California Institute for Water Resources
Annual Technical Report
FY 2013

Introduction

The California Institute for Water Resources (CIWR) is a special program within the University of California's (UC) Division of Agriculture and Natural Resources (ANR). The Institute is enabled by the federal Water Resources Research Act (WRRA), with the mission of supporting research and extension activities that contribute to the efficient management of California's water resources, in water quality, quantity, and reliability.

Headquartered at ANR's offices within the University of California's Office of the President, CIWR is well positioned to coordinate research, education, and extension activities across the 10 campuses of the UC system, as well as academic institutions across the state. Throughout California, ANR is an engine for problem solving. Serving as the bridge between local issues and the power of UC research, ANR has more than 300 campus-based specialists and county-based advisors working to bring practical, science-based answers to Californians.

CIWR brings together federal, state, and local communities to identify issues and builds support for water-related research. The CIWR mission is to provide leadership that links stakeholders with UC resources to carry out statewide water planning, research, and outreach.

The UC system supports nine additional water-related research centers and two water-related programs with the sustained efforts of approximately 271 UC faculty members on eight of UC's 10 campuses. The CIWR engages with these water centers and programs as well as with non-UC water centers and academics interested in California water (e.g., several CSUs, Stanford University, and others)to enhance their research and outreach programs.

Given the WRRA statutory mission of education and outreach, CIWR is best suited to linking water research to the needs of water managers and users throughout California. The CIWR serves an important linkage niche: science to public policy, science to education and outreach, researchers to State agencies and the public, ANR initiatives to each other, UC water centers to each other, and UC water centers to other academic institutions.

The Institute's Director is housed within ANR to facilitate a statewide focus. The Institute may have affiliate faculty from ANR, the different UC campuses and other universities as appropriate. The CIWR Director serves as a key spokesperson on California water issues; working with federal, state, regional, nonprofit, and campus stakeholders to improve the understanding of water issues through advocacy and outreach programs.

The Director also serves as Leader for ANR's Strategic Initiative on Water Quality, Quantity and Security. Thus, part of CIWRs mission is to assist ANR in the management of this Strategic Initiative. As part of that Initiative, CIWR helps to manage ANR's competitive grants portfolio. Through this partnership, CIWR is developing such strategic themes of importance as irrigation efficiency, ecosystem services, source water production and protection, water policy, drinking water, food safety, and water quality.

2013 Highlights

Staff: A water program analyst was hired in March 2013 to support the mission of the institute.

Pilot advisory committee: We established a pilot advisory committee that helped us to review our mission, set priorities for our competitive grants program and aided in grant proposal reviews.

Competitive grants program: CIWR began its own competitive grants program in 2013. Working with our advisory committee, we solicited proposals for California water related research, education, and extension

projects from academics at qualified institutions statewide to be funded under the 2014 WRRA (contingent on funding).

Program development: We are developing several program areas. One key area is in nutrient management, where we are in the process of holding a series of nitrogen management workshops for certified crop advisors throughout the state, with the support of the California Department of Food and Agriculture. We are also managing the Rosenberg International Water Policy Forum, an ongoing program of the University of California, which brings water scholars from the around the world together on a biannual basis to collaborate on water related conflict.

Outreach: We established a new website that provides new content and incorporates resources that were part of the former UC Water Resources Center, creating rich content for users. In addition we are establishing a strong social media presence that enables us to quickly reach out to journalists and others. In a short period of time, we have become a go-to source for water information across the state.

Research Program Introduction

The California Institute for Water Resources (CIWR) is involved in three competitive grants programs. We manage a Request for Proposals to allocate funds from our USGS 104b program and the Joseph G. Prosser Trust. We also assist, through the University of California Agriculture and Natural Resources (ANR) Water Strategic Initiative, with the ANR competitive grants program.

USGS 104b: The CIWR receives funds from USGS that are used to support the operations of the Institute, our Information Transfer and our Competitive Grants Program. Information on outcomes from our 104b competitive grants program is provided elsewhere in this report.

Joseph G. Prosser Trust: The Irrigation Management Program, funded by the Joseph G. Prosser Trust, supports a broad spectrum of research related to crop irrigation management, focusing on conserving water, improving irrigation efficiency, and optimizing yields. Emphasis is placed on research outputs that improve current practices and on dissemination of information.

ANR Grants Programs: ANR invests in research, education and outreach projects that meet the goals of its mission by conducting a competitive grants program aimed to support high priority issues, encourage collaboration among ANR representatives and key players from throughout the state, support short-term high-impact projects, continue to strengthen the research-extension network, yield policy relevant outcomes, and achieve significant statewide economic, environmental and social impacts in California. To address some of these challenges, ANR developed the Strategic Vision 2025 to identify and meet the statewide scientific, technological, social, and economic demands facing California. As an initial implementation strategy, ANR identified five Strategic Initiatives that are favorably positioned within the Division to achieve maximum results. To attest to the importance of California water research, one of the five grant categories is specifically dedicated to “Water Quality, Quantity, and Security.”

Award--Monitoring and Forecasting Climate, Water and Land Use for Food Production in the Developing World

Basic Information

Title:	Award--Monitoring and Forecasting Climate, Water and Land Use for Food Production in the Developing World
Project Number:	2008CA262S
Start Date:	10/1/2008
End Date:	9/30/2013
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

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Research Program

The University of California, Santa Barbara, engages in a program of research in support of U.S. Geological Survey Famine Early Warning Systems Network (FEWS NET) activities. The research focuses on the development and application of techniques for identifying conditions impacting the physical variables governing crop growth, such as the timing and amount of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators. This is accomplished with a network of field scientists from Africa and Central America collaborating with research scientists at the University of California, Santa Barbara. This approach leverages the credibility and relationships developed by field scientists to ensure communication both to and from people on the ground, in order to maximize the impact of research activities conducted domestically, with an eye towards reducing the severity of outcomes resulting from food insecurity in the developing world.

Field Scientists
The field scientists were responsible for numerous trainings on the use of advancing technologies as well as more specific rainfall and crop monitoring tools, presentations at key meetings, as well as interaction with local agencies and officials to both share and acquire data and information to be used in assessing the food security of vulnerable peoples. Field scientists trained FEWS NET national and regional technicians in the use of core remote sensing and analysis datasets, and how to implement such sources to inform food security decision making. The field scientists also worked with national meteorological and agricultural services to build capacity in remote sensing and GIS technologies at those institutions. Their regional expertise was called on to participate in climate outlook forums as well as a number of United Nations meetings. These members of the project raise the profile of FEWS NET activities and communicate significant findings from the field to the FEWS NET home office, as well as from scientists in the United States to decision makers in the field.

GeoWRSI
The GeoWRSI tool continued to be refined and developed in order to allow users to drive the crop model with the addition of their own input rainfall and crop parameters. This work included trainings in southern Africa, eastern Africa, and Central America. Through this process there were improvements to the software and the software continues to improve and take traction as a critical component of our work.

EWX datasets and development
A flagship web application, the Early Warning Explorer (EWX), was developed by the team at UCSB. This tool allows the user to view a variety of rainfall, temperature and NDVI in a mapping environment. Development of this tool required significant programming and debugging. Besides the development of the web interface of the EWX, there was also substantial time spent creating the data underlying the website because it involves developing anomalies and z-scores for all observations. This technology was eventually transferred to USGS and is currently available on their servers.

Temperature Impacts on crop development
Drought and heat stress are two of the most important environmental factors influencing crop growth, development, and yield. However, the role of temperature in maize production is often overshadowed by the more apparent limitation of water availability, especially for rainfed agricultural systems. Historical warming trends, and projected growing season temperature increases with climate change, indicate that fundamental plant responses to high temperature can no longer be overlooked. Like water stress, extreme levels of heat can endanger yield-influencing

plant processes such as seedling survival and fertilization. Additionally, the speed at which a crop grows is directly determined by its thermal environment. This results in the control of the timing of development stages and duration of growth, both strong determinants of yield, by growing season temperature. By quantifying the historical role of temperature on maize development we gain insight to the level of risk faced at particular locations. That is, when changes to maize phenology or heat stress exposure induced by local warming place limitations on maize yield potential that have previously been unseen. This information can be used to assist current seasonal crop forecasting models and improve projections of what the maize growing regime will be like with continued climate change.

Climate Change Activities

Climate projections are in general agreement with observations, however within season variation is dependent on the particular global climate model (GCM). Combined results were synthesized for the food security community in a USGS-USAID fact sheet titled “Using observed warming to identify hazards to Mozambique maize production”.

We have determined that the long-term warming of the west Pacific Ocean can be attributed to increases in regional tropospheric water vapor. The warming of the west Pacific Ocean in conjunction with the La Nina phase of El Nino-Southern Oscillation (Hoell and Funk 2013, in review) have been linked to longer, more frequent and more intense global droughts, particularly over eastern Africa (Hoell et al. 2013, in review). Warm west Pacific Ocean sea surface temperatures during La Nina events present a new characterization of ENSO events, with different teleconnections than traditional La Nina. (Hoell and Funk, 2013).

Satellite-based Rainfall Estimates

Satellite rainfall-based gridded products have been created at a global spatial extent at 0.05° resolution and pentadal timestep. The two primary products are the Climate Hazards Group Historical Infrared Precipitation (CHIRP) and the CHIRP with stations (CHIRPS). The CHIRP combines NOAA B1 IR data with TRMM data which is then multiplied by the climatology to create a time-series from 1981 to present. Once this dataset is complete, an algorithm is used to blend available stations into the product to make sure the rainfall estimates are in line with station observation. This effort has resulted in a state of the practice dataset which will be integrated into FEWS NET monitoring activities.

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Effect of forest management on water yields and other ecosystem services in Sierra Nevada forests

Basic Information

Title:	Effect of forest management on water yields and other ecosystem services in Sierra Nevada forests
Project Number:	2012CA292B
Start Date:	1/1/2012
End Date:	12/31/2015
Funding Source:	104B
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	Ecology, Water Supply, None
Descriptors:	None
Principal Investigators:	Kevin O'Hara

Publications

There are no publications.

Research Program

The Sierra Nevada harbors globally distinctive forest resources that deliver a wide variety of benefits to the citizens of California and elsewhere. These benefits derived from natural ecosystems – also called ecosystem services – include recreation, biodiversity-, conservation, water, and forest product-related services. These ecosystem services often pose competing aims relative to forest management, but there are few mechanisms to evaluate the tradeoffs and complements related to different strategies.

Water is arguably the highest-value ecosystem service associated with the conifer forests of California's Sierra Nevada. Yet the provision of this essential service is vulnerable to changes in the energy and water balance associated with climate warming. To date, we have observed more precipitation falling as rain versus snow, earlier snowmelt, and greater summer water deficits. Such climate forcing will impact the water balance for the foreseeable future. However there is the potential to manage the water balance in forest ecosystems. The dominant vegetation (i.e., trees) is highly productive, forms dense canopies, and consequently, uses a great deal of water. There is a strong positive correlation between annual net primary productivity (the ultimate measure of the photosynthetic capacity of the ecosystem) and evapotranspiration (the primary cause of water loss). Any manipulation that reduces the productivity (i.e., removes trees) reduces evapotranspiration, shifts the balance of energy driving snowmelt, and thus may affect soil-water storage and streamflow. Water from the Sierra Nevada provides both hydropower and water supply to downstream users. Reducing and restructuring the forest vegetation density can also mitigate the negative impacts of wildfires as well as accomplishing important forest-restoration.

Project Objectives

1. Determine rates of evapotranspiration in Sierran mixed-conifer/true fir forests;
2. Determine the water use efficiency of trees and shrubs in Sierran mixed-conifer/true fir forests;
3. Determine the potential for forest management to delay snow melt in Sierran forests;
4. Determine the potential economic tradeoffs of forest management treatments to affect water yield and ecosystem services; and
5. Involve stakeholders in decision-making regarding forest management and watershed effects.

Summary of Activities/Outcomes to Date

This long-term project has completed two years of field work and is active in outreach and site selection for future work. This involves four areas:

1) developing leaf area prediction equations for Sierra Nevada conifers. This work is complete and we now have a set of equations for both prediction of leaf area on intensive research plots and for leaf area prediction from inventory data;

2) we have placed sensors in streams in control and burned areas, as well as in areas scheduled for future forest vegetation treatments to develop streamflow and stream temperature records. We have also placed soil-moisture, temperature, humidity, snow-depth and solar radiation sensors in strategic locations to develop spatial estimates of these quantities (Figure 1). We have initiated hydrologic modeling to estimate the effects of forest vegetation treatments on the water cycle in mixed-conifer mountain forests. This modeling involves extensive analysis of field data and calibration of spatially explicit models using snow, soil moisture and streamflow data. The scales of modeling extend from 300-10,000 ac scale (Figure 2). The initial modeling is being leveraged from ongoing work in the study area.

3) involvement of stakeholder groups through newsletters and a social media presence: http://ucanr.edu/sites/cff/Sierra_Nevada_Watershed_Ecosystem_Enhancement_Project/Newsletters_204/;

4) we have narrowed our search for field implementation sites to two areas on the Tahoe and Stanislaus National Forests. It is possible both areas will be used. Additionally, a private forest products company, Sierra Pacific Industries, has approaches us about installing similar studies on several of their watersheds.

We continue to anticipate that this work will provide new insights into the effects of forest structure on snow retention and water yields from Sierra Nevada mixed-conifer forests. The region continues to experience controversy over wildlife management, threats from fire, and water shortages are becoming a greater threat as we understand more about potential climate change in California. This work is as timely as when it was first proposed.

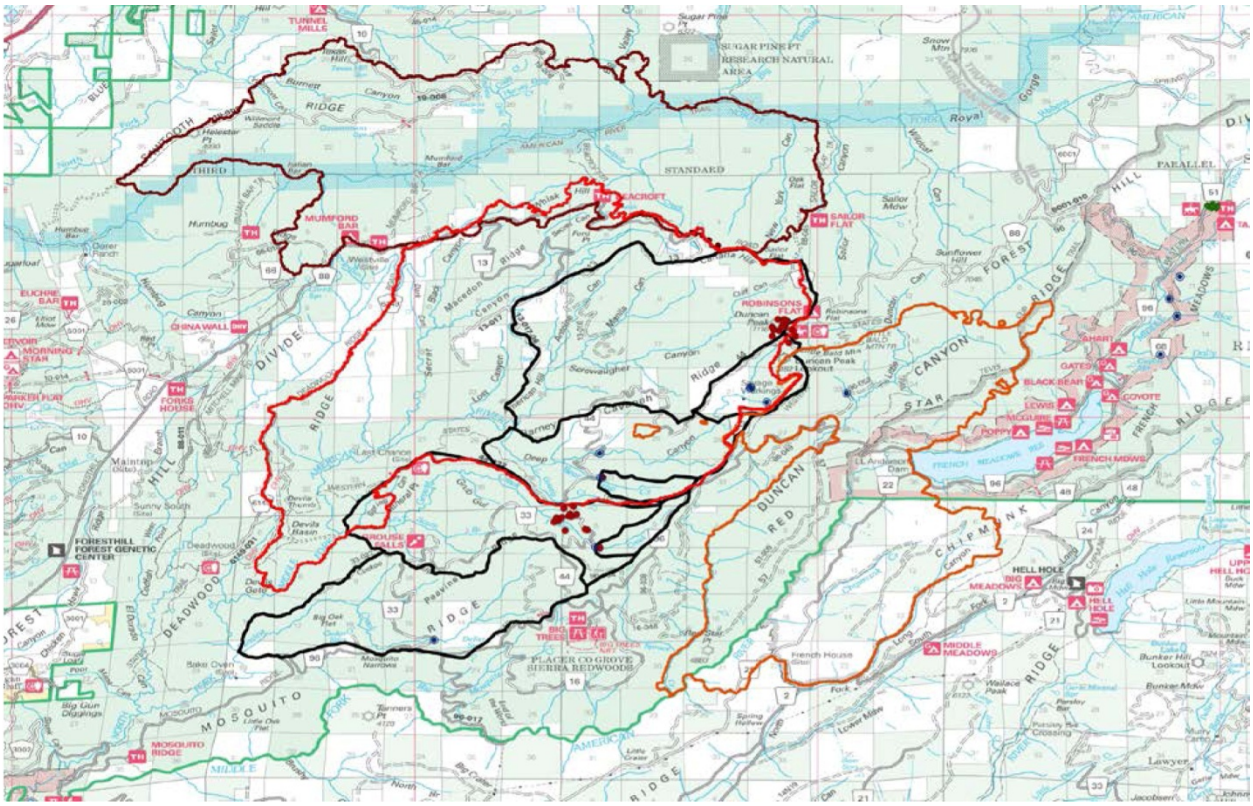

Figure 1. Map showing perimeters of watersheds and fires. Red dots are locations of snow, temperature and soil moisture sensors. Blue circles are stream level sensors.

Figure 2. Watershed surrounding unnamed steam in El Dorado County, California.

Information Transfer Program

We have developed an annual newsletter that is posted on our website: http://ucanr.edu/sites/cff/Sierra_Nevada_Watershed_Ecosystem_Enhancement_Project/Newsletters_204/?newslist=4051. We also have a mailing list for distribution of these newsletters as well as a social media presence.

Outreach and Extension Programs for Co-management of Food Safety and Ecosystem Services in Fresh Produce

Basic Information

Title:	Outreach and Extension Programs for Co-management of Food Safety and Ecosystem Services in Fresh Produce
Project Number:	2012CA293B
Start Date:	9/1/2011
End Date:	3/15/2013
Funding Source:	104B
Congressional District:	44
Research Category:	Ground-water Flow and Transport
Focus Category:	Agriculture, Irrigation, Management and Planning
Descriptors:	None
Principal Investigators:	Mary Bianchi

Publications

There are no publications.

Research Program:

Growers and distributors of California's fresh produce have long realized that reliably safe products and responsible use of resources inspire brand trust and consumer loyalty. Balancing food safety and sustainability goals has become a vital element of produce management. On their farms, growers are active stewards of the land, protecting soil and water quality as well as supporting wildlife populations by preserving their habitat. At the same time, growers must ensure that their crops are free from contamination by fecal matter, which may introduce pathogens that can cause food borne illnesses. Balancing these unique management objectives while maintaining a sound bottom line is a central challenge for California's fresh produce producers and distributors.

Co-management offers a solution. Co-management minimizes the risk of fecal contamination and the resulting microbiological hazards associated with produce production while simultaneously conserving soil, water, air, wildlife, and other natural resources.

Information Transfer Program:

Since organizing the seminal co-management research conference in 2007, ANR advisors and specialists have participated in outreach, extension and research efforts. In cooperation with the Farm Food Safety and Conservation Network, ANR academics have organized and participated in biennial Co-management Forums on the Central Coast to bring the latest research information to policy makers, conservation and food safety professionals including FDA, EPA, USDA, DFG, USF&WS, and CA LGMA. ANR academics have received more than $1.5 million dollars in research funds to answer some of the critical research questions regarding microbial contamination in the production environment

Recognizing the need for a widely distributed and science-based description of co-management, ANR produced an Issues Brief in 2012, presented to the Food Science and Technology and the Sustainability Committees at the United Fresh 2012 meetings in Dallas Texas. This Issues Brief, *"Balancing food safety and sustainability: Opportunities for co-management*," has been distributed to federal and state policy makers as well buyers and distributors of fresh produce.

Co-management is widely recognized as a necessary consideration in fresh produce production. Consideration of co-management is included in the California and Arizona Leafy Greens Marketing Agreement and the 2011 Food Safety Modernization Act. By working together, food safety and sustainability managers can build understanding of how food safety practices may affect natural resources and how conservation practices affect food safety. Building understanding of co-management into all levels of management - from farm to fork - will ensure that the fresh produce industry continues to lead the way to successful balance of food safety, sustainability and a sound bottom line.

Regarding the Co-management Forums - Hank Giclas, senior vice president for strategic planning, science and technology at Western Growers said "despite the challenges, growers are committed to providing safe food while ensuring conservation of vital natural resources and these forums are

important settings in which a free flow of ideas and experiences are exchanged to further both objectives".

We are continuing to work with stakeholders to identify and engage appropriate produce buyers and food safety professionals. These audience members have helped us to design appropriate and effective mechanisms of ongoing outreach and actionable training materials for outreach to industry decision makers.

Creek Carbon - Dynamics of Carbon and Nitrogen in Restored Mediterranean Riparian Zones

Basic Information

Title:	Creek Carbon - Dynamics of Carbon and Nitrogen in Restored Mediterranean Riparian Zones
Project Number:	2012CA294B
Start Date:	9/1/2011
End Date:	8/30/2013
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Category:	Water Use, Surface Water, Nitrate Contamination
Descriptors:	None
Principal Investigators:	David Lewis

Publications

1. UC Delivers, Sequestering Carbon from Watershed Restoration Conservation Practices 2013
2. Policy Brief, Realistic expectations for C sequestration from conservation practices 2013
3. Temporal vs. spatial and local vs. landscape control of C sequestration dynamics by riparian forests in Ca. coastal watersheds 2013
4. (ANR 8000 Series and/or Cal. Ag.), Watershed conservation practices also improved air quality 2013
5. UC Delivers, Sequestering Carbon from Watershed Restoration Conservation Practices 2013
6. Policy Brief, Realistic expectations for C sequestration from conservation practices 2013
7. Temporal vs. spatial and local vs. landscape control of C sequestration dynamics by riparian forests in Ca. coastal watersheds 2013
8. (ANR 8000 Series and/or Cal. Ag.), Watershed conservation practices also improved air quality 2013

Research Program:

Land managers have restored river and stream banks using revegetation technologies with native plant material for over four decades in coastal California, achieving multiple ecosystem functions and natural resource management objectives. The number of river and stream restoration projects in the U.S. has steadily increased since the 1980s with over $2 billion spent on river restoration in California. In Marin County alone, 25 miles of stream has been restored since the 1960s.

Despite the increase in stewardship effort and funds expended, there has been limited documentation of improvements in water quality, watershed functions, and ecosystem services. Though evidence of improved wildlife habitat is abundant, the current knowledge base is lacking an understanding of the biophysical relationships between soil properties, flooding, riparian forests, and the temporal vs. spatial variability controlling how conservation practices have restored watershed functions.

In addition to wildlife habitat and water quality, watershed restoration appears to have also improved air quality. Total and labile carbon increase over time as project age increases. The upperbank locations have consistently higher amounts than floodplains; however, the rate of carbon sequestration appears greater in floodplain soil and correlates to the rapid increase in canopy cover and root density as sites transition from grassland to riparian forest. Multivariate analysis is in progress to ascertain if keystone species or certain functional groups maximize long-term carbon storage. The conservation partnership, including most importantly its farmers and ranchers, have a fuller appreciation for what they have accomplished and are applying our results towards options to improve long-term agricultural viability.

Understanding long term carbon sequestration potential within coastal California streams provides a foundation of knowledge to maximize these ecosystem services. In doing so, the researchers are adding to the growing body of knowledge validating the outcomes from ecological restoration and conservation practices. The information is timely for policies and programs to mitigate greenhouse gas emissions and develop market driven incentives for carbon sequestration. It is also needed by restoration planners for optimizing revegetation project design and setting realistic objectives. Lastly, the funding community will utilize this research to guide the allocation of financial resources and document long term project effectiveness.

The objectives of our project include: 1) documenting the potential to store carbon and nitrogen pools in soil and vegetation across a chrono-sequence of riparian restoration projects; 2) measuring carbon pool fractions within riparian soils to document long term carbon sequestration potential within these systems; 3) understanding the characteristics of riparian restoration (age, biodiversity, stream characteristics) that affect processes of carbon and nitrogen storage in order to maximize these ecosystem services for future efforts; and 4) making the research information available to restoration practitioners, funders, and permitting agencies for integration of carbon sequestration and nitrogen storage into stream restoration objectives.

Figure 1 - 30 year old stream restoration site (left) and aggrading soil in a floodplain plot (left) depicting layers of annual leaf litter and sediment deposition (right).

Information Transfer:

Changes in Knowledge
The above ground component of carbon sequestration has been well understood and justifies revegetation with woody species as a mitigation tool for climate change. However, research into the below ground storage is showing the importance of recalcitrant carbon forms to long-term sequestration. Understanding the recovery processes of riparian forest systems offers pragmatic applications to riparian buffer management and maximizing ecosystem services over multiple decades.

Changes in Skill/Behavior/Practice
The effectiveness of existing conservation practices to impact new societal concerns offers the feedback needed to improve and fine-tune approaches for maximizing environmental returns. Stream restoration can now target watershed locations and soil types that provide the greatest potential for long-term carbon sequestration. Landowners are prioritizing new sites for conservation and restoration projects in addition to organizing old ranch photos that document pre-project conditions of previously restored sites.

Changes in Conditions
The conceptual relationships between vegetation and ecosystem function provides the foundation for impacting communities' approach to stewardship. Local Resource Conservation Districts are implementing water quality trading credits and grant funds are being leveraged to install new stream restoration projects. Policies encouraging ecosystem services have also utilized our results to validate how conservation practices have improved numerous ecological attributes and functions.

Creating or strengthening partnerships with stakeholders
The on-farm conservation partnership working across Marin, Sonoma, Napa, and Mendocino counties has directly benefited by this project in addition to numerous local programs such as the Marin Carbon Project. For example, the Natural Resource Conservation Service, local Resource Conservation Districts, university researchers, and private consultants are incorporating the

concepts and preliminary results from this project into their assessments of conservation practice effectiveness and plans to compensate landowners for providing ecosystem services.

Our research findings are being disseminated on multiple levels to local partners, regional programs, and international disciplines. The interest is very high in our results in part because of the critical reviews watershed restoration has received in recent years after spending over $2 billion dollars across the US. In addition, on-farm conservation practices are existing stewardship systems hungry for evidence supporting or refuting effectiveness to mitigate climate change that are reviewed by applied scientists in economics, agriculture, engineering, and many others with international exposure.

In summary, we documented the variation of carbon trajectories in streamside soil and vegetation from watershed restoration programs and the associated conservation practices. The information provides a data-driven quantification of actual outcomes for potential inclusion in market-based payments for ecosystem services and carbon or water quality credits. The conservation partnership, including most importantly its farmers and ranchers, have a fuller appreciation for what they have accomplished and greater options to improve long-term working landscape viability.

Award--Innovations for an Integrated Approach to Climate Analysis and Food Security Monitoring

Basic Information

Title:	Award--Innovations for an Integrated Approach to Climate Analysis and Food Security Monitoring
Project Number:	2013CA306S
Start Date:	12/12/2012
End Date:	2/11/2014
Funding Source:	Supplemental
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Management and Planning, Water Supply
Descriptors:	
Principal Investigators:	Doug Parker

Publications

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Research Program

The University of California, Santa Barbara, engages in a program of research in support of U.S. Geological Survey Famine Early Warning Systems Network (FEWS NET) activities. The research focuses on the development and application of techniques for identifying conditions impacting the physical variables governing crop growth, such as the timing and amount of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators. This is accomplished with a network of field scientists from Africa and Central America collaborating with research scientists at the University of California, Santa Barbara. This approach leverages the credibility and relationships developed by field scientists to ensure communication both to and from people on the ground, in order to maximize the impact of research activities conducted domestically, with an eye towards reducing the severity of outcomes resulting from food insecurity in the developing world.

Field Scientists
The field scientists were responsible for numerous trainings on the use of advancing technologies as well as more specific rainfall and crop monitoring tools, presentations at key meetings, as well as interaction with local agencies and officials to both share and acquire data and information to be used in assessing the food security of vulnerable peoples. Field scientists trained FEWS NET national and regional technicians in the use of core remote sensing and analysis datasets, and how to implement such sources to inform food security decision making. The field scientists also worked with national meteorological and agricultural services to build capacity in remote sensing and GIS technologies at those institutions. Their regional expertise was called on to participate in climate outlook forums as well as a number of United Nations meetings. These members of the project raise the profile of FEWS NET activities and communicate significant findings from the field to the FEWS NET home office, as well as from scientists in the United States to decision makers in the field.

DSI Development
The Decision Support Interface (DSI) represents and attempt to integrate rainfall and greenness measure for known agricultural areas in the developing world to identify hazardous conditions. This work was developed at UCSB, and incorporates concepts borrowed from the United States Drought Monitor product. A web-based visualization interface for the DSI data stream was designed and implemented by the EROS team, and the tool is now freely available and regularly updated for incorporation in monitoring activities.

Developing Near-real Time Drought Impact Assessment Using Dekadal WRSI
Preliminary calculations of vulnerability models for millet in Niger and maize in Kenya, Malawi and Mozambique have been conducted. These models estimate the loss in crop production as a result of water deficits, as estimated by the RFE2 rainfall estimates and available yield data. From these models, loss exceedance curves estimating the probability of experiencing a particular loss in these countries have been calculated. These models represent a new development in the field of hazard risk analysis.

Station Database
A PostgreSQL database has been established, including global precipitation station data that contains a variety of sources including the GHCN, GSOD, GTS, GHA as well as other sources obtained through personal contacts in Latin America. The goal of creating a comprehensive, one stop, data portal for precipitation data is close to realization, and has been internally tested. We have accumulated nearly 200,000 stations, over 955,000,000 daily precipitation observations and over 45,000,000 monthly estimations dating back to 1832. Our data stream updates daily with new

observations being automatically ingested, and when appropriate, calculating monthly and pentadal precipitation accumulations. Our goal has been to develop a data stream that will allow us to get the latest and most comprehensive precipitation data available in one location.

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Enhancing Groundwater Recharge through Distributed Stormwater Capture

Basic Information

Title:	Enhancing Groundwater Recharge through Distributed Stormwater Capture
Project Number:	2013CA307B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Ground-water Flow and Transport
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Andrew Fisher

Publication

1. Russo, T. A., A. T. Fisher, and B. S. Lockwood, Assessment of managed aquifer recharge potential and impacts using a geographical information system and numerical modeling, Ground Water, in press.

Research Program

California leads the nation in both overall fresh water demand and use of groundwater. California also faces an ongoing water supply crisis, with many parts of the state not having access to high-quality water where and when it is needed. The problem is exacerbated by limitations in the availability of new surface water storage (and the political challenges in developing new surface storage facilities); a massive, complex, expensive, energy-demanding, and over-allocated system for state-wide conveyance of fresh water; rapid population growth and associated demand for housing, infrastructure, and services in some of the driest parts of the state; a changing climate that influences the magnitude, timing, locations, and forms of fresh water available throughout the year; and the need to plan for variability and uncertainty.

One result of the ongoing imbalance between fresh water supply and demand is massive, statewide groundwater overdraft (estimated to be millions of acre-feet/year). Although it is a common phenomenon, the ultimate causes and impacts of groundwater overdraft are locally variable. Specific problems include: ground subsidence and permanent loss of storage, seawater intrusion, upflow of lower-quality water from depth, losses from critical surface systems (streams, lakes, and wetlands), and damage to fragile aquatic ecosystems.

Our overall project objectives are to (1) create regional partnerships among resource managers, regulators, landowners, and other stakeholders, (2) help to establish managed aquifer recharge (MAR) systems as highly controlled, quasi-natural systems that are manipulated and monitored in real-time, and (3) use stormwater runoff, excess winter stream and wetland flows, and recycled water to improve both the quantity and quality of fresh water resources. NIWR funding on this project supported part of the costs for development, instrumentation, and monitoring of a field site where an MAR system was installed, so that we and project partners can quantify the processes and properties that are most important in making these system successful. NIWR funding also supported completion of a geographical information system and modeling study of a groundwater basin in overdraft, to identify locations where future MAR projects might be best placed.

Project development, operation and monitoring occurred during the 2013-14 water year at the Bokariza-Drobac Ranch (BDR). This site comprises ~125 acres that are actively farmed and ranched, draining into a collection basin having an area of 2.5 acres. Drainage is controlled through manipulation of a series of channels and gates, so that inflows during major storm events can be regulated. Soils in the collection basin are mainly sandy loam and clayey sand, and infiltration rates are estimated to be on the order of 0.2 to 4 m/day. Inflow to the collection basin occurs mainly through a single culvert. Instruments deployed during the project period included: pressure gauges and staff plates to measure inflow and water levels in the basin, thermal probes to determine infiltration rates across the basin, a precipitation gauge and time-lapse camera, and sediment monitoring and collection systems to assess what kinds of maintenance may be needed year by year to maintain this system. This year we also installed a data logger and transmission system to telemeter some of our field data back in near-real time, so that we could monitor system performance.

Unfortunately this was a drought year in California, so total inflows to this system were only about 20 ac-ft. But when this information is combined with monitoring from previous years, we have data that suggests that normal to wet year benefit should be on the order of 100-150 ac-ft/yr. In addition, sediment collection studies from the last water year demonstrate that the basin collected about 450 tons of sediment along with inflowing water, and this sediment has a grain size that is finer, on average, than native soil. These observations suggest that site maintenance will be required to assure that the collection basin is not clogged over time.

We also completed a regional analysis of the Pajaro Valley Groundwater Basin to (a) assess regional suitability for MAR, and (b) quantify the relative impact of MAR activities on groundwater levels and seawater intrusion. The first step comprised an analysis of surface and subsurface

hydrologic properties and conditions, using a GIS. Surface and subsurface data coverages were compiled, georeferenced, reclassified, and integrated (including novel approaches for combining related data sets) to derive a spatial distribution of MAR suitability values. In the second step, results from the GIS analysis were used with a regional groundwater model to assess the hydrologic impact of potential MAR placement and operating scenarios.

GIS results suggest that about 7% (15 km^2) of the basin may be highly suitable for MAR. Modeling suggests that simulated MAR projects placed near the coast help to reduce seawater intrusion more rapidly, but these projects also result in increased groundwater flows to the ocean. In contrast, projects placed farther inland result in more long-term reduction in seawater intrusion and less groundwater flowing to the ocean. This work shows how combined GIS analysis and modeling can assist with regional water supply planning, including evaluation of options for enhancing groundwater resources.

Information Transfer

We have presented results of this work at numerous public meetings and, as a result, there is growing interest regionally in applying what we have learned to other settings. Invited presentations were made during the reporting period to the following groups. Presentations made to a general audience are marked with *. Other presentations were technical in nature:

2014	*UCSC Chancellor's Associates reception	Santa Cruz, CA
	*California Naturalists Program, UCSC	Santa Cruz, CA
	Climate Change, Water and Society IGERT, UCD	Davis CA
	*Bay View Elementary School, Fourth Grade	Santa Cruz, CA
2013	*Rotary Club, Santa Cruz Chapter	Santa Cruz, CA
	*Community Water Dialog, Pajaro Valley	Watsonville, CA
	*Chancellor's Associates reception, Chancellor's residence	Santa Cruz, CA
	Managed Aquifer Recharge in the Urban Environment, GRA, CA	Burlingame, CA
	Human-Environmental Security in Asia Pacific: Water-Energy-Food Nexus	San Francisco, CA

We were interviewed by the following media groups, generating stories that were published in popular media:
- KUSP public radio story on Groundwater Recharge, Santa Cruz, CA
- National Geographic online story on the California Drought and methods needed to address it

Students supported with NIWR and associated funds, in part, during the project:
Sarah Beganskas, Ph.D. student (2012-)
Ryan Harmon, B.S. (expected June 2014)
Eric Lujan, B.S. (expected June 2014)
Emily Edwards, B.S. (2013)
Barbara Taylor, B.S. (2013)

Notable Achievements

We have demonstrated initial efficacy of stormwater capture linked to MAR, and will be preparing peer-reviewed publications based on this work (after collecting one more year of field data). We also tested and demonstrated utility of real-time data monitoring of MAR. In part on the basis of

this work, we prepared two successful proposals, in collaboration with the Resource Conservation District of Santa Cruz County. Funding for both projects should arrive later in 2014 (about $200k in total). One project (funded by the California State Coastal Conservancy) involves a GIS and runoff analysis to assess application of stormwater capture and MAR on a regional basis. The other project (funded by the CA Department of Water Resources through the Integrated Regional Watershed Management Program) involves installation of two new MAR systems to capture stormwater runoff. We are conducting initial meetings and field visits to start work on both of these projects in Spring 2014. We recruited two outstanding new graduate students to work on these projects, starting in Fall 2014. Lead PI was also invited to consult with Governor Brown's Science and Policy staff on development of new responses to the ongoing drought, at a meeting in Sacramento (with other selected UC faculty).

Publications and Citations

One peer-reviewed paper supported by this project has been accepted for publication and is now in press. We have made presentations at technical and public meetings, as listed below, and we acknowledge NIWR support in all papers and when making all presentations.

*Paper published in peer-reviewed journals (*student co-authors)*
*Russo, T. A., A. T. Fisher, and B. S. Lockwood, Assessment of managed aquifer recharge potential and impacts using a geographical information system and numerical modeling, Ground Water, *in press*.

*Papers Presented at Professional Meetings during review period (*student co-authors)*

- Fisher, A. T., *Racz, A., *Schmidt, C., Los Huertos, M. Lockwood, B., Russo, T., Using Multiple Intrinsic Tracers to Map Spatial and Temporal Variability during Managed Recharge, Web seminar ("Real GRACast" presented by the Groundwater Resources Association of California), series on *Groundwater Recharge, Part 5: Tracers and Groundwater Recharge*, broadcast on the World Wide Web, 20 March 2013.
- *Racz, A. J., Fisher, A. T., *Schmidt, C. M., Los Huertos, M., Lockwood, B. S., Multi-year impacts of sedimentation during managed aquifer recharge, *Am. Geophys. Union,* Hydrology Days, 33rd Annual Meeting, Colorado State University, 25-27 March 2013.
- Fisher, A. T., *Russo, T., Lockwood, B., Los Huertos, M., Identification and Investigation of MAR Project Sites for use of Stormwater Capture, *Managed Aquifer Recharge in the Urban Environment: Technical and Policy Challenges,* Burlingame, CA, 23 May 2013.
- *Beganskas, S., Fisher, A. T., and Los Huertos, M., Developing and testing a system of linked stormwater capture and managed aquifer recharge, *29th Biennial Groundwater Conference and 22nd GRA Annual Meeting*, Sacramento, CA, 9 October 2013.
- Fisher, A. T., Water Supply in California and the Future of Managed Aquifer Recharge, , *Seminar presented at the monthly meeting of the Santa Cruz Rotary Club,* Santa Cruz Elks Lodge, Santa Cruz, CA, 8 November 2013.
- *Beganskas, S., Fisher, A. T., *Hill, C., and Los Huertos, M., Coupling stormwater capture and managed aquifer recharge, *Eos Trans Am. Geophys. Union*, Fall Meeting, Suppl., San Francisco CA, H11F-1220, 9 December 2013.

Online Irrigation and Nitrogen Management Tool for Vegetables

Basic Information

Title:	Online Irrigation and Nitrogen Management Tool for Vegetables
Project Number:	2013CA308B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Category:	Irrigation, None, None
Descriptors:	
Principal Investigators:	Michael D Cahn

Publications

There are no publications.

Research Program

The main objective of this project was to increase the capacity of CropManage (CM), an online resource that uses weather, soil, and crop data to assist growers in using water and nitrogen fertilizer efficiently for producing cool season vegetables. Specifically, we expanded CM to include additional vegetables such as broccoli and cauliflower, thereby providing a tool to growers that comprehensively addresses the cool season vegetable production system. We also interfaced CM with the UC Davis SoilWeb so that growers can easily import soil data into their ranch data base. Finally, we automated the capability to import and display soil moisture data from sensors in the field. Potentially this project will increase efficient use of water and nitrogen fertilizer, increase grower compliance with water quality regulations, and enhance safety of drinking water supplies.

Cool season vegetable production requires significant inputs of water and nitrogen (N) 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 and other cool season vegetables. 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, the quick soil nitrate test and weather-based irrigation scheduling, have been shown to help lettuce producers better manage water and fertilizer nitrogen. Trials we conducted in commercial fields have demonstrated that soil nitrate concentrations greater than 20 ppm NO_3-N, are sufficient to maximize crop production. In addition, we have shown that evapotranspiration data available from the California Irrigation Management and Information system (CIMIS), can be used to accurately estimate the appropriate volume of water to apply to meet crop needs and minimize potential leaching losses of nitrate-N.

Both the quick nitrate soil test and weather based irrigation scheduling require increase management time for growers to implement these practices in their farming operations. The quick nitrate soil test entails collecting a representative soil sample in the field, extracting the sample, and calculations to estimate the concentration of soil nitrate. Weather based irrigation scheduling requires calculating crop evapotranspiration (ET) from CIMIS reference ET data and a crop coefficient corresponding to the developmental stage of the lettuce crop. In addition, information on the soil type and irrigation system is needed to determine the optimal irrigation interval and run-time. With multiple fields and ranches to track throughout the season, customizing water and fertilizer for individual fields could become a significant cost for growers.

CropManage, (ucanr. org/cropmanage) an online database-driven tool, was developed by UC Cooperative Extension to assist growers and farm managers in determining water and nitrogen fertilizer applications on a field-by-field basis. The software automates steps required to calculate crop water needs from CIMIS ET data, and estimates fertilizer N needs for lettuce using quick N test data and models of crop N uptake. The web application 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.

Tasks completed:

1. Analyze data from commercial fields and develop algorithms for crop growth rate, rooting pattern, and total nitrogen uptake for broccoli, cauliflower and cabbage.

Canopy cover, N uptake, and root depth data for broccoli, cauliflower and cabbage, collected from commercial fields during the past 2 years, was analyzed to develop algorithms for the CropManage online decision support tool. Canopy cover data shown in Fig. 1 were fit to a developmental model proposed by Gallardo et. al. (1996):

$$\text{Canopy cover (\%)} = Gmax/(1 + \exp[A + B \times day/(Maxday * Fmax)] \quad (1)$$

where Gmax is the maximum canopy cover, *A* and *B* are fitted parameters, day is the number of days after planting or transplanting, *Maxday* is the total days between planting and the end of the crop (last harvest), and *Fmax* is the fraction of the crop cycle when the maximum canopy size is achieved. Parameters for this model were determined for broccoli, cabbage, and cauliflower grown under various planting configurations and shown in Table 1 for broccoli. N uptake data determined from whole plant biomass and tissue N content data were fit to models to describe crop N uptake patterns. Rooting depth was found to follow a linear pattern to a 48 inch depth for broccoli, cauliflower, and cabbage.

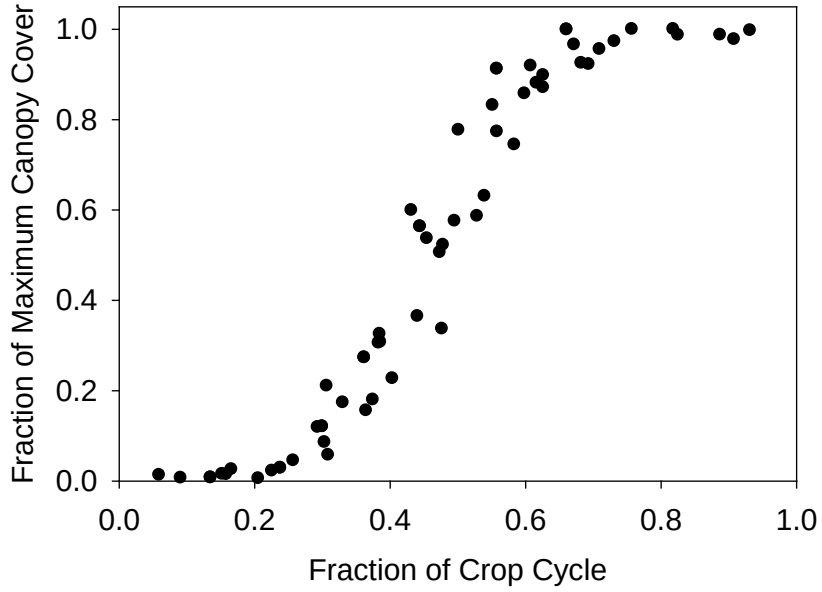


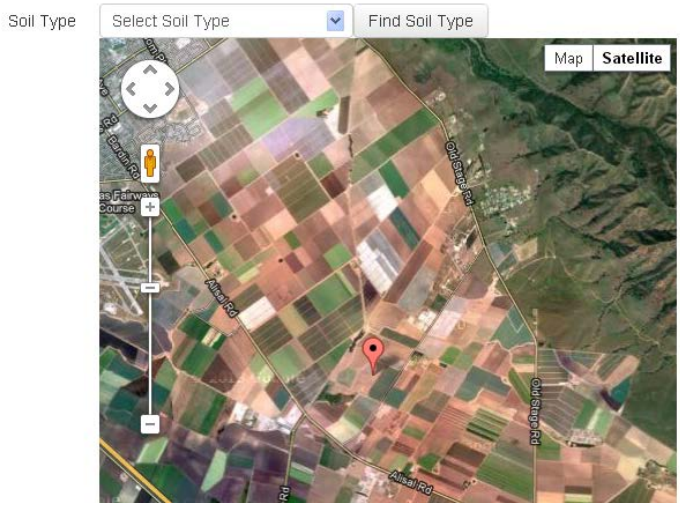
Figure 1. Canopy development of summer planted broccoli expressed as a fraction of maximum cover.

Table 1. Canopy cover model parameters for broccoli.

					Model Parameters				Model fit
Crop description	number of sites	bed width	seedlines	Crop Cycle	A	B	Gmax	Fmax	R^2
	#	inches	#	days			%		
Winter, direct seeded	3	40	2	137	5.39	-7.70	89	0.96	0.87
Summer, direct seeded	6	40	2	87	6.51	-10.82	98	0.78	0.91
Summer, transplanted	1	80	5	87	5.35	-11.13	99	0.91	0.97
Summer, transplanted	2	40	2	87	3.34	-7.83	99	0.93	0.95

2. Link CropManage to the UC Davis SoilWeb tool.

CropManage was linked to the UC Davis SoilWeb tool so that users can determine the soil type and physical properties required to make irrigation and nutrient uptake decisions for their fields. When setting up a ranch, the user selects the field to query for soil type using the cursor (Fig 2).



Soil Name:
Elder sandy loam, 0 to 2 percent slopes
Soil Series:
Elder
Soil Texture:
sandy loam

Soil Depth	Silt (%)	Sand (%)	Clay (%)	Organic (%)	Density (g/cm^3)	Soil Tension (cbar)	Mineralization Rate (lb N/acre/day)
1 ft	19.6%	67.4%	13%	2.5%	1.6	7	0.2
2 ft	19.6%	67.4%	13%	2.5%	1.6	5.8	0.2

Figure 2. Interface for selecting a soil type in CropManage using a mapping tool and UC Davis Soil Web.

3. Automate CropManage to retrieve and display soil moisture data from fields

This task was reduced due to a cut of 48% of the original funding request. UC ANR programmers added capacity to CropManage to import soil moisture data files and display in graphical and/or tabular form. An example of a graphical display of soil moisture tension data as viewed in CropManage is shown in Fig. 3. To save programming costs, a web tool provided by Google, is used for the graphical display. The ANR programmer also added the ability to import data files from third-party providers of soil moisture data. This feature will allow CropManage to be used by commercial companies providing soil moisture monitoring services to growers. Improvements still need to be made in the graphical interface for importing and displaying soil moisture data.

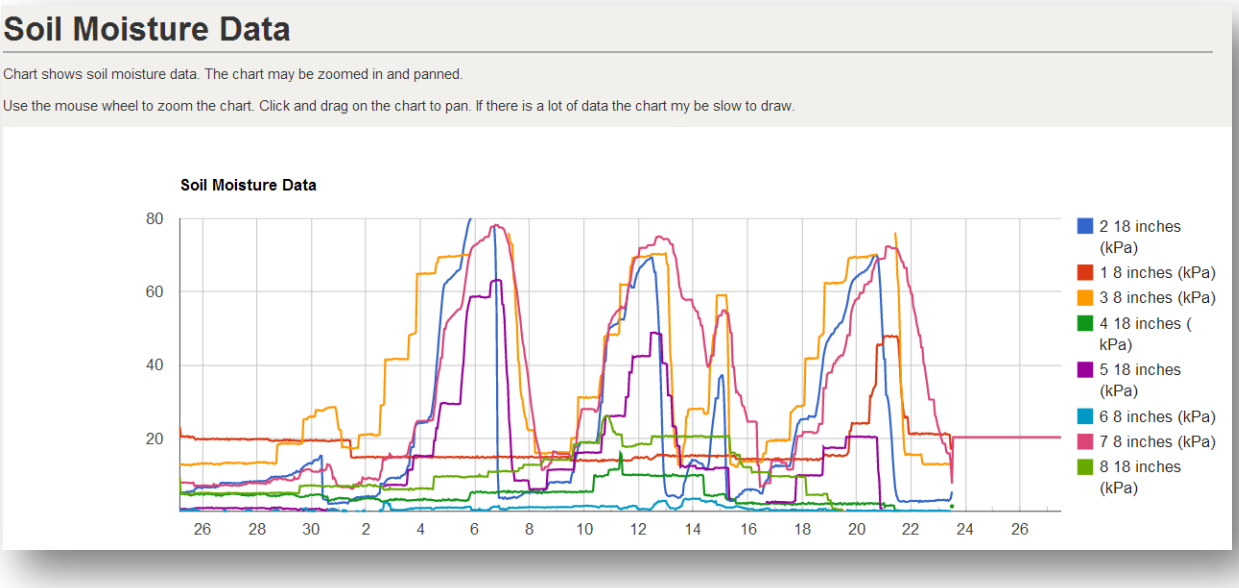


Figure 3. Soil moisture tension data displayed in CropManage.

4. <u>Field demonstrate CropManage tool to growers and crop advisers</u>

We reduced the number of participating growers from 3 to 2 for this task due to the cut-back in requested funding by 48%. We conducted demonstration trials in 2 commercial broccoli fields during the 2013 season. Plots, the width of a commercial harvester, and the length of the field, were managed either under the Grower's standard practice for irrigation or by following the recommendation of CropManage which uses the model of crop canopy and CIMIS reference ET data to determine water needs. Water savings compared to the Grower standard practice was approximately 50% (14 inches) during the drip phase of the crop. The reduced application of water increased the final soil nitrate concentration at harvest, indicating that less nitrate leached under the CropManage recommended practice.

Table 2. Applied nitrogen fertilizer and water, and yield results for broccoli strip trials.

Strip Trial #	Management treatment	Applied Water: Sprinkler	Applied Water: Drip	Fertilizer N	Final soil nitrate-N[x]	Marketable Yield	difference between
		inches		lbs/acre	lbs/acre	lbs/acre	%
		harvested 9/11/13					
1	Grower	7.4	26.1	166	23.3	14006	
	CropManage	7.4	12.9	166	181.9	14741	5.2
		harvested 9/30/13					
2	Grower	4.4	31.0	187	48.3	20930	
	CropManage	4.4	15.2	187	83.2	20382	-2.6
		Average					
	Grower	5.9	28.5	176	35.8	17468	
	CropManage	5.9	14.0	176	132.6	17561	1.3

[x] estimated after harvest for the 0 to 3 foot depth.

Information Transfer

Despite a reduction in funding, we were able to carry out all proposed to tasks to improve CropManage capabilities and to demonstrate the decision support tool to growers. Fortunately matching funds were secured from a CDFA specialty crop block grant which were used to supplement this project. The field trials completed in commercial fields demonstrated that following CropManage recommendations can potentially reduce water use by 50% after crop establishment in broccoli.

Notable Achievements

Matching funds were secured from a California Department of Food and Agriculture specialty crop block grant were used to leverage this project in spite of a reduction in NIWR funding.

Evaluation of Surface Water Quality on Soil Leaching Fraction and Alfalfa Yield in the Delta

Basic Information

Title:	Evaluation of Surface Water Quality on Soil Leaching Fraction and Alfalfa Yield in the Delta
Project Number:	2013CA309B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	None
Principal Investigators:	Michelle LeinfelderMiles

Publications

There are no publications.

Research Program

The Sacramento-San Joaquin River Delta region is a unique agricultural region of California. While the region is named for its waterway configuration, the Delta region is also unique for its fertile soils, and of the 738,000 total acres, approximately 500,000 acres of the Delta are farmed. As the Delta Crops Resource Management Advisor for the University of California Division of Agriculture and Natural Resources (UC ANR), my role is to do research and outreach on topics of local concern. My program is shaped by themes of sustainable crop production and soil resource management. In that vein, I am evaluating the effect of surface water quality on soil salinity in Delta alfalfa fields. In 2012, alfalfa was the second most widely grown crop in the Delta at approximately 72,000 acres.

Delta farming is challenged by soil salinity, which can stress crops and reduce yields. In general, plants are stressed by saline conditions because they must expend more energy to take up water, leaving less energy for plant growth. This trade-off is challenging for alfalfa growers because the marketed crop is the vegetative growth, and extra energy to take up water reduces hay yields. To prevent this trade-off, Delta soils should be leached of salts by applying water in excess of that used by evapotranspiration, or the amount of water evaporated by the soil and transpired by the plant during photosynthesis. The leaching fraction is defined as the minimum fraction of the total applied water that must pass through the soil root zone to prevent a reduction in crop yield from excess salts.

Two factors establish the leaching fraction: the salt concentration of the applied water and the salt sensitivity of the crop. Alfalfa is moderately sensitive to salinity and is irrigated with surface water in the Delta; thus, the quality of surface water in the Delta affects growers' ability to leach salts. Currently, state water policy salinity standards for the south Delta – an area southwest of Stockton, CA – are set at levels meant to sustain agricultural yields, based on crop tolerances of salt-sensitive crops. Salinity levels, however, vary over space and time, and sometimes the salinity exceeds the standards.

The reporting period marked the first year of this project. The objective of the work was to gain knowledge on the current leaching fraction being achieved in south Delta alfalfa soils and update the state of knowledge on how surface water quality and rainfall affect the leaching fraction. Seven south Delta alfalfa fields were selected based on similar soil characteristics but differing irrigation source water. Measured parameters included soil salinity in the spring and fall of 2013, groundwater salinity, surface water salinity with each irrigation, alfalfa yield, and winter rainfall over the 2013-14 season. Anticipated outcomes of the proposed work will be to update the state of knowledge on the achievable leaching fraction, to inform future policy on south Delta salinity standards and assist growers with irrigation strategies for effective salinity management.

Information Transfer Program

Information transfer has occurred through written and online publications and personal consultations. As a new project, it was important to communicate effectively with growers in order to gain their support for the project. The project is relevant for growers because the information gained will be translated into strategies for salinity management. Through personal consultations, I found seven growers who were interested in cooperating. I maintained frequent communication with these growers to discuss the protocols and data. I have written about the project in newsletter articles. The Field Notes newsletter is published and sent out of our local UC Cooperative Extension office and reaches 1,787 people. I have also written about the project for the UC ANR Alfalfa and Forage News blog, to which 168 people are subscribed.

Additionally, my information transfer program reaches non-government and government agencies. I have been in communication with the manager of the South Delta Water Agency and a senior water resources control engineer of the State Water Resources Control Board. I provided a

field tour, including demonstrations of protocols, to these individuals who have interest in surface water quality in the Delta.

Notable Achievements or Awards

After receiving the federal funds, the South Delta Water Agency supported my program in the amount of $15,000.

Publications

Other publications:

Leinfelder-Miles, M.M., 2013. Delta research overview. Field Notes. University of California Cooperative Extension, San Joaquin County, Stockton, CA. p.7-8.

Leinfelder-Miles, M.M., 2013. Alfalfa, salinity, and soil leaching. Alfalfa and Forage News. University of California, Agriculture and Natural Resources. Retrieved from http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=9529.

Leinfelder-Miles, M.M. and Prichard, T., 2013. Soil leaching requirement of alfalfa. Field Notes. University of California Cooperative Extension, San Joaquin County, Stockton, CA. p. 3.

Assessing Water Quality & Conservation Attitudes in a Low-Income Multi-Ethnic, Urban California Community

Basic Information

Title:	Assessing Water Quality & Conservation Attitudes in a Low-Income Multi-Ethnic, Urban California Community
Project Number:	2013CA310B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Conservation, None, None
Descriptors:	None
Principal Investigators:	Leigh Taylor Johnson

Publications

There are no publications.

Research Program

Water supplies are critical to urban populations in southern California. These supplies and the associated ecosystems are impacted by residents' decisions with respect to water conservation, pollution prevention and landscape plants that may infest riparian areas. However, typical public education programs have failed to motivate environmentally sustainable behaviors with respect to watershed and surface water areas of the Chollas Creek south branch in San Diego, CA. A better understanding of the social values (Dietz et al 2005, Daniel et al. 2012) that residents of this urban low-income, multi-ethnic community associate with local ecosystem services is needed to improve effectiveness of educational programs to motivate adoption of environmentally sustainable behaviors and to inform water management programs.

Focus group interviews are needed to guide development of survey instruments to collect such data from a larger sample of the local population and to aid ongoing educational programs. Project findings will be utilized to support the survey research and to utilize the US Geological Survey's SolVES software in analyzing it. SolVES has been applied to social values data collected from visitors to protected areas such as national forests and parks, incorporated into GIS warehouses and analyzed with respect to management policies (Sherrouse et al. 2011, Van Riper et al. 2012). Applying such techniques to urban, low-income and ethnically diverse communities is a novel use of the software.

Continued collaborative partnerships:

- UC Berkeley Extension Natural Resource Specialist Dr. Christy Getz continued to serve as an advisor to the project.
- UCANR 4-H Youth Development Academic Coordinator agreed to and served as an advisor.
- Two community organizations, Jacobs Center for Neighborhood Innovation and Groundwork San Diego – Chollas Creek, worked closely as partners on the project. They contributed the time of three experienced staff, two of whom had grown up and raised children in the neighborhood. Their knowledge of the community and their networks have been invaluable in developing the project. Groundwork has agreed to host a set of focus group meetings at a restoration site they call the Earthlab.
- Jacobs Center and Groundwork will recruit youth to participate. The goal is to include 12 youth per focus group, or a total of 48 youth. They will obtain the documented parental consent and youth assent that the IRB requires. (See below for explanation of IRB.)
- A third community organization, the Jackie Robinson YMCA, has agreed to host a set of focus group meetings, allow us to provide tours of their Chollas Creek restoration site, and to help advertise the project to YMCA members and local high school students.

Continued developing the project:

- As we had decided to work with local youth, instead of adults, the project was restructured to accommodate developmental differences among younger and older youth and compared to adults. Because youth speak English, meeting notes and transcripts will not need to be translated. However, parental consent/youth assent forms and recruitment fliers will need to be translated to Spanish to accommodate parents who do not speak English well.
- We developed a detailed plan comprising four meetings, organized by age group and by topics. Two meetings will be held for youth in 5th-8th grades and two for youth in 9th-12th grades.
    - At one of the two sets of meetings youth will discuss words they associate with each of 12 social values from the academic literature in terms of how they believe these values apply to the Chollas Creek watershed that runs through the community. Youth will also discuss safety, as it is important to people who visit urban, outdoor areas but it does not fit well with the values derived from the literature. At these meetings, youth will work in groups of three (triads). An adult consultant, paid by project funds, will facilitate each triad and create a transcript from notes and recordings of the discussion.

    - At the second set of meetings, youth will discuss their attitudes toward water conservation (framed as the current drought), pollution prevention (framed as polluted runoff to Chollas Creek), and invasive riparian species (framed as *Arundo donax*, the "giant cane" that infests much of the creek's watershed and that is a subject of local restoration projects). At these meetings, youth will work in groups of four (quads). An adult consultant, paid by project funds, will facilitate each quad and create a transcript from notes and recordings of the discussion.
    - Each of the four meetings will begin with a tour of an adjacent restoration site along Chollas Creek to set the stage for focus group discussions.
    - Meetings will be held on two Saturdays in August 2014 with two meetings per day. Each meeting will be an hour with extra time before and after to allow for arrival, settling in, finishing up and departure.
- Since the January 15, 2014 status report, PI Johnson has met eight times with Jacobs Center and Groundwork representatives and once with YMCA representatives to develop the project, visit venues and seek commitments. She communicated extensively with them via email and telephone between meetings to continue developing the project and materials.
- Logistics and a recruitment plan for each meeting were outlined. Recruitment materials were drafted and provided to the community organizations for review. We will provide an allowed "educational (save the date) flier" before schools close for the summer, while the IRB reviews the "recruitment flier."
- Johnson also developed the human subjects research protocol and supporting materials for submission to the UC Davis' Institutional Review Board (IRB). These materials are nearly ready for submission. Johnson is waiting for the three community organizations to confirm dates at the venues, to provide photographs of local youth (with parental permission) for use in recruitment fliers and to provide layouts of the fliers in a format they felt would attract interest. The goal is to submit materials to the IRB by the end of May 2014.
- Johnson and the two Jacobs Center representatives completed the IRB's required training for human subjects research and were certified by the national CITI organizations. The Groundwork representative had taken the training in 2013, so it is still valid. Johnson has copies on file of the training certifications for all four of us.
- Once the four facilitator-consultants are hired, they must take this training. Johnson will begin the hiring process once materials have been submitted to the IRB. Hiring them too early would risk losing them to other activities and potentially wasting funds spent on their training.
- The IRB representative reviewed and advised on the project planning process, consent/assent forms, recruitment materials, and aspects of the protocol. He said that we could expect one month for review and two more weeks for "modification" approval, for example the Spanish versions of approved, consent/assent and recruitment flier and to add the hired consultants to the list of project staff after they have completed the required CITI certification for human subjects research.

Effect of forest management on water yields and other ecosystem services in Sierra Nevada forests

Basic Information

Title:	Effect of forest management on water yields and other ecosystem services in Sierra Nevada forests
Project Number:	2013CA311B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Kevin O'Hara

Publications

There are no publications.

Research Program

The Sierra Nevada harbors globally distinctive forest resources that deliver a wide variety of benefits to the citizens of California and elsewhere. These benefits derived from natural ecosystems – also called ecosystem services – include recreation, biodiversity-, conservation, water, and forest product-related services. These ecosystem services often pose competing aims relative to forest management, but there are few mechanisms to evaluate the tradeoffs and complements related to different strategies.

Water is arguably the highest-value ecosystem service associated with the conifer forests of California's Sierra Nevada. Yet the provision of this essential service is vulnerable to changes in the energy and water balance associated with climate warming. To date, we have observed more precipitation falling as rain versus snow, earlier snowmelt, and greater summer water deficits. Such climate forcing will impact the water balance for the foreseeable future. However there is the potential to manage the water balance in forest ecosystems. The dominant vegetation (i.e., trees) is highly productive, forms dense canopies, and consequently, uses a great deal of water. There is a strong positive correlation between annual net primary productivity (the ultimate measure of the photosynthetic capacity of the ecosystem) and evapotranspiration (the primary cause of water loss). Any manipulation that reduces the productivity (i.e., removes trees) reduces evapotranspiration, shifts the balance of energy driving snowmelt, and thus may affect soil-water storage and streamflow. Water from the Sierra Nevada provides both hydropower and water supply to downstream users. Reducing and restructuring the forest vegetation density can also mitigate the negative impacts of wildfires as well as accomplishing important forest-restoration.

Project Objectives

1. Determine rates of evapotranspiration in Sierran mixed-conifer/true fir forests;
2. Determine the water use efficiency of trees and shrubs in Sierran mixed-conifer/true fir forests;
3. Determine the potential for forest management to delay snow melt in Sierran forests;
4. Determine the potential economic tradeoffs of forest management treatments to affect water yield and ecosystem services; and
5. Involve stakeholders in decision-making regarding forest management and watershed effects.

Summary of Activities/Outcomes to Date

This long-term project has completed two years of field work and is active in outreach and site selection for future work. This involves four areas:

1) developing leaf area prediction equations for Sierra Nevada conifers. This work is complete and we now have a set of equations for both prediction of leaf area on intensive research plots and for leaf area prediction from inventory data;

2) we have placed sensors in streams in control and burned areas, as well as in areas scheduled for future forest vegetation treatments to develop streamflow and stream temperature records. We have also placed soil-moisture, temperature, humidity, snow-depth and solar radiation sensors in strategic locations to develop spatial estimates of these quantities (Figure 1). We have initiated hydrologic modeling to estimate the effects of forest vegetation treatments on the water cycle in mixed-conifer mountain forests. This modeling involves extensive analysis of field data and calibration of spatially explicit models using snow, soil moisture and streamflow data. The scales of modeling extend from 300-10,000 ac scale (Figure 2). The initial modeling is being leveraged from ongoing work in the study area.

3) involvement of stakeholder groups through newsletters and a social media presence: http://ucanr.edu/sites/cff/Sierra_Nevada_Watershed_Ecosystem_Enhancement_Project/Newsletters_204/;

4) we have narrowed our search for field implementation sites to two areas on the Tahoe and Stanislaus National Forests. It is possible both areas will be used. Additionally, a private forest products company, Sierra Pacific Industries, has approaches us about installing similar studies on several of their watersheds.

We continue to anticipate that this work will provide new insights into the effects of forest structure on snow retention and water yields from Sierra Nevada mixed-conifer forests. The region continues to experience controversy over wildlife management, threats from fire, and water shortages are becoming a greater threat as we understand more about potential climate change in California. This work is as timely as when it was first proposed.

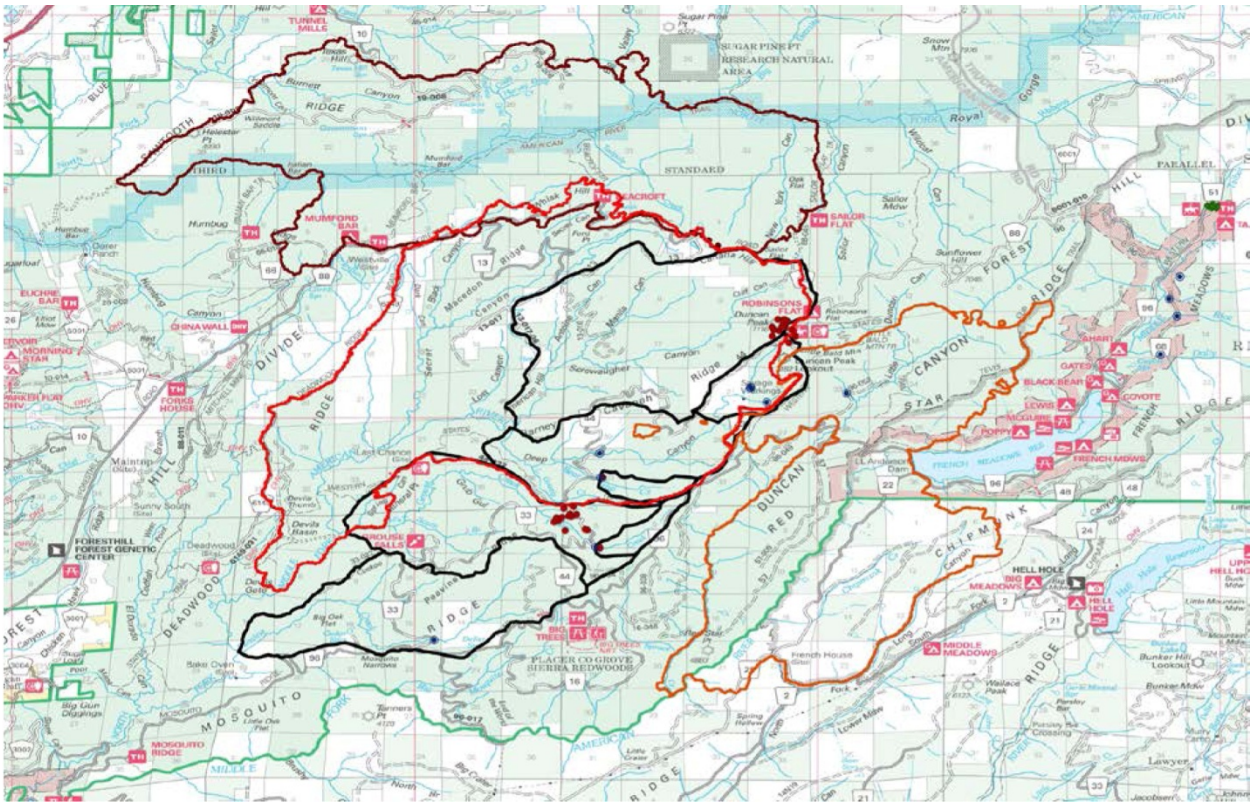


Figure 1. Map showing perimeters of watersheds and fires. Red dots are locations of snow, temperature and soil moisture sensors. Blue circles are stream level sensors.

Figure 2. Watershed surrounding unnamed steam in El Dorado County, California.

Information Transfer Program

We have developed an annual newsletter that is posted on our website: http://ucanr.edu/sites/cff/Sierra_Nevada_Watershed_Ecosystem_Enhancement_Project/Newsletters_204/?newslist=4051. We also have a mailing list for distribution of these newsletters as well as a social media presence.

Soil Survey Decision Support Tools for Water Resources Sustainability and Agricultural Productivity

Basic Information

Title:	Soil Survey Decision Support Tools for Water Resources Sustainability and Agricultural Productivity
Project Number:	2013CA312B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Anthony T. O-Geen

Publications

1. Maynard, J.J., R.A. Dahlgren and A.T. O'Geen, 2014. Autochthonous and allochthonous carbon cycling in a eutrophic flow-through wetland. Wetlands. 34:285-296.
2. Beaudette, D.E., R.A. Dahlgren, A.T. O'Geen, 2013. Terrain-shape indices for modeling soil moisture dynamics. Soil Science Society of America Journal. 77:1696-1710.
3. Beaudette, D.E., P. Roudier, A.T. O'Geen, 2013. Algorithms for quantitative pedology: A toolkit for soil scientists. Computers and Geosciences. 52:258-268.
4. Saal, Mathew, 2014, Repackaging Soil Survey into a Decision-Support Tool for Agricultural Groundwater Banking in California. Dept. of Land, Air and Water Resources, College of Agriculture and Environmental Sciences, University of California, Davis, CA, p. 1-36.
5. Moradi, A.B., N. Bilga, A.T. O'Geen, J. Hopmans, 2013. SoilWeb. On-demand and easy access to soil survey data anywhere at anytime. Citrograph Fall issue Volume 4 Issue 5. Pages 30-32.

Research Program

Our project had three general objectives:

Obj. 1. Develop a suitability index for agricultural groundwater banking for the maintenance and protection of groundwater resources in CA.

Progress: We developed an agricultural groundwater banking index for the Central Valley. The intent was to identify soil landscapes and cropping systems that could be flooded to recharge aquifers at times of water excess, i.e. flood events. The index evaluates the suitability of the land for this practice based on hydrologic parameters of soil) and the susceptibility of permanent crops to standing water. Moreover, because the permeability of soils has been modified by deep tillage in many places, and this has not been documented by most soil surveys which collected information prior to deep tillage operations, we created a new "modified soils" GIS layer to account for this increase in groundwater recharge potential in the region. Once completed, this product will serve as a guide for growers to make informed decisions about the potential for recharge and risks to crops associated with flooding their land. It may also serve as a regional guide to develop informed policy in relation to the protection of CA's groundwater supply.

Obj. 2. Develop soil-landscape specific nutrient management guidelines and BMP placement tools.

Progress: We worked to compile an exhaustive dataset of chemical and physical properties of soil. This dataset currently contains over 1000 soil samples where we have measured exchangeable K, K fixation, available P, and P sorption index. The conceptual model for the fate of K in soils is largely controlled by the type of parent material (presence of mica) and degree of soil development. The conceptual model for the fate of P in soils is a function of soil pH, extractable iron, clay content and calcium concentration. This conceptual model will create regional templates that inform nutrient management decisions relative to the propensity of soils to supply and retain nutrients. Once completed, this product will lead to more efficient nutrient management strategies and policies. It will ultimately result in more sustainable agricultural systems by creating place-based nutrient management strategies and BMP placement. Multiple field workshops have been held in the foothill region of central California to promote this effort.

Obj. 3. Develop drought tolerance decision support tools.

Progress: No work performed on this objective.

Information Transfer Program

My information transfer program involves the communication of science via written, oral and internet based communications. During this reporting period I performed four field days that were relevant to objectives 1-3. During these field days we discussed the systematic variability of soils, soil landscape relationships, decision support tools for water and nutrient management and soil informed management practices. These field days were primarily in viticulture systems located in the Sierra Nevada Foothill Region and in the Central Valley. I also gave approximately 20 oral presentation on topics related to these three objectives. Audiences include growers, ranchers, UCCE Advisors, and master gardeners.

Internet-based information delivery is also a major focus of my program. We have created two new apps that compliment SoilWeb (http://casoilresource.lawr.ucdavis.edu/gmap/), our web based soil survey delivery mechanism from which most of our decision support tools are developed

from. These new apps include a interactive map display of important soil properties (http://casoilresource.lawr.ucdavis.edu/ca-soil-properties/) and an app that displays the distribution of soils across the state: http://casoilresource.lawr.ucdavis.edu/mike/series-geojson/ . These apps are widely used by clientele across the state and nation-wide. They are also critical development steps in the creation of online decision support tools that are currently under development. During the reporting period we published an article in a trade journal that describes some of these apps (Moradi et al., 2013).

Notable Achievements

During the reporting period SoilWeb and associated web-based apps have been highlighted in the *Idaho Press Tribune*, USDA-NRCS main web page, Home and Garden TV website, updates to congress by USDA, *Beef Magazine, Farm Journal Magazine*, *Ag Weekly*, and *Water Citizen News*.

Publications

Peer reviewed

Maynard, J.J., R.A. Dahlgren and A.T. O'Geen, 2014. Autochthonous and allochthonous carbon cycling in a eutrophic flow-through wetland. *Wetlands*. 34:285-296.

Beaudette, D.E., R.A. Dahlgren, A.T. O'Geen, 2013. Terrain-shape indices for modeling soil moisture dynamics. *Soil Science Society of America Journal*. 77:1696-1710.

Beaudette, D.E., P. Roudier, A.T. O'Geen, 2013. Algorithms for quantitative pedology: A toolkit for soil scientists. *Computers and Geosciences*. 52:258-268.

Dissertations

Saal, Mathew, 2014, *Repackaging Soil Survey into a Decision-Support Tool for Agricultural Groundwater Banking in California*. Dept. of Land, Air and Water Resources, College of Agriculture and Environmental Sciences, University of California, Davis, CA, p. 1-36.

Other

Moradi, A.B., N. Bilga, A.T. O'Geen, J. Hopmans, 2013. SoilWeb. On-demand and easy access to soil survey data anywhere at anytime. *Citrograph* Fall issue Volume 4 Issue 5. Pages 30-32.

Effects of Application of Winery Wastewater on Soil, Grape Nutrition, and Juice and Wine Quality

Basic Information

Title:	Effects of Application of Winery Wastewater on Soil, Grape Nutrition, and Juice and Wine Quality
Project Number:	2013CA313B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Anita Oberholster

Publications

There are no publications.

Research Program

The California wine industry is presently facing key issues such as limited water availability due to increasing demands from urban users and climate change, and the disposal of winery wastewater (WWW). Applying wastewater to vineyards has the potential economic, legal, and marketing advantages of reducing water input, retaining wastes, and recycling on the winery's own property. Although the recycling and use of WWW on agricultural fields is occurring, the full implications of both current (sodium- and phosphorus-rich water) and emerging (potassium-rich) practices on soil fertility, soil physical and chemical properties, and grapevine nutrition and juice characteristics, and resulting wine is not known. In addition, because the impact of WWW irrigation on vines are not known most wineries will use WWW for irrigation of landscaping and frost and heat protection of their vines but not actually for irrigation purposes. We are addressing these issues by analyzing effects of both sodium and potassium enriched WWW on grapevine and grape development, nutrition and chemistry as well as evaluating the chemical composition and sensory characteristics of the resulting wines.

The objectives of this study are to evaluate the effects of WWW on: 1) grapevine development, yield, and nutrition; 2) juice and wine chemistry, and wine sensory characteristics, and 3) soil properties. Two commercial vineyards in California, one in the Napa valley (Vineyard A in 2013) and the other in Sonoma (Vineyard B in 2014) will be used. The Control treatments from vineyards A and B will be vines which received source water only (no WWW) whereas the WWW treatments will be Na-enriched (Vineyard A, 2013) and K-enriched (Vineyard B, 2014). Leaf, petiole and grape samples are taken at 50% véraison and at harvest and the Na^+, K^+, Ca^{2+}, Mg^{2+} content determined by ICP-MS together with water and soil samples taken before and after the harvest period. Additionally, the basic chemical (pH, titratable acidity, residual sugar, nitrogen) and phenol composition of grape and wine samples will be determined.

Findings so far for the 2013 investigation comparing control vines with those irrigated with WWW enriched with Na^+ (Na^+, 310 mg/L; K^+, 100 mg/L; Ca^{2+}, 6 mg/L and Mg^{2+}, 17 mg/L) indicate no significant differences between the two treatments. ICP-MS analyses to determine the Na^+, K^+, Ca^{2+}, Mg^{2+} content of the different control and Na-enriched WWW irrigation treatment samples are still underway, however basic chemical parameters and phenol composition of the grapes show small differences at véraison between the control and WWW treatments, which disappears for the harvest samples and respective wines. Triangle sensory testing was performed on the wine replicates to determine whether there are any perceptible sensory differences among the wine treatments and replicates.

Results indicate that there were no significant sensory differences between wines made from grapes sourced from vines receiving well-water or Na-enriched WWW. Initial results indicate that irrigation of grapevines with Na-enriched WWW has no adverse effects on the composition quality of the grapes and wines. It has to be noted however that the Napa winery only performed limited on-demand irrigation with the Na-enriched WWW and that the WWW was pretreated with a Lyve treatment system.

In the 2014 season, grapevines irrigated with untreated K-enriched WWW will be investigated. If the proposed study demonstrates that no negative grapevine impacts occur with winery wastewater (WWW) application, then wastewater recycling within a vineyard/winery operation is a sustainable option that demonstrates commitment to lowering on- and off-site environmental impact. Reducing water usage and waste water flow to water treatment plants.

Information Transfer Program

Most dissemination activities (Wine Flavor 101 and Grape Day workshops, Annual American Society of Enology and Viticulture Conference) are planned in 2015 after completion of

the project. However the project has been discussed at several meetings such as the Water and Energy Efficiency across Food Systems symposium and Outreach Tech Transfer meeting.

Information Transfer Program Introduction

While research on solutions to California's water problems is critical for meeting the State's needs, efforts are needed to translate and transfer university research. Implementation of solutions to California's water problems hinges upon education and outreach.

Each of the California Institute for Water Resource (CIWR) projects has some information transfer component. These are listed in the individual projects' reports. In addition to project information transfer, CIWR engages stakeholders in ways that transfer water based knowledge. This may be through direct presentations or meeting participation, through organizing and sponsoring conference and workshops, or through organizational actions that allow other scientist to engage better with stakeholders.

CA-CIWR Information Transfer

Basic Information

Title:	CA-CIWR Information Transfer
Project Number:	2013CA314B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	44
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, None
Descriptors:	None
Principal Investigators:	Doug Parker

Publications

There are no publications.

Information Transfer:

Our outreach capability has been essential to the development of programmatic areas including nutrient management. For example, CIWR organized the creation of a nitrogen management curriculum for California agriculture. This curriculum was delivered to over 500 Certified Crop Consultants (CCAs) in five different workshops during early 2014. The CCAs that have attended the training are now qualified to write and sign nutrient management plans for growers within the state.

In addition, one of our primary efforts in FY2013 has been to use our website and social media presence to coordinate drought response efforts across California's academic institutions. In the midst of historic drought, our academic institutions serve as a tremendous resource for near-term management advice to farmers and ranchers and for information on the innovative work being carried out by researchers on a vast array of issues from drought resistant crops to snow sensors to climate change.

In early 2014, as it was clear the drought would be severe, we developed a list of drought and water experts from across the state's academic institutions. This experts list became a popular resource that quadrupled our web traffic and our Twitter followers. In the last four months alone, over 400 articles in a variety of major media outlets including the *New York Times*, *Washington Post*, *Time*, *BusinessWeek*, and *Mother Jones* have included interviews with academic water and drought experts.

In addition, drought events ranging from seminars to workshops have been held across the state. Many of the early drought impacts were first felt by the communities that UCANR serves, such as ranchers and farmers. We collaborated across the academic network, often with support from the California Department of Water Resources, to quickly respond to local needs.

We also gathered practical resources from across the UC system that have been of immediate use in agriculture, rangelands, and home and commercial landscape management. We have a wide variety of tools, including SierraNet real-time hydrological data and a virtual tour of California's water system, developed by researchers throughout the UC system. In addition, many UC ANR resources on water conservation are available in Spanish. Much of this drought work will continue through a recently funded project with the California Department of Water Resources.

The CIWR Director has made many presentations to audiences on drought impacts to California and nitrate pollution in California's groundwater basins. The Director has participated in discussions on management of the Colorado River Basin, environmental services markets, climate change adaption by California agriculture, and groundwater nitrate pollution.

In addition, the Director of CIWR currently serves as the member at large for the executive board of the National Institutes for Water Resources (NIWR). In that position, he is a member and current chair of the Natural Resources Board at the Association for Public and Land-grant Universities (APLU). The CIWR worked with the APLU to draft a Natural Resources Roadmap that was released in May 2014.

Finally, the CIWR manages the Rosenberg International Water Policy Forum. The Forum brings water scholars from the around the world together on a biannual basis to collaborate on water related conflict.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	4	0	0	1	5
Ph.D.	6	0	0	0	6
Post-Doc.	3	0	0	0	3
Total	13	0	0	1	14

Notable Awards and Achievements

2013CA308B, Cahn: Matching funds were secured from a California Department of Food and Agriculture specialty crop block grant which were used to leverage this project.

2013CA309B, Leinfelder-Miles: After receiving the federal funds, the South Delta Water Agency supported my program in the amount of $15,000.

2013CA312B, O'Geen: During the reporting period SoilWeb and associated web-based apps have been highlighted in the Idaho Press Tribune, USDA-NRCS main web page, Home and Garden TV website, updates to congress by USDA, Beef Magazine, Farm Journal Magazine, Ag Weekly, and Water Citizen News.

2013CA314B, PI Fisher: We have demonstrated initial efficacy of stormwater capture linked to managed aquifer recharge (MAR), and will be preparing peer-reviewed publications based on this work (after collecting one more year of field data). We also tested and demonstrated utility of real-time data monitoring of MAR. In part on the basis of this work, we prepared two successful proposals, in collaboration with the Resource Conservation District of Santa Cruz County. Funding for both projects should arrive later in 2014 (about $200k in total). One project (funded by the California State Coastal Conservancy) involves a GIS and runoff analysis to assess application of stormwater capture and MAR on a regional basis. The other project (funded by the CA Department of Water Resources through the Integrated Regional Watershed Management Program) involves installation of two new MAR systems to capture stormwater runoff. We are conducting initial meetings and field visits to start work on both of these projects in Spring 2014. We recruited two outstanding new graduate students to work on these projects, starting in Fall 2014. Lead PI was also invited to consult with Governor Brown's Science and Policy staff on development of new responses to the ongoing drought, at a meeting in Sacramento (with other selected UC faculty).