

## Application for 2015 University of California Larry L. Sautter Award for Innovation in Information Technology

**Date:** May 6, 2016

**Project Title:** CropManage – A Web Application for Data-Driven Water and Fertilizer Conservation

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CropManage URL: <https://cropmanage.ucanr.edu>

CropManage API URL: <https://api-cropmanage.ucanr.edu>



**CropManage:** a web-based software to assist growers better manage fertilizer and water for their crops

- Facilitates practical application of UC-based agricultural research
- Web application with dynamic database and responsive multi-device user interface
- Iterated over four years of deployment, leading to recent introduction of RESTful API
- Demonstrates ability to significantly reduce fertilizer and water usage without impacting yields
- Wide-scale adoption by over 300 commercial farms

### The Issue

Cool season vegetable production on California's central coast requires significant inputs of water and nitrogen (N) fertilizer to maximize yield and quality. Ground water from wells is used for watering crops and is also the primary drinking water source for coastal communities. After many years of over-irrigation and high nitrogen fertilizer application rates, intended to produce good yields for these crops (known as commodities), many rural wells now show nitrate concentrations in excess of safe drinking water standards. Proposed changes in water quality regulations on the central coast and higher fertilizer prices in recent years have also prompted grower interest in increasing efficiency of nitrogen fertilizer use in lettuce. Additionally, long term drought in California has reduced water supplies to very low levels prompting conservation efforts state-wide. By improving water management and matching nitrogen applications to the uptake pattern of the crop, growers can reduce fertilizer use and address water quality concerns and conservation efforts.

Growers frequently put 50%-100% more fertilizer and 50%-100% more water on vegetables than needed to assure crops attain maximum yields and that the produce meets market quality standards. This practice both wastes water and flushes excess nitrogen deep into the soil beyond the reach of crops roots. Lost fertilizer ultimately ends up contaminating the ground water in addition to wasting

resources. Over-fertilizing in the past has resulted in groundwater contamination with nitrate, a serious concern in the Salinas Valley and other farming regions. In coastal areas, over-pumping wells can also lead to sea water intrusion into the aquifer.

### Scope of Application

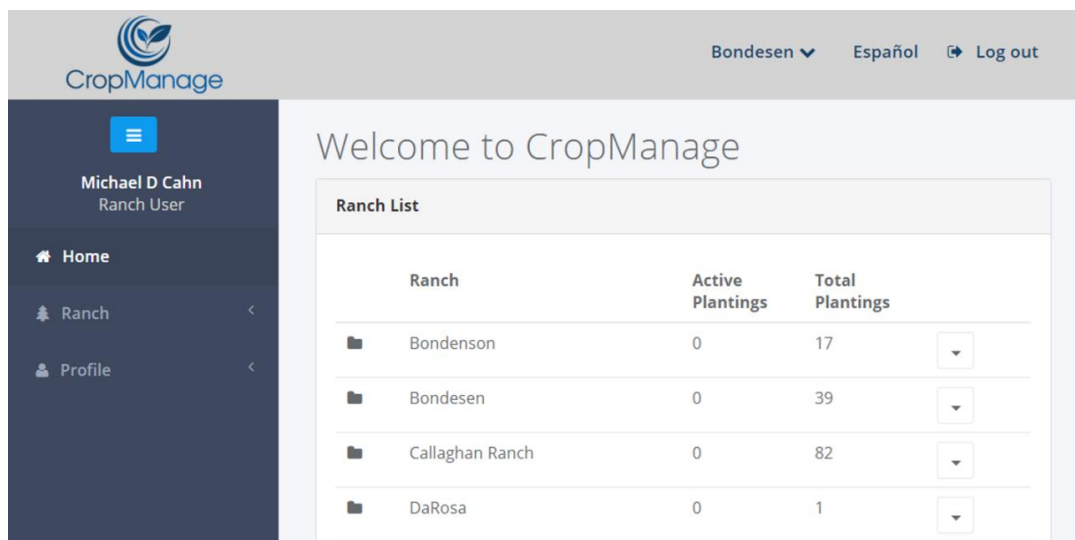
Two previously developed UC ANR tools address these problems by helping farmers conserve water and make better use of nitrogen fertilizer while maintaining crop productivity and quality: weather-based irrigation scheduling and the soil nitrate quick test. The soil nitrate quick test is an in-field assessment to quickly determine whether a grower's soil has adequate nitrogen. Weather-based irrigation scheduling uses weather station data to determine actual crop water needs. Both tools also use information about specific crop characteristics to determine precisely how much fertilizer and water is needed.

By compiling years of research and doing many field trials with these tools, UC Advisors and Specialists have developed guidelines expressed as mathematical algorithms for optimizing water and nitrogen use.

**Weather-based or Evapotranspiration (ET) based irrigation scheduling:**

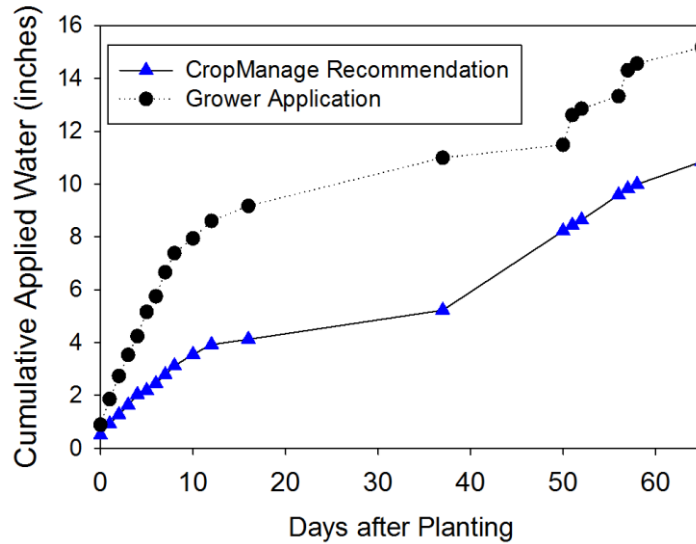
$$ET_{crop} = ET_{ref} \times K_{crop} \text{ (with } K_{crop} \text{ varying from 0.1 to 1.2)}$$

CropManage is an easy and accessible, data-driven application that employs these algorithms to customize fertilizer and water recommendations based on the site-specific needs of the crop, including development stage, soil type, and weather conditions. The software automates the steps required to calculate crop water needs from California Irrigation Management Information System (CIMIS) data, and estimates fertilizer N needs for lettuce using quick N test data and models of crop N uptake. It also helps growers track irrigation schedules and nitrogen fertilizer applications on multiple fields and allows users from the same farming operations to view and share data. CropManage is the first of its kind: a UC research-based, data-driven agricultural technology to conserve water and fertilizer while maximizing crop yields.



*CropManage User Interface (Desktop view)*

The system works by integrating data the user provides on specific plantings with information on location, soil type, plant date, expected harvest date, acreage, crop type, the irrigation system used, soil nitrogen, and previous crop residues. That information is then used to calculate irrigation and fertilizer application needs, which the user can adapt as needed.



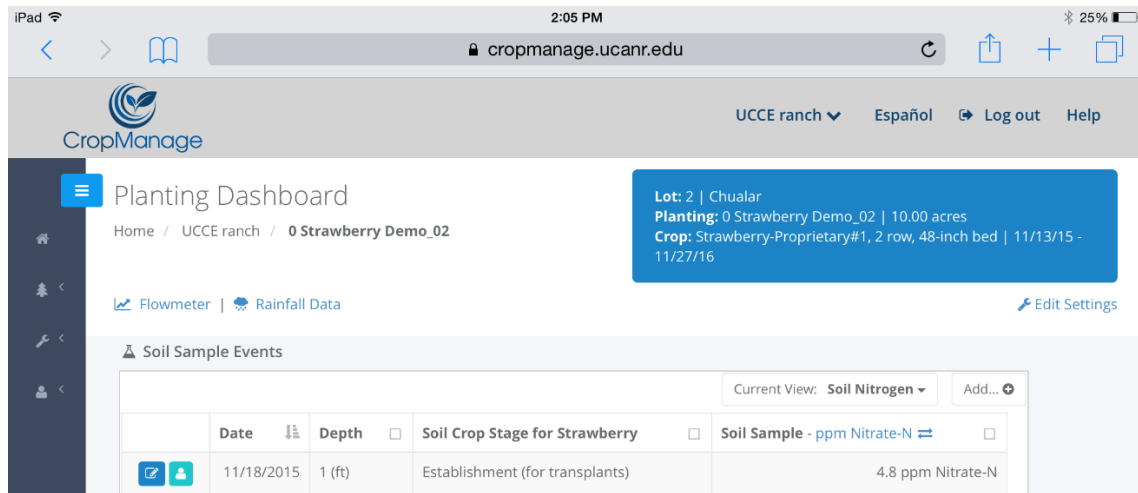
*Example water use reduction from CropManage recommendations*

CropManage combines datasets from many different sources, such as CIMIS and the UC Davis California Soil Resource Lab (SoilWeb). Pulling data from these services provides a seamless way to get required data that would be difficult to access and integrate otherwise. Farmers can monitor the progress of their farms by viewing online tables where irrigation, fertilization and growth are tracked. At any time, all the data can be exported from CropManage and downloaded as an Excel file the farmer can use for accounting or reporting.

### **Application Rewrite in 2015-16**

Initially created by UC ANR in 2011 to provide recommendations for lettuce growers, CropManage was developed in ColdFusion utilizing a SQL database.

Based on direct feedback from CropManage users, ANR rewrote the application starting in 2015. A crucial aspect of the rewrite was to make CropManage extensible to needs or uses not in the scope of the original project, particularly through the addition of an application interface (API). Many growers and companies already use crop management software. Adopting another is not helpful to them. Instead the CropManage API allows them to integrate water saving and nitrogen reducing features into their own software, while also allowing the UC to manage and update the core algorithms as research progresses. In addition, when rewriting CropManage, the development team used a highly modular approach so that growers of multi-year crops, such as nut trees, could also use the application or API.



*CropManage dashboard (tablet view)*

To increase the application’s performance and stability, ANR developers rewrote CropManage version 2 in C# .Net utilizing a SQL database. HTTP/FTP requests fetch external data. In addition, the CropManage Web-API is a RESTful API patterned on Twitter’s API. Scheduled Tasks bring in weather data daily, run any daily calculations, import flow meter or soil moisture data. Bootstrap was deployed to create a responsive UI that renders correctly on any size of device (mobile, tablet or desktop) and gives the user more flexibility and customization options. The UC ANR team worked with collaborating growers and designed the user-interface and menu structures to be intuitive for growers and farm managers to navigate. The interface incorporates a structure that growers commonly use to maintain records of fertilizers, soil tests, and irrigation.

CropManage has been entirely free to use since its inception; the team is looking at alternative licensing models as more features are added to ensure its sustainability and usefulness to the agriculture community. User data was seamlessly transitioned to version 2, and all the information uploaded to CropManage is held confidentially and securely on a UC server, protected by private email address and password. The CropManage website's privacy policy outlines setup options for users who wish to remain completely anonymous.

A consistent element of CropManage has been an on-going effort to raise awareness of the tool among farmers and to foster on-going communication with program participants. The CropManage blog, hosted on UC ANR servers and written by Michael Cahn regularly publishes background research material, important service updates and upcoming opportunities to connect directly with the program’s creators. The blog has received over 20,000 visits since October 2012.

The program began with only one crop, but is currently available for vegetables such as romaine lettuce, iceberg lettuce, broccoli (summer and winter plantings), cauliflower (summer and winter plantings), cabbage (red and green), spinach (baby, teen, bunch), celery, leaf lettuce, baby lettuce, mizuna, and peppers. Berries include strawberry, raspberry and blackberry.

## Results

Commercial-scale trials in lettuce demonstrated that growers using CropManage can reduce nitrogen and water without compromising quality or yield. The nitrogen rate recommended by CropManage

generated yields similar to those of the growers' standard practice, but with an average reduction of 32% in nitrogen fertilizer. Commercial-scale CropManage trials with broccoli used 48% less water than is used for conventional plantings, with no reductions in yield or crop quality.

Since the trials concluded, several major vegetable growing operations in the Salinas Valley have begun using CropManage to help make their water and fertilizer use more efficient. One lettuce grower using CropManage recommendations brought nitrogen applications down by more than 40%. As more commodities and features are added to the online tool, we expect increasing numbers of farmers to start using CropManage to reduce their costs, and improve environmental conditions.

As more commodities and features have been added to the online tool, increasing numbers of farmers are using CropManage. To date, there have been over 1000 users of the software, representing over 300 ranches.

Logins	Virtual Ranches Created	Plantings Created	Irrigation Recommendations	Fertilization Recommendations	Total Recommendations	Soil Samples	Irrigations	Fertilizations
9586	574	2254	18505	5359	23867	4452	18508	5358

*Cumulative CropManage Usage Data (2011 - April 2016)*

Opportunities exist for expanding CropManage to additional commodities and adding in new features and data sources. Currently, ANR is working on adapting the application for commodities grown in other regions of the state, such as warm season vegetables, field crops, and trees crops, while also targeting faster computing time and increased integration with other agricultural management applications.

### Select Publications and Presentations

Cahn, M., T. Hartz. 2013. Irrigation and nitrogen management web-based software for lettuce production. 21th annual CDFA Fertilizer Research and Education Program Conference Proceedings. Oct 29-30. Modesto, CA. pp. 15-19.

Cahn, M., and T. K. Hartz. 2014. Irrigation and nitrogen management web-based software for lettuce production. CDFA-Fertilizer Research and Education Program. Final Report. pp. 20.

Biscaro, A.S.; Cahn, M.D.; Smith, R.; Daugovish, O. and Hartz, T.K. 2015. Developing Web-based Irrigation and Nutrient Management Software for Celery Production. VIII International Symposium on Irrigation of Horticultural Crops, Lleida, Spain. Oral presentation.

Cahn, M., Hartz, T., Smith, R., Noel, B., Johnson, L., and Melton, F. 2015. CropManage: an online decision support tool for irrigation and nutrient management. Proceedings of the Western Nutrient Management Conference. Volume 11 March 5-6, 2015 Reno, NV. pp. 9-13.

Johnson, L., M. Cahn, S. Benzen, I. Zaragoza, L. Murphy, F. Melton, F. Martin, A. Quackenbush, T. Lockhart, 2015. Testing an irrigation decision support tool for California specialty crops. American Geophysical Union Fall Meeting, 14-18 Dec., San Francisco CA (#H53G-1745)

Biscaro, A.S.; Cahn, M.D.; Smith, R.; Daugovish, O. and Hartz, T.K. 2015. Developing Web-based Irrigation and Nutrient Management Software for Celery Production. VIII International Symposium on Irrigation of Horticultural Crops, Lleida, Spain. Oral presentation.

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