conduct training workshops for alfalfa, processing tomato, and almond growers
At least 3 training workshops will be conducted in the Central Valley to introduce CM to alfalfa, almond, and processing tomato growers. Workshops are taught in groups of 30 to 40 participants, and cover steps in using CM, including establishing a farm, entry of irrigation and fertilizer events, as well as getting recommendations.

Task 4. Survey users on modules for almond, processing tomato, and alfalfa.
CM users will be surveyed for feedback on modules for alfalfa, almond, and processing tomato. Users participating in the workshops outlined above (Task 3) will be asked to provide feedback during and at the end of the trainings. Participants frequently provide feedback on CM during the 3 hour hands-on workshops. Additionally, 15 to 20 minutes will be allocated at the end of the trainings for participants to provide suggestions on how to improve CM. We will also conduct small focus groups with users to determine where improvements are needed.

Task 5. Write interim, annual and final reports
We will submit a 6-month interim report, an annual and final report.

F. Project Management, Evaluation, and Outreach.

Project Management: Michael Cahn (PI) will be the overall manager of the project, oversee proposed tasks, and be responsible for interim and annual reporting. Dave Krause (UCANR Communication Services and Information Technology) will guide and manage ANR programmers and coordinate with Breyta Inc. programmers on user-interface tasks. Cahn will also regularly evaluate progress on programming tasks and communicate progress and problems with co-PI’s and collaborators. Each of the commodity that will be added to CropManage will have one or two leads responsible for assuring that algorithms are implemented correctly and calculations are accurate. Leads will provide suggestions for modifying the user-interface to accommodate their specific commodities. They will also participate in quality assurance by using standard test data to determine that the algorithms calculate accurately. Patrick Brown and Saiful Muhammad will provide guidance on the Almond N recommendation model. Allan Fulton will be the lead for implementing the irrigation model for almonds. Daniel Geisseler will collaborate with Michael Cahn on implementing the N fertilizer and irrigation recommendation models for processing tomatoes. Daniel Geisseler will also collaborate with Cahn on updating
the N mineralization model. Dan Putnam will collaborate with Michael Cahn on implementing an irrigation recommendation model for alfalfa.

**Project evaluation:** Evaluation of the project will happen at several levels. CM users will be surveyed during the 2nd and 3rd years of the project to determine if the user interface and new commodity modules are optimized through online surveys, focus groups, and feedback at workshop trainings. Additionally, we will track the use of the online application before and after changes are made to CM. We anticipate the number of users and farms on CropManage will increase, as well as the number of decisions on water and fertilizer applications.

**Outreach:** The CropManage online application is an outreach tool that provides users with recommendations for water and fertilizer N tailored to their site-specific conditions. Models employed in the application are based on previous UC research, much of which has been or is currently funded by CDFA-FREP. Additionally, we will promote the new features and commodities added to CropManage through 3-hour hands-on training workshops (Task 3, year 3) as well as presentations at grower and industry meetings. We will also expand the help section to provide guidance on using the new features added to CM (Task 5, year 1). Finally, new features in CropManage will be promoted through blog, newsletter, and trade journal articles.

**G. Budget Narrative**

**Personnel:** Funding ($36,600) is requested to support UCD Project Scientist, Saiful Muhammad, to assist Patrick Brown with adding the almond N recommendation model to CropManage. We estimate approximately 0.17 FTE per year of his time is needed to oversee this task.

**Supplies:** A total of $1500 is requested for supplies during the 3 years of the project. Supplies include misc. office supplies (paper, ink cartridges), annual software updates (SAS, sigmaplot), and misc. materials needed for conducting CropManage workshops (extra extension cords, batteries, projector bulb, postage costs, agendas, etc.)

**Travel:** $1000 per year is requested to support travel of PI, co-PIs, and collaborators to meet in Davis during years 1 and 2. Each trip would have an approximate cost of $200 (~300 miles, hotel). $1000 is requested for travel during the 3rd year for trips to Davis CA and for conducting CropManage trainings in the Central Valley.

**Professional services:** A total of $180,000 is requested to support programming efforts during the 3 years of the project. Programming rates vary from $90 to $120 per hour depending on the skill and experience of the personnel. Approximately 70% of the funding for programming would be for UC ANR computers services staff with the remainder to support Breyta staff work on the user interface.

**Literature Cited**


Saa Silva, Sebastian, Patrick H. Brown, Saiful Muhammad, Andres Olivos-Del Rio, Blake L. Sanden, and Emilio A. Laca. 2014. Prediction of leaf nitrogen from early season samples and
