CDFA Fertilizer Research and Education Program
2010 Request for Project Proposals

Title: Irrigation and Nitrogen Management Web-based Software for Lettuce Production

Project Location: Monterey, San Benito, and Santa Cruz Counties
Project Duration: Three years

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California Leafy Green Research Board
Monterey County Resource Conservation District
Cachuma Resource Conservation District
Monterey Bay National Marine Sanctuary, NOOA
Chiquita/ FreshExpress

4. Other Funding Sources:

University of California Cooperative Extension, UC Davis, Oregon State University

	Year 1	Year 2	Year 3	Total
CDFA requested funding	$45,284	$49,213	$46,921	$141,418
Other Funding Sources	$8,190	$16,190	$8,190	$32,570
Annual Budget	$53,474	$65,403	$55,111	$173,988

Executive Summary:

Commercial lettuce production requires significant inputs of water and nitrogen fertilizer to maximize yield and quality. Proposed changes in water quality regulations on the Central Coast and higher fertilizer prices in recent years have prompted grower interest in increasing efficiency of nitrogen fertilizer use in lettuce. By improving water management and matching nitrogen applications to the uptake pattern of the crop, growers could potentially reduce fertilizer use and address water quality concerns. Two tools available to growers, the quick nitrate test and CIMIS evapotranspiration data, could help lettuce producers better manage water and fertilizer nitrogen. However, adoption of these practices has not been wide spread. One reason is that these techniques can be time consuming to use, and many farm managers have several hundred fields to keep track of for irrigation, fertilization, and pest control during a single season.

The overall goal of this project is to develop a web-based software tool that will aid growers in optimizing water and nitrogen fertilizer applications in lettuce. The software will employ established guidelines to recommend the amount of fertilizer and water to apply during upcoming irrigation and fertilizer applications. Use of this tool may help growers reduce production costs by applying less fertilizer and water, and minimize water quality impacts of vegetable production on surface and ground water supplies. The software will also help growers track irrigation schedules and nitrogen fertilizer applications on multiple fields. We plan to establish an advisory committee of growers and industry personnel to guide us on the features of the software that would be most useful to them and to provide testing of preliminary versions of the program. We will use funding for this project to hire a professional systems programmer to develop the software. The software program will use a database to manage information of multiple fields. Growers and farm managers will be able to access the software through the internet using a secured logon procedure. The software will automatically update water requirements for each of the growers' fields using evapotranspiration data from regional weather stations and measurements of applied water derived from in-field flow meters. The evapotranspiration data will be automatically downloaded from the California Irrigation Management and Information System (CIMIS), operated by the Cal. Dept. of Water Resources. Flow meter data from individual fields will be uploaded using cell phone communication. A nitrogen uptake module included in the software will provide information on the amount of nitrogen needed for upcoming fertilizer applications.

In addition to software development, we will evaluate the accuracy of the decision support module of the software. We will conduct strip trials in commercial fields to compare lettuce yield using the grower standard management and the software recommended irrigation and N fertilizer management, and to compare potential savings in N fertilizer, water, and nitrate leaching.

We anticipate that this project will lead to the implementation of better fertilizer and water management practices in lettuce production, thereby assisting growers to reduce production and management costs and maintain or even improve crop yields while at the same time achieving water quality targets for ground and surface water supplies on the central coast. This project would also help growers address proposed regulations to limit nitrate discharges to ground and surface waters on the central coast. Improved water management would also help conserve ground water, and minimize the risk of sea water intrusion into the coastal aquifer.

Information developed in this project will be extended through seminar meetings, bulletins, and newsletters. The target audiences for the project are vegetable growers and farm managers, produce company personnel, NRCS and RCD personnel, and crop consultants.

Justification:

Problem: The largest region of cool season vegetable production in the United States is along the central coast of California. California produced more than 350,000 acres of lettuce and broccoli (80% of US production) valued at $2.2 billion in 2007. The intensive production of these commodities requires high inputs of fertilizer, irrigation water, tillage, and pesticides. Agricultural run-off from these lands has impacted the quality of adjacent surface water bodies, and leached nitrate has contaminated ground water supplies.

The Central Coast Regional Water Quality Control Board (CCRWQCB), the regulating authority for water quality in California, identified irrigation tail water from vegetable farms as a source of nutrient, sediment, and pesticide impairments in the Salinas and Pajaro River watersheds on the central coast of California. Both watersheds drain into the Monterey Bay National Marine Sanctuary that protects the unique diversity of the coastal habitat, which includes 50 species on the Federal government's special status list. Under the mandate of the Federal Clean Water Act, the CCRWQCB is establishing total maximum daily loads (TMDL) for nutrients, sediment, and pesticides into the Pajaro and Salinas Rivers. The concentration of sediment and nutrients in agriculture run-off, and the amount of runoff, will need to be reduced to meet the TMDL targets for this region.

In addition to federal water quality regulations, the existing state agricultural discharge waiver for irrigated agriculture on the central coast will expire in July 2010. More stringent regulations are currently proposed to replace the existing waiver and include ground water monitoring for nitrate and reporting of nitrogen fertilizer applications. Growers would also be required to minimize nitrate discharge to ground water and surface water supplies by implementing best management practices.

Improving water and fertilizer management is a key to addressing water quality issues on the central coast. Tail water leaving fields carries nitrogen and phosphorus into surface water bodies which has impacted the Salinas River and coastal sloughs such as Elkhorn slough. Nitrate leached below the root zone has led to high nitrate concentrations in ground water in the Salinas and Santa Maria valleys. Because of the high value of cool season vegetables such as lettuce and the sensitivity of crop growth to deficiencies in water and nitrogen, many growers apply excessive amounts of these inputs. Because of the mobility of nitrate in soil, reducing N fertilizer applications without improving water management may risk causing N deficiency in the crop.

There is evidence that many vegetable growers are making use of new technology and better management to reduce their inputs of water and nitrogen on lettuce. An example of this is the adoption of drip irrigation. Virtually unknown 20 years ago, drip irrigation is now used on approximately 50% of the lettuce acreage in Monterey County, and has greatly reduced irrigation return flows. A survey of fertilizer use in lettuce (Hartz 2010, personal communication) has also documented a substantial decrease in nitrogen fertilizer use over the past 10 years as growers find ways to improve fertilizer management. To sustain these trends and further reduce the impacts of agricultural runoff, growers will need to implement additional conservation practices.

Two additional tools available to growers to manage nitrogen fertilizer and water are the soil nitrate quick test and CIMIS evapotranspiration (ET) data. The soil nitrate quick test is a field test that uses nitrate-sensitive paper strips to estimate the amount of mineral nitrogen available in soil. Previous studies demonstrated that at the time of the first side dress application, growers can reduce N fertilizer applications in lettuce without reducing yields if soil nitrate-N exceeds 20 ppm in the top foot of the soil profile. Soil sampling and the quick nitrate test require less than an hour of time per field. CIMIS (California Irrigation Management and Information System) provides estimates of evapotranspiration for each of approximately 120 weather stations located in most of the agricultural regions of California. The weather stations provide daily estimates of evapotranspiration for a reference crop of grass. The reference evapotranspiration for grass is then used, in conjunction with crop specific coefficients, to estimate the evapotranspiration from other crops of interest, including lettuce. The Department of Water Resources CIMIS staff checks the quality of the CIMIS weather data, maintains weather station instruments, and provides the resulting evapotranspiration data for download and email delivery from the CIMIS website (wwwcimis.water.ca.gov).

Cahn and Smith (2009) conducted 5 large-scale field trials in lettuce demonstrating that the combined use of the soil nitrate quick test and weather based irrigation scheduling can minimize nitrate leaching, reduce fertilizer costs, and maintain yields. Water use was reduced by an average of 16% and N fertilizer use was reduced from an average of 175 lb N/acre to 120 lb of N/acre.

Although the results of these trials are promising, growers have expressed concern with implementation of these recommended practices. Though the nitrate quick test is a relatively straight forward method to monitor soil nitrate, relating the test to a fertilizer rate is more challenging because the N uptake rate of the crop and nitrate concentration of the irrigation water would need to be factored in to the calculation. Using the CIMIS evapotranspiration data for determining irrigation schedules requires a number of calculations that can be time consuming, including accounting for the effects of canopy cover, rooting depth, and soil water depletion on water use of lettuce. Furthermore, most growers are managing several hundred fields simultaneously and cannot dedicate sufficient time to calculate watering schedules for each field.

<u>CDFA/FREP goals</u>

This project will address FREP goals by developing a tool that helps lettuce growers manage fertilizer N and minimize nitrate leaching. The project supports FREP goals: 2 (fertilizer practices), 3 (water and fertilizer interaction) and 7 (Education). By advising fertilizer rates that match crop N uptake, the software should improve N use efficiency of lettuce and minimize N losses. Furthermore, because the software would potentially improve water management, nitrate would be less likely to be lost from the root zone of the lettuce crop. Finally, the software will be designed to educate growers on nitrogen and water management of lettuce by allowing the user to view graphs of nitrogen uptake and water use for their fields. They will be able to see the site specific effects of weather, soil type, and crop growth on fertilizer requirements and water management. Explanations of how water use and nitrogen uptake are calculated will be available in the software. We will also have trainings on using the software.

FREP was originally established in 1990 as a recommendation of the nitrate working group (NWG) to address nitrate contamination of ground water in California. This project addresses the recommendation 4 of the NWG:

> "Develop(ing) nitrate-reducing farming practices tailored to the high-priority areas and that fit into the management programs, in cooperation with growers and other government agencies. "

The Central Coast is high priority area in terms of the number of wells in agricultural areas with nitrate concentrations above the drinking water standard (10 ppm NO_3-N). This project would provide a tool to improve nitrogen management tailored to lettuce which is the most widely grown cool season vegetable in the region. We would be coordinating with growers, produce companies, and partner agencies in this project to have the best possibility of adoption.

Impacts

This project could have potential impacts at several levels. The use of the software would facilitate growers to better manage water and nitrogen fertilizer in commercial lettuce production. Nitrate would be less likely to leach to groundwater because N fertilizer would be managed to match crop uptake demand and water would be managed to minimize leaching while maximizing crop growth. The software would also help growers justify their use of N fertilizer to regulatory agencies by accounting for site specific conditions, such as soil type, time of year, and weather conditions. The software would also help growers keep records of their fertilizer and water management practices. Because the software would be developed in a database, the users would be able to request summary reports of their fertilizer and water use for specific fields or ranches.

Implementation of this project could also help growers save on fertilizer and pumping costs. Large plot lettuce trials conducted in 2008 and 2009 by Cahn and Smith (2010) demonstrated an average savings of $42 per acre for both fertilizer and ground water pumping by using weather based irrigation scheduling and the quick nitrate test. At a site where the grower applied high rates of water and fertilizer $99 per acre was saved by using weather based irrigation scheduling and the quick nitrate test.

In addition to lettuce, this project could also have impacts for other commodities grown on the Central Coast. The software could eventually be adapted for water and nitrogen fertilizer management of cole crops, celery, and strawberries, and other commodities that traditionally require frequent irrigations and high inputs of N for maximizing production.

We do not believe that the risk of regulatory agencies requiring growers to use irrigation and N management software is significant. First, the software will be the property of the University of California which is an educational institution. Second, the Regional Water Quality Control Board has a policy not to recommend practices that growers need to implement to achieve water quality targets. Third, if a regulatory agency mandated that this software be used by growers, the agency may risk liability for potential yield losses. A grower that chooses to use the proposed software would need to agree to sign a liability waiver that explains the potential risks of using a decision support program. The CIMIS website includes a liability waiver statement because the staff cannot guarantee the accuracy of the data.

Long-term solution

This project is aligned with the long term goal of improving water quality on the California Central Coast. By providing a decision support tool for water and N fertilizer management growers may be better able to lessen the impacts of vegetable production on both surface and ground water. Improving N management and irrigation scheduling of vegetables will reduce run-off and limit the transport of nutrients to coastal rivers and sloughs that are important habitats to threatened and endangered species of fish and marine mammals. With improved water management, less N fertilizer may be required to achieve commercial production, and therefore, less nitrate would be lost as leachate which can potentially contaminate ground water.

Related Research:

Nitrogen use and nitrate leaching in lettuce Lettuce is a relatively shallow rooted crop, and generally produced with high rates of nitrogen fertilizer and irrigation water. Because 70% to 80% of N uptake occurs during the 4 week period before harvest (Thompson and Doerge, 1995, 1996), nitrate is easily leached from the root zone during the early phase of growth. Ground water in many of the lettuce production areas of the United States is contaminated with nitrate levels that exceed EPA safe drinking water standard of 10 mg L^{-1} NO_3-N (Lund 1979, US Bureau of Reclamation 1991). Adriano et al. (1972) estimated that 65% of nitrogen applied to lettuce, produced in the southern region of California, was leached below the root zone. Jackson and Stivers (1993) found that a major portion of soil nitrate in commercial lettuce fields was located below the root zone (1.5 ft) by harvest.

Optimizing production, irrigation and N applications can minimize nitrate leaching in lettuce. Aggelides et al. (1999) found that scheduling irrigations using soil water tensions (SWT) of 30 kPa maximized yield and N uptake. Also, Thompson and Doerge (1995,1996) demonstrated that N leaching can be minimized and yield maximized by optimizing irrigation scheduling through the monitoring of soil moisture tension of drip-irrigated romaine and leaf lettuce. Cutting back on N applications in fields with high soil nitrate levels can also minimize nitrate leaching. Hartz et al. (2000) demonstrated that 1 to 2 sidedress N applications could be eliminated in commercial lettuce fields if soil NO_3 in the 0 to 12 inch soil layer was above 20 mg kg^{-1}N at the time of first sidedressing. They found that using the presidedress soil nitrate test reduced the need to apply an average of 127 lb $acre^{-1}$ N. Smith (2009) suggested that the low N needs of lettuce up to 30 days after plantings reduces the need to apply large amounts of N fertilizer until later in the crop cycle.

Water management of lettuce Lettuce growth is sensitive to deficits in soil moisture (Cahn 2009, Shock 2007). Optimal SWT ranges from 7 to 20 kPa (Thompson and Doerge, 1995, 1996, Sammis 1980, Sutton and Merit 1993, Aggelides et al. 1999). Because of the sensitivity of growth to high soil moisture tensions, irrigation scheduling software for lettuce needs to consider water holding capacity and the relationship between volumetric moisture and soil moisture tension. Scheduling irrigations for lettuce using reference crop (grass) evapotranspiration (ET_o) data during the early phase of growth can be problematic because the crop coefficient for lettuce depends on factors influencing soil evaporation. Gallardo et al.

(1996a) developed an ET–based water-use model for lettuce that accounts for evaporative losses from the soil surface. The model estimates ET of overhead-sprinkler irrigated lettuce using ETo, percentage of shaded ground, and an experimentally determined soil hydraulic parameter. At early stages of growth (< 30 DAP), when the crop canopy is small, almost all of the moisture applied with overhead sprinklers was lost by evaporation from the soil surface (Gallardo et al. 1996a, 1996b). Transpiration represented a greater portion of ET after 35 DAP when the leaves of crisphead lettuce cover more than 10% of the ground. Most of the growth and ET occurred during the last 20 days of the crop for spring and summer plantings (Gallardo et al. 1996a, 1996b).

Existing irrigation management software Existing irrigation scheduling software includes: Cropwat (Smith 1992), Basic Irrigation Scheduling (BIS) (Snyder et al. 2000), Consumptive use program (CUP+M) (Orang et al 2004), Wateright, Check book irrigation scheduler (CIS), Washington irrigation scheduling expert (WISE), IrrigatorPro, Kansched, IWM-online. BIS, CUP and CIS are spreadsheet programs that allow the user to estimate irrigation amounts and intervals using evapotranspiration data. WISE (Lieb et al, 2001), Wateright, and IWM-online are web-based programs that allow the user to plan irrigation schedules for multiple fields and crops using historical evapotranspiration data. Wateright (CIT, CSU Fresno) is most suitable for the needs of lettuce growers, permitting access via the internet, and for multiple fields to be managed. However it does not accurately model lettuce crop coefficients. The various irrigation scheduling programs described above offer a multitude of capabilities, but none provide all of the operational features needed for the particular challenges outlined earlier for lettuce irrigation on the central coast of California. The ideal management software would provide for conjunctive management of multiple fields, automated downloading of CIMIS weather data and uploading of irrigation application data from individual fields in real time, and none integrate nitrogen fertilizer management into the scheduling program.

Contribution of proposed project to knowledge base:

This project would develop a novel tool for growers to manage water and fertilizer N in lettuce and maintain records of their practices for multiple fields. Though specific tools exist for improving the management of N and for scheduling irrigation, few tools are available which combine together water and nitrogen management. Integrating management of N and irrigation water may be a key to improving N management in lettuce since NO_3-N is highly soluble and mobile in cool season vegetable systems which require high soil moisture regimes to maximize production.

This project proposed to use a ‘next generation’ scheduling program known as ‘Irrigation Management Online’ (IMO) developed at Oregon State University during the past 5 years with funding from the NRCS and other USDA agencies. IMO is a web-based decision support program for system design, pre-season planning and real time irrigation scheduling. The program provides sophisticated analytical and decision support capabilities, and can be readily modified for additional analytical options. These characteristics make IMO particularly suitable for management of lettuce irrigation in the Salinas valley, including:

(i) The IMO program automatically downloads both current and historical weather data from CIMIS weather stations for use in estimating current crop water use and forecasting crop water requirements to the end of the season;
(ii) the program can be readily modified to also automatically upload flow meter data for use in calculating a daily water balance and forecasting when further irrigation will be needed;
(iii) the program provides for conjunctive management of all fields that share a source of water (rather than managing each field independently) in order to facilitate optimal rotation of deliveries of irrigation water among multiple fields;
(iv) crop water requirements are forecast for two weeks ahead, giving irrigation managers more time and flexibility to modify irrigation schedules to accommodate other field operations;
(v) a flexible and adaptable interface permits users to adapt the system to accommodate local circumstances, science and preferred practices and enable individual managers to utilize their unique experience, awareness of constraints and individual preferences.
(vi) an existing model of nitrogen dynamics in irrigated soils will be incorporated into the model;

Grower Use of the Software:

Growers will likely need to implement practices that minimize water quality impacts to surface water and reduce loading of nitrate to ground water in the upcoming years. They also may need to justify their practices and maintain records of how they are managing both water and fertilizer N.

We anticipate that features of the software such as, the user-friendly design, ability to automatically update weather and field information, and accessibility from the field by cell phone, will facilitate adoption of this tool by growers. Also the involvement of growers and vegetable industry personnel as partners in the development of the software should encourage adoption by the industry.

Objectives

The overall goal of this project is to develop a web-based software tool that will aid growers in optimizing water and nitrogen fertilizer applications in lettuce, thereby saving production costs and minimizing water quality impacts. Specific objectives of the project are to:

1. Develop irrigation and nitrogen management software.
2. Evaluate irrigation and nitrogen management software in commercial lettuce fields.
3. Conduct educational trainings and develop a user guide for the software.

Work Plans and Methods:

Software development: We will develop web-based software that will help users to manage water and nitrogen fertilizer in multiple fields and lettuce plantings. The software will aid record keeping and provide advice for upcoming irrigation and fertilization events in individual fields. Specifically, the software will advise when the next irrigation should be scheduled and inches of water to apply. When fertilizer applications are planned, the program will suggest an amount of N-fertilizer to apply based on a current quick nitrate test result and/or the estimated N uptake of the crop. The software will automatically import evapotranspiration data from the nearest CIMIS station and specific water, soil, crop, and irrigation system information for a field from a database (Figure 1). The software will also have the option for growers to automatically import flow meter data from individual fields via a cell phone-internet connection. We will incorporate grower suggestions in the development of the user interface and display features of the software. Privacy for the user will be assured through a password security login. The software will require a server and program administrator. We plan to use the existing server at the UC Cooperative Extension Office in Monterey County. Users will be able to access the program from computers or cell phones with internet service.

Algorithms used by software: The software will use a crop coefficient algorithm to calculate cumulative crop evapotranspiration since the last irrigation. This algorithm is based on Gallardo et al. (1996) and separately estimates transpiration and soil evaporation for lettuce. The algorithm also estimates canopy growth for lettuce. The recommended amount of water to apply (irrigation requirement) is based on the cumulative ET estimate, uniformity of the irrigation system and salinity concentration of the irrigation water. The software recommends the time interval between irrigations by estimating the allowable volumetric water depletion to attain a user defined soil moisture tension. This algorithm estimates the relationship between volumetric moisture and soil moisture tension from soil texture and bulk density data. The algorithm also estimates crop rooting depth to calculate the volume of available soil moisture.

Software language and computer platform: The software will be written in C# or similar language and operate on the existing network server at the Monterey County Cooperative Extension Office in Salinas CA.

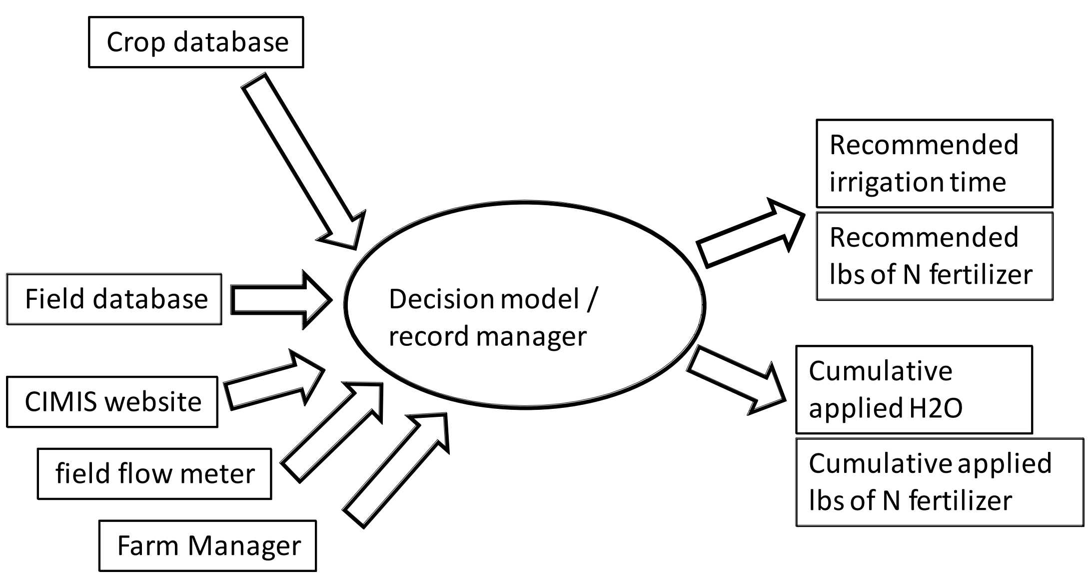

Figure 1. Input and output data sources for the irrigation and nitrogen management program.

Work Plan Year 1.

Task 1. Develop irrigation and nitrogen management software

Summary of sub-tasks for Task 1. We have sub-divided Task 1 into groups of sub-tasks to illustrate the steps required to develop the preliminary version of the irrigation and nitrogen management software. The post-doctoral researcher and/or contracted professional programmers will be responsible for the software development. Marshall English and Michael Cahn will supervise the software development. Tim Hartz will provide expertise for the nitrogen management algorithms employed by the software.

Sub-Task 1.1. Develop and modify algorithms for decision module of software.

A. Finalize lettuce crop canopy and crop coefficient algorithms
B. Develop lettuce root depth algorithm
C. Finalize soil moisture release algorithm
D. Finalize irrigation scheduling algorithm
E. Develop nitrogen fertilizer recommendation algorithm

Sub-Task 1.2. Grower oversight of software development.

A. Establish advisory panel of growers and industry personnel
B. Advisory meeting on user interface.

Sub-Task 1.3. Develop user interface module of software

A. Develop user login interface
B. Develop user input interface
C. Develop output interface

Sub-Task 1.4. Develop software database

A. Define information fields for database
B. Develop preliminary database
C. Integrate database with user interface

Sub-Task 1.5. Develop modules to import external data

A. Develop module to import reference ET data from CIMIS website
B. Develop module to import flow meter data from Campbell scientific datalogger
C. Integrate data acquisition with decision module

Sub-Task 1.6. Report to FREP

A. Write interim and annual reports.
B. Present oral report and interpretive summary.

Work Plan Year 2.

Task 2. Field evaluate irrigation and nitrogen management software We will work with a core group of growers and produce company personnel to test preliminary versions of the software. The software will also be made available to produce companies interested in adapting it to their internal databases (eg. planting/harvesting schedule). The users will first use the software to shadow their own decisions for specific fields. They will maintain their records of irrigation and fertilizer events in the software. We will conduct interviews with growers and farm managers who beta-test the software to determine the usefulness of decision support program, including programming bugs they identify, usefulness of the decision support module, usefulness of record keeping module, etc.. We will use the feedback from the group to modify the software.

After the user recommendations are incorporated into the software, we will conduct at least 5 field trials to compare the irrigation and N fertilizer recommendations between the decision support program and the normal practices of growers. A strip within a lettuce field will be managed using the software after thinning stage. The test strip will be sufficiently wide for commercial harvest measurements. Flow meters will be used to monitor the water applied to the grower standard area and to the test strip. Soil moisture will be monitored in both treatments using watermark sensors. Soil samples will be taken weekly in both treatments to monitor soil nitrate status. Fertilizer applications will also be recorded for the grower and test strip areas of the field. Commercial yield of the test strip will be compared to commercial yield of the grower area on either side of the strip.

Summary of sub-tasks Michael Cahn and the UC SRAIII will participate in completing the subtask 2.1. The post-doctoral researcher will participate in subtask 2.2.

Sub-Task 2.1. Cooperate with a core group of growers to evaluate the irrigation and nitrogen fertilizer recommendations of software on 4 to 5 lettuce fields.

Sub-Task 2.2. Interview growers and farm managers on the usefulness of the software and incorporate feedback into final version.

Sub-Task 2.3 Conduct strip trials comparing applied water, N fertilizer and yield between grower treatment and treatment following software. Note that this task will be started during year 2 and completed by year 3.

Sub-Task 2.4. Report to FREP.

A. Write interim and annual reports.
B. Present oral report and interpretive summary.

Work Plan Year 3.

Task 3. Conduct educational trainings and develop a user guide for the software. We will conduct at least one educational workshop to train growers to use the software, and conduct one-on-one trainings with farm managers as needed. We will also write a user manual that will be available on the website.

Summary of sub-tasks Michael Cahn and the UC SRAIII will participate in completing the subtask 3.2 and 3.3. The post-doctoral researcher will complete subtask 3.1 under the supervision of Marshall English and Michael Cahn.

Sub-Task 3.1. Write user guide for irrigation and nutrient management software. The guide will be downloadable from the UC Cooperative Extension Website and also integrated into the software in the help section.

Sub-Task 3.2. Conduct a workshop to train participants on using the irrigation and nitrogen management software. The workshop will cover principles used in the decision support module of the software (N uptake of lettuce, water use of lettuce), data input requirements, and demonstrate examples.

Sub-Task 3.3. Conduct individual trainings on using irrigation and nitrogen management software. These trainings will include onsite visits with growers, farm managers, and agency personnel who cannot attend the general workshop or need additional training.

Sub-Task 3.4. Report to FREP.

A. Write interim and final reports.
B. Present oral report and interpretive summary.

Project Management, Evaluation, and Outreach

Management Michael Cahn will serve as the principal investigator on the project, and he will have the responsibility to oversee that all tasks are carried out, provide progress and final reports, and manage the budget. Michael Cahn and Marshall English will oversee the software development. Tim Hartz will provide input on the nitrogen management module of the software. Marshall English will supervise a post-doctoral researcher who will do a majority of the programming. As needed, phases of the software development will be contracted to a professional programmer familiar with web-hosted data base programming. A staff research associate III, working under the supervision of Michael Cahn, will organize the grower/industry group that will oversee the development and beta-testing of the software. In addition, the staff research associate will implement the field trials that compare the decision support approach to the grower standard practice.

Evaluation We will evaluate the project at several levels. First we will organize a group of growers to help oversee the software development. Second we will interview the beta-testers of the software and incorporate their suggestions into an improved version of the program. Third, we will conduct strip trials to validate the accuracy of the decision support component of the software and to estimate potential savings in N fertilizer, water, and nitrate leaching. Finally, we will have an evaluation questionnaire after conducting training workshops on using the software.

Outreach This project will consist of several types of outreach activities:

1. Workshop to train users on irrigation-nitrogen management software
2. Individual trainings on software
3. Presentations on software at educational meetings such as the annual UC irrigation and nutrient management seminar held annually in Salinas CA.
4. Development of a user manual to accompany the irrigation-nitrogen management software.
5. Popular trade journal article and newsletter article

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