
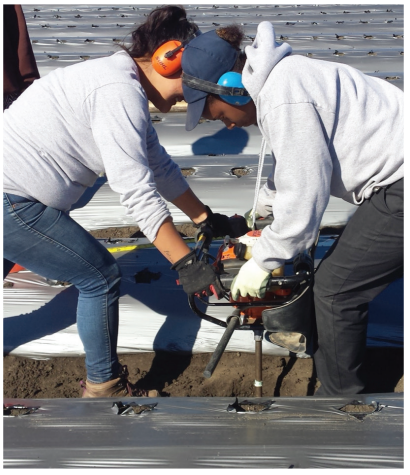
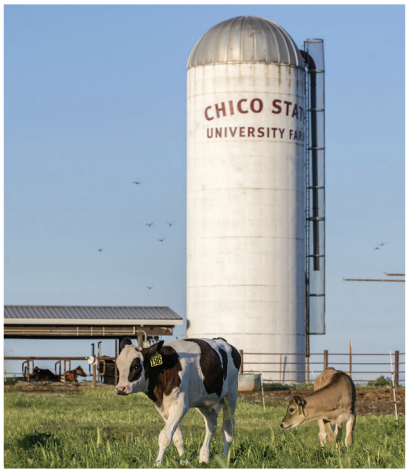

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THE IMPACT OF LAND FALLOWING ON AQUIFER CONDITIONS AND THE ECONOMY IN NORTHERN CALIFORNIA

Houk E.[1], Mehl S.[2], Anderson K.[3]

[1] *College of Agriculture, California State University, Chico*; [2] *Department of Civil Engineering, California State University, Chico*; [3] *Graduate Student, Geological and Environmental Sciences, California State University, Chico*.

Contact: Eric Houk, ehouk@csuchico.edu

Identification of Problem and Significance to California Agriculture: This project examines how various land fallowing scenarios impact agricultural production, aquifer conditions, and the economy in the Sacramento Valley. This research is timely considering the recent passage of the Sustainable Groundwater Management Act (SGMA), which requires basins to develop Groundwater Sustainability Plans. Improving agricultural water management can contribute to the long-term sustainability of California's agricultural production, valued at over $47 billion in 2015.

Rationale: Rice producers in the Sacramento Valley often fallow rice fields during water shortages and transfer their surface water to other regions of California. Although fallowing rice fields reduces total water consumption within the region, it also reduces a source of local groundwater recharge. This project models those impacts to demonstrate how rice field fallowing could negatively affect aquifer conditions and the economy in the Sacramento Valley.

Experimental Approach: The USGS Central Valley Hydrologic Model (CVHM) was used to investigate a set of potential land fallowing scenarios in the Sacramento Valley. The scenarios were identified by randomly selecting rice fields and changing the modeled land use to represent increased rice field fallowing in five-percent increments. To understand the difference between short-term and long-term changes, one set of scenarios reflected single year land fallowing while a second set represented ten consecutive years of land fallowing. In addition to the impacts on aquifer conditions, the value of foregone rice production and the impact on the regional economy was modeled using IMPLAN (IMpact analysis for PLANning).

Results: All modeled rice field fallowing scenarios showed decreased aquifer recharge and a reduced volume of groundwater storage within the study area. The magnitude of maximum storage loss increased as the proportion of single year fallow rice fields increased. Each five-percent increase in single year fallowing corresponds to a mean of about 67,000 acre-feet of additional aquifer storage loss, but the aquifer would begin to recover in the following years as cropping patterns returned to normal. The ten-year continuous fallow scenarios showed a compounded effect with even larger losses in aquifer storage and no recovery as expected. In addition, for every $1 of lost rice production we estimated an additional $.65 of lost economic activity in the study area as result of multiplier effects.

Conclusions: Overall, modeled results indicate that rice field fallowing can negatively affect available groundwater storage in the Sacramento Valley. The temporal distribution of these effects are compounded over time as rice field idling continues, but aquifer storage gradually recovers after idling ceases. The consequences of fallowing rice fields and foregoing agricultural production can also have negative impacts on the regional economy. Providing a better understanding of the relationships between land fallowing, aquifer conditions, and the associated economic impacts should be useful to a variety of stakeholders.

ENHANCING BIOCHAR PRODUCTION FROM FOREST RESIDUAL FEEDSTOCKS

Jacobson A.[1]

[1]*Department of Environmental Resources Engineering and Schatz Energy Research Center, Humboldt State University*

Contact: Arne Jacobson, arne.jacobson@humboldt.edu

Identification of Problem and Significance to California Agriculture (or Natural Resources): Woody biomass residuals from forest operations are often piled and burned or left to decompose in the forest due to high transportation costs. Alternatively, this resource can be utilized to produce biochar, which is an agricultural product to increase water holding capacity and decrease nutrient leaching in soils.

Rationale: Biochar produced from forest residuals displays a significant market potential for increased use in the agricultural sector, the full environmental benefits of its widespread adoption have not been realized due to high production costs and labor requirements. Through prior research, the Schatz Energy Research Center (SERC) has successfully characterized biochar quality, throughput, and emission rates by working with a biochar producer, the Redwood Forest Foundation, Inc. (RFFI), and a biochar equipment manufacturer, Biochar Solutions, Inc. (BSI). Through their previous work, SERC identified various operational and mechanical functions that can be modified to improve the economics of biochar production by reducing the labor effort per unit output and enhancing safety features and productivity of the machine.

Experimental Approach: The project team will design, engineer, install, and test an automation system that focuses on four key areas for improvement to the biochar production machine including: 1) achieving constant production rate and consistent biochar quality, 2) improving combustion characteristics to reduce emissions from the gas flaring system, 3) increasing reliability of the automated feeding system, and 4) reducing operator labor and risks involved with the propane combustion system. To address these issues, the team is building an automated control system that uses real-time measurements from sensors on the machines to adjust the operating conditions to optimal settings.

Results: The project is ongoing, so results are not yet final. The economic impacts of this project are anticipated to decrease the operating a cost of a biochar machine by reducing labor requirements by 40%. If these technological improvements are adopted and promulgated throughout the biochar production industry, it is expected to lower the production cost of biochar, thus making it more affordable for large-scale agricultural use.

Conclusions: Biochar produced from forest residuals has multiple benefits including reducing a greenhouse gas emissions source, sequestering carbon and creating a water saving soil amendment. Widespread adoption has yet been achieved in part due to high production costs and labor requirements. The research conducted in this project is expected to lower the labor requirements, thus making biochar production more efficient for future producers and reducing the cost to purchase this soil amendment for large scale agricultural consumers.

LYSIMETRIC EVALUATION OF CROP WATER REQUIREMENT FOR SUGARBEET (*BETA VULGARIS L.*) UNDER DRIP IRRIGATION

Thao T.[1,3], Cassel S. F.[1,3], Mele A.[1,3], Goorahoo D.[1,3], Ayars J.[2], Ashkan S[3], F. Melton[4], K. Post[4], and L. Johnson[4]

[1]*Department of Plant Science, California State University, Fresno;* [2] *Water Management Research, USDA-Agricultural Research Service, Parlier;* [3]*Center for Irrigation Technology, California State University, Fresno;* [4]*School of Natural Sciences, California State University, Monterey Bay.*

Contact: Touyee Thao, touyee1@mail.fresnostate.edu

Identification of Problem and Significance to California Agriculture: Efficient management of water resources is essential for the sustainability of irrigated agriculture. In California, prolonged droughts have limited the availability of water supplies and required growers to adopt management practices that optimize water use efficiency at the farm level, following a concept commonly known as "more crop per drop". One approach to conserve water relies on improving irrigation management through the implementation of irrigation schedules that accurately predict crop water requirements (CWR) and timing of application.

Rationale: Sugarbeet (*Beta vulgaris L.*) is a biennial plant with multiple usages, including livestock feed, production of sugar and sweetener, as well as bio-ethanol. The plant is also known to be fairly tolerant to both drought and salt stresses, and can adapt to a wide range of climatic and soil conditions. Given the scarcity of water supplies and the elevated salinity found in many soils and groundwaters, sugarbeet can serve as a profitable rotation crop for California farmers. However, due to the paucity of data available on its water usage, there is a need to develop new CWR that better reflect the cultural and irrigation practices observed in the state today.

Experimental Approach: Our experiment was conducted from 2014 to 2017 (3 years) using a test variety (year 1) and a commercial sugar variety (years 2 and 3) grown under drip irrigation. The most accurate method to determine CWR involves the measurements of crop evapotranspiration (ET_c) and crop coefficients (K_c) using precision weighing lysimeters (WL), following a soil-water balance approach. Therefore, our study utilized two large WL located at the University of California Westside Research and Extension Center in Five Points, CA. One lysimeter was cropped with sugarbeet to measure the actual ET_c while the second lysimeter was planted with a tall fescue grass to obtain the reference ET (ET_o). A CIMIS weather station located near the grass lysimeter also provided ET_o data. Daily sugarbeet K_c values were generated using the ET_c data divided by the ET_o obtained either from the grass lysimeter or from CIMIS. In addition, measurements of crop fractional ground cover (F_c) were performed regularly during the growing seasons with an infrared camera to derive relationships between K_c and F_c.

Results: Over the three-year study, seasonal ET_c for sugarbeets ranged from 540 mm to 870 mm. Average K_c values generated for the different crop growth stages reached: 0.46-0.52 at the end of the initial stage, 0.89-1.26 during mid-season, and 0.66-0.92 at late season. Strong relationships were observed between sugarbeet K_c and F_c for each growing season, suggesting that K_c could be estimated from F_c measurements. We also found that K_c values generated with the CIMIS ET_o data were generally lower than those obtained with the grass lysimeter.

Conclusions: This study represents the first reporting of ET_c and K_c for sugarbeets grown under drip irrigation, and establishes the first relationships between K_c and F_c. Our findings also highlight the variability of CWR based on varietal and seasonal differences.

USES OF SOUTHERN CALIFORNIA BLACK WALNUT (*JUGLANS CALIFORNICA*) IN LANDSCAPING AND RESTORATION.

E.J. Questad[1], E. Bobich[1], K. Bozak, E. Hernández[1], J. Paolini[1], S. Lauman[1], and J. Marfori[1].
[1]*Biological Sciences Department, California State Polytechnic University, Pomona*

Contact: Erin Questad, ejquestad@cpp.edu

Identification of Problem and Significance to California Agriculture (or Natural Resources): The economic effects of the prolonged drought in California extend to industries such as agriculture, water supply, and ornamental horticulture, with estimated economic losses up to $1.8 billion in 2015 alone. Because water supplies are at record lows, water conservation has never been more important in California's recent history. Currently, most landscaping plants in Southern California require substantial irrigation. Hence, the use of arid-adapted plants in landscaping is essential for regional water conservation and is already a popular approach to reducing water needed for irrigation.

Rationale: The best candidates for low water-use landscapes are native plants that are adapted to Southern California's long-term variability in its rainfall regime. A native tree that shows promise for landscaping is the rare, deciduous *Juglans californica* (Southern California black walnut). In addition to being drought-tolerant and deciduous, *J. californica* is allelopathic and produces a compound known as juglone that chemically inhibits other species. Determining which species can co-occur with *J. californica* and be used as companion plantings can increase the use of this drought-tolerant tree in landscaping and aid in its restoration.

Experimental Approach: In order to determine companion plantings for *J. californica*, we established a field experiment by planting six native shrubs, a native bunchgrass, four native annual species, and four common non-native, invasive species underneath the canopy, along the dripline, and outside of the canopy of eight different *J. californica* trees at Cal Poly Pomona's Lyle Center for Regenerative Studies. We carried out complementary laboratory and greenhouse experiments to test the effect of the chemical juglone on seed germination and seedling growth.

Results: Most species had inhibited seed germination in the presence of low concentrations of juglone; however, seeds germinated readily under field conditions. Species such as *Heteromeles arbutifolia, Prunus ilicifolia,* and *Phacelia distans* had the greatest growth under canopy or dripline conditions, compared to open areas; whereas, other species did not.

Conclusions: Potential allelopathy due to juglone did not appear to be a barrier to seed germination or plant growth in contrast to studies of other *Juglans* species. This finding may occur because of the drier soil conditions in Southern California compared to more temperate climates. While all species tolerated conditions under trees, *Heteromeles arbutifolia, Prunus ilicifolia,* and *Phacelia distans* are the top candidates for companion plantings with *J. california* trees and should be considered for use in landscaping and the restoration of the understory of this ecosystem.

USE OF DAIRY IN THE TREATMENT OF MODERATE MALNUTRITION IN PREGNANT WOMEN IN MALAWI

Papathakis P.[1], Schaffner A.[2], Manary M.[3], Reaves S.[1], Glosz C.[1], Kitagawa M.[1], Garcia P.[2], Eckert R.[1], Fry J.[1]

[1]*Department of Food Science and Nutrition, California Polytechnic State University, San Luis Obispo;*

[2]*Department of Statistics, California Polytechnic State University, San Luis Obispo;*

[3] *Department of Pediatrics, Washington University School of Medicine, St. Louis*

[5]*Department of Food Science and Nutrition, California State University, Chico*

Contact: Peggy Papathakis, ppapatha@calpoly.edu

Identification of Problem and Significance to California Agriculture: In low income countries, pregnant women are particularly vulnerable to malnutrition due to inadequate intake and higher nutrient requirements. The dairy industry is the single biggest agriculture commodity in California, contributing $63 billion in economic output to California annually. It is a major producer of milk powder which can be used in foods to treat undernutrition in women and children, increasing demand for milk powder.

Rationale: Malnutrition during pregnancy is associated with poor birth outcomes with lifelong consequences to individuals and society. Use of dairy products can substantially contribute to alleviation of maternal malnutrition.

Experimental Approach: An assessor-blinded, randomized, controlled clinical trial was conducted in southern Malawi among 1828 pregnant women with moderate malnutrition, [mid-upper arm circumference (MUAC) ≥20.6 cm and ≤23.0 cm]. Women received one of three dietary treatment regimens, either dairy-containing ready-to-use supplementary food (RUSF), a fortified corn soy blend (CSB+) with a daily multiple micronutrient antenatal supplement (CSB+UNIMMAP), or standard of care [CSB+, iron, and folic acid (CSB+IFA)]. As secondary outcomes, serum micronutrient status and body composition determined by anthropometric measurements were assessed.

Results: At enrollment, on average, women were late in their second trimester, 21.5 years, and for nearly half this was their first pregnancy. Most women completed 1–6 years of primary education; 71% of the women were classified as severely food insecure. Only 35% of mothers recovered from malnutrition before delivery; there was no difference in recovery or birth outcomes by treatment group. Mothers receiving RUSF had the highest weight gain during supplementation (3.4 ± 2.6 kg, 3.0± 2.2 kg, 3.2 ±2.4 kg in RUSF, CSB+UNIMMAP, CSB+IFA, respectively, $p = 0.03$). Newborns had a mean length-for-age z score of -1.3± 1.2 and 22% were stunted at birth; incidence of low birth weight was higher in the CSB+UNIMMAP group (18%, 24%, 17%, in RUSF, CSB+UNIMMAP, CSB+IFA, respectively, p=0.02). Deficiencies in vitamin B_{12} (21.2%), ferritin (22.9%), zinc (35.4%), and marginal concentrations of vitamin D (31.9%), retinol (32.4%) and folate (22.4%) were seen at enrollment. Low albumin (42.7%) was common and nearly 50% had high levels of inflammation. Status of vitamins D and B_{12} were improved in the RUSF group only. Women had high muscle mass and low fat stores, before and after supplementation, with women in the RUSF group experiencing the largest increase in muscle mass (1.16±0.13, 0.82±0.13, 0.72±0.13 cm^2 in RUSF, CSB+UNIMMAP, CSB+IFA, respectively, p = 0.039). Among HIV+ women, only those receiving RUSF had a significant increase in muscle mass (p<0.0001).

Conclusions Women improved their nutritional status during treatment, however only 1/3 recovered from malnutrition before delivery. RUSF improved maternal weight gain, muscle mass, especially for HIIV+ mothers, and vitamins D and B_{12} status. The large amount of the food given and the modest effect on linear growth in newborns suggests that stunting *in utero* is unlikely to be reduced by supplemental food alone. More research is needed on the optimal composition, timing and dose of RUSF during pregnancy to optimize both maternal and infant outcomes.

EFFECTS OF POST-WEANING BREWERS GRAIN SUPPLEMENTATION ON GROWTH AND REPRODUCTIVE PERFORMANCE OF ANGUS AND RED ANGUS HEIFERS

DeAtley K.[1], Daley D.[1], Doyle P.[1], Wisniewski J.[1], Moore K., Butterfield S.[1]

College of Agriculture, California State University, Chico

Contact: Kasey DeAtley, kdeatley@csuchico.edu

Identification of Problem and Significance to California Agriculture (or Natural Resources): Cattle and calves are the fourth largest agriculture commodity in California; however, drought conditions in the state have caused producer feed inputs to increase from ~60 to 80 percent of total production costs. Simultaneously, microbrewery popularity has increased rapidly in the state and lead to increased byproduct production.

Rationale: Byproducts of the brewing process (i.e., spent brewers grains (BG), yeast and water), now classified as biochemical hazards, may provide an additional feed source for livestock. However, minimal research is available on the effects of feeding wet brewers grain as part of a development ration for beef heifers on growth and reproduction.

Experimental Approach: Objectives of this study were to determine the effects of supplemental brewers grain on growth performance and reproductive characteristics of Angus and Red Angus heifers in a 3-yr study. A total of 85 spring-born, weaned heifers were randomized via gate cut and placed on an 84 d supplementation trial. Treatment groups were either control (CON; n = 43; initial BW = 311.90 ± 8.57 kg) or wet brewers grain (WBG; n = 42; initial BW= 309.43 ± 8.57 kg) groups. Heifers were housed on adjacent improved pastures (TDN: 56.5%; CP: 11.19%; NDF: 64.8%) and supplemented once daily at 1800 with either the control (CON; alfalfa hay + corn silage; TDN: 52.4%, CP: 8.2%, NDF: 65.6%) or WBG (Alfalfa hay + corn silage + wet brewers grain; TDN: 53.6%; CP: 9.8%; NDF: 66.2%) ration. Diets were balanced to target 0.68 kg ADG/head and were offered on an *ad libitum* basis. Fifteen days after supplementation period, heifers were synchronization using the 14 d controlled internal drug release-PG + heat detection + timed AI protocol. Traits collected were: BW at d 0, 28, 56, and 84, total gain, ADG, response to synchronization protocols and ultrasound pregnancy rate. During yr-2, weekly blood serum samples were collected via jugular venipuncture for determination of serum progesterone concentration. Age at puberty was defined as heifer age in days on date of second consecutive progesterone values > 1 ng/mL. Growth performance measures were analyzed as a completely randomized block design (block = year of study) and age at puberty was analyzed as a completely randomized design.

Results: No difference ($P > 0.05$) was detected between the control and treatment groups for heifer BW on d 28 (325.97 ± 8.88 vs. 324.86 ± 8.88 kg), d 56 (341.54 ± 8.57 vs. 341.84 ± 8.57 kg), d 84 (361.42 ± 8.21 vs. 360.38 ± 8.21 kg), and ADG (0.14 ± 0.01 vs. 0.14 ± 0.01 kg). Age of puberty did not differ ($P > 0.05$) between treatment groups. Results indicate that heifers supplemented with brewer's grain showed no deviation in development compared to heifers fed the control ration.

Conclusions: Cumulative results suggest that WBG could be used as part of a heifer development ration to help offset costs associated with diet ingredients; however, economic analyses of ration and development costs need to be investigated further.

QUANTIFYING PREY DELIVERY RATE OF NESTING BARN OWLS (*Tyto alba*) IN NAPA VALLEY VINEYARDS IN RELATION TO LOCAL AND LANDSCAPE CHARACTERISTICS

St. George D., Johnson M.

Department of Wildlife, Humboldt State University

Contact: Dane St. George, Dane.StGeorge@humboldt.edu

Identification of Problem and Significance to California Agriculture: The Napa Valley is a world renown center for wine production with an estimated $13 billion annual impact. Wine grape farmers in the Napa Valley have erected nest boxes to attract barn owls (*Tyto alba*) to their properties in an attempt to help control economically damaging rodent pests, find environmentally sustainable treatment methods, and support conservation of local fauna.

Rationale: The foraging behavior of barn owls on rodents in vineyards has yet to be rigorously examined, and the effect of local and landscape characteristics on pest removal is unknown. Identifying the relationship between habitat variables and pest removal rates will allow us to better understand the effect of habitat on the pest control service provided by barn owls.

Experimental Approach: This study used remote video cameras to record prey deliveries to nest boxes throughout the duration of the 2017 nesting season. A total of 23 cameras were deployed in spatially explicit nest boxes located within vineyards. Focal boxes had clutches ranging from 1 to 7 fledglings. Using imaging processing software, we will identify the occurrence and timing of prey deliveries.

Results: Preliminary data from two separate barn owl boxes showed that during the week of peak chick growth, parent owls are delivering an average of 4.33 rodents per chick per night. Time between first and last delivery within a night averaged 7.78 hours. Preliminary results also indicate that different levels of local and landscape heterogeneity may be responsible for variation in prey delivery rates.

Conclusion: With most of the data currently being processed, there are no definitive conclusions. However, prey delivery rate in the two boxes during the peak weak of chick growth exceeded that of a similar preliminary study in the Central Valley of California which concluded that a nest of two adults and four young removed over 900 rodents per owl breeding season. Our final analyses will better inform this figure. In addition, our analyses will reveal if natural habitat conditions surrounding a vineyard affect prey delivery rates. Understanding the patterns of foraging barn owls in relation to habitat can inform the strategic deployment of nest boxes to maximize the provisioning of this pest control service, and it may also incentivize habitat conservation that can increase the occupancy and local foraging by owls in vineyards.

PRELIMINARY FINDINGS FROM EASY GAP ON-FARM FOOD SAFETY IMPLEMENTATION IN NORTHERN CALIFORNIA

Bianco S.[1,3], Doyle P.[2], Stamper N.[3], McQuaid S.[3], Herrnstadt Z.[3]

[1]*Department of Nutrition and Food Science, California State University, Chico*
[2]*College of Agriculture, California State University, Chico*
[3]*Center for Healthy Communities, California State University, Chico*

Contact: Stephanie Bianco, sbianco@csuchico.edu

Identification of Problem and Significance to California Agriculture: The Centers for Disease Control and Prevention (CDC) estimates that one in six Americans is affected by unsafe food each year. Of these 48 million people, 128,000 are hospitalized and approximately 3,000 die (CDC, 2011). Foodborne illness outbreaks place a large financial burden on our healthcare system and national economy. In addition to public health risks and costs associated with foodborne illness, outbreaks pose a substantial financial risk and even jail time to individual farmers and their respective industries. Many California farming operations, and associated agricultural businesses, have filed for bankruptcy due to the indirect costs associated with an outbreak, such as legal fees, victim awards, recalls, investigations, lost product and future sales, and decline in industry sales. Once an outbreak has been publicized, trust in that farmer and the industry is significantly jeopardized.

Rationale: In many instances, on-farm food safety practices or Good Agricultural Practices (GAPs) are not followed by small farms. Many small growers do not have food safety plans in place for reasons including perceived cost and unfamiliarity with food safety requirements. In order to mitigate these challenges, EASY GAP provides GAP training and food safety plan resources for regional farmers as a means for promoting compliance with national food safety requirements, foodborne illness prevention, and market expansion.

Experimental Approach: This project employs a pre/post, intervention/control group, quasi-experimental design. Food safety knowledge and practices for at least 48 intervention and 12 control North State farms are being evaluated using matched pre-assessment and post-verification audit forms. Intervention farmers receive online training in addition to on-site GAP development and implementation assistance. Control farmers only receive online training and access to online resources. Pre-assessment and post-verification forms are used to assess the effectiveness of the food safety training proposed and methods developed for on-farm food safety application strategies.

Results: Pre-assessment data is currently being entered and analyzed. Data includes safety practices associated with employee hygiene, product traceability and recall, land assessment, soil amendments, pre and post-harvest water, pesticide and herbicide use, crop handling, equipment sanitation, and product storage.

Conclusions: None of the farms that have participated in EASY GAP thus far possessed food safety or product recall plans prior to starting the program. In addition, none of the participants were following water-sampling schedules that would satisfy FSMA or GAP standards. Providing water testing has proven to be an important component of the program. Through one test, a participating farm discovered a high microbial load in their irrigation water and referred to EASY GAP materials to determine next steps. In some cases, providing guidance has been challenging due to a lack of clarity in portions of FSMA. In these situations, staff consults with food safety experts. Participant recruitment has also been somewhat challenging due to issues including farmer time constraints and hesitancy to meet in a one-on-one setting. Plans are underway to offer group meetings (5-10 farmers) to make the initial meeting less intimidating and promote a collaborative approach to on-farm food safety.

MEASURING and MONITORING NITROGEN DYNAMICS IN CENTRAL VALLEY CROPS

Author: **Vang, K[1]**., Moreno, J.[1], Vang, J.[1], Lee, S[.1],

[1] *Center for Irrigation Technology, California State University, Fresno*

Contact: Kaomine Vang, kaominev@csufresno.edu

Identification of Problem and Significance to California Agriculture: Groundwater pollution due to agricultural practices is a pervasive issue in irrigated areas all over the world. It is also of ever growing importance in California where in regions such as the Tulare Lake Basin and Salinas Valley, one-third of the tested irrigation and domestic wells exceed the maximum contaminant level (MCL) of 45 mg/L (Boyle et al., 2012). Efforts to combat this problem are exemplified in Section 83002.5 of Senate Bill SBX2-1 that defines a mission to "improve understanding of the causes of [nitrate] groundwater contamination, identify potential remediation solutions and funding sources to recover costs expended by the State, to clean up or treat groundwater, and ensure the provision of safe drinking water to all communities." The highly mobile nature of nitrate and the potential for additional nitrogen movement in the form of ammonia volatilization threaten water and air quality. This concern highlights the need for methods and tools to evaluate nitrogen transport in agricultural areas.

Rationale: Currently there is no real-time systematic process to gather information of nitrate use and movement in the soil during irrigation. This projects objective is to develop a framework to rapidly characterize nitrogen and water dynamics in agricultural fields.

Experiment Approach: This study utilized a distributed sensor network (DSN) system of robust site instrumentation that coupled with physical sampling to measure nitrate leaching below the root zone.

Results: Utilizing the wick system from a decagon drain gauge with passive capillary lysimeter the team was able to build a decision support system that was able to sample nitrates in the field. Originally the thought was to automate the system and make it a remote system, but this proved challenging. However, the team was able to automate parts of the system utilizing a CR 1000 program and has been able to convert the system to run primarily on solar powered batteries and generators.

Conclusion: While the project was a success and the team was able to build a nitrate sampling system it was not as robust and intended. Additional changes and upgrades to the approach are needed. Further study of movement of water and nitrate in different soil types is needed. Also an automated fertilizing system could be built in conjunction with this system.

QUANTIFYING THE BENEFITS OF ON-FARM BMPS FOR IRRIGATION AND NUTRIENT MANAGEMENT

Melton F. [1]**,** Haffa A. [1], Aqueche K. [1], Cahn M. [2], Cassel-Sharma F.[3], Dexter J. [1], Duque J. [1], Goorahoo D. [3], Hang M. [1], Johnson L. [1], Kortman S. [1], Patron E., [1] Post K. [1], Prescott K. [1], Wang T. [1], Zaragosa I. [1]

[1]School of Natural Sciences, California State University, Monterey Bay; [2]University of California Cooperative Extension, University of California, Davis; [3]Department of Plant Science, California State University, Fresno

Contact: Forrest Melton, fmelton@csumb.edu

Identification of Problem and Significance to California Agriculture: With the passage of the Sustainable Groundwater Management Act (SB 1168 and AB 1739), and the implementation of the 2012 Irrigated Lands Regulatory Program (ILRP) under SBX2, growers across California are working to respond to increased water quality regulations and the potential for future restrictions on nitrogen fertilizer and use of groundwater. Growers need information on the benefits of using low-cost best management practices (BMPs) so that they can quantify and report benefits of on-farm BMPs as part of an integrated irrigation and nutrient management strategy.

Rationale: Quantifying water use and nitrate leaching below the root zone or lost via tile drain effluent provides a comprehensive evaluation of crop water budgets and nitrate loss in high-value specialty crops planted in California. These data can be used to implement a combination of low-cost, practical on-farm BMPs.

Experimental Approach: We are conducting field studies focused on key crops in the Salinas Valley (strawberries, lettuce, and broccoli) and the San Joaquin Valley (fresh market tomatoes) conducted in collaboration with industry partners to quantify the benefits of on-farm BMPs for reducing nitrate losses from agricultural systems. BMPs evaluated include use of the UC Cooperative Extension CropManage software for irrigation and nutrient management and use of soil nitrate quick tests to monitor soil nitrogen and manage fertilizer applications. We are using a combination of capillary lysimeters, solute concentrations (Cl^-, Br^-) and soluble Rhodamine WT dye tracers, soil moisture sensor networks, flow meters, and soil sampling to quantity nitrate concentrations and total nitrate loads lost below the root zone or discharged via tile drains under different irrigation and nutrient management strategies. Applied water and yields are also measured in each treatment to evaluate the impacts of these BMPs on water use efficiency and crop yield.

Results: Preliminary data indicate that implementation of BMPs resulted in lettuce, broccoli and strawberry yields that equaled or exceeded regional averages. When compared to treatments with higher water and fertilizer use, BMP's did not result in any substantial soil moisture deficits and yields were comparable between treatments. Data analysis and additional trials are ongoing. Importantly, preliminary analyses of BMP implementation in lettuce fields indicates use of BMPs supported an overall reduction in applied water of more than 15%, yields were maintained and a nearly complete elimination of nitrate loss below the root zone was measured during the period of crop production.

Conclusion: These data support the development and implementation of low-cost on-farm BMPs for irrigation and nutrient management in nutrient-intensive specialty crops that are economically important for Monterey and Fresno County. The preliminary results indicate the potential to lower the environmental footprint of growing high-value specialty crops while maintaining yield and quality.

UTILIZATION OF SPROUTED GRAINS AS AN ALTERNATIVE SOURCE OF ENERGY IN THE DAIRY COW RATION

T.N. Herren, B.M. Roque , C.A.Daley, and C.R. Phillips

College of Agriculture, California State University, Chico.

Contact: Cynthia Daley, cdaley@csuchico.edu

Identification of Problem and Significance to California Agriculture:
The dairy industry contributes over $8 billion dollars to California's economy. Escalating costs of production and record low farm gate milk price has created a significant financial burden for producers. Feed costs account for 65% of the cost of milk production, any efficiency that can be gained through alternative, more cost effective feeds, is important to the success of the industry. Sprouted grains is an alternative feed that may have applications as a low cost source of highly digestible energy.

Rationale: Producers who use sprouted grains (fodder) have reported a significant cost savings without loss in milk production suggesting fodder can be used as a replacement for grain in the dairy cow ration. This project tested the feasibility of an alternative feed with the potential to reduce energy costs while enhancing feed efficiency and rumen health. The primary objective was to determine if barley sprouts could be used as a substitute for grain in a total mixed ration (TMR).

Experimental Approach: To better understand the utility of fodder as an energy source for cattle, four ruminally cannulated heifers were used to determine characteristics of in-situ dry matter (DM) degradation rates of grain-based and fodder-based total mixed rations (TMR). Dry matter degradation, separated by substrate, was measured in intervals over a 96-hour time period.

Results: Feed substrates show a slight tendency to degrade feed faster over time with the fodder-based diet, however, there is no significant difference between either diet for any substrate in overall DM degradation. Rumen pH levels did not differ between diets.

Conclusions: While this study showed no statistical difference in total DM degradation between treatments, fodder based rations did increase the rate of substrate degradation at 12 and 24 hours within the rumen. Based on these findings, a total mixed ration (TMR) containing fodder as a substitute for grain, can increase feed efficiency, although cost of production is highly variable. Additional research into the nature of the change in rate of DM degradation within the fodder diet and the cost of fodder production is warranted.

THE USE OF CULTURAL METHODS TO OPTIMIZE ANAEROBIC SOIL DISINFESTATION IN STRAWBERRY PRODUCTION

Winslow, J.[1], Mazzola, M.[2], Holmes, G.[1], and **Ivors, K.**[1]

[1]*Strawberry Center, California Polytechnic State University, San Luis Obispo;* [2]*USDA ARS, Wenatchee, WA*

Contact: Kelly Ivors, kivors@calpoly.edu

Identification of Problem and Significance to California Agriculture: Since the 1950s, conventional growers of strawberries and other specialty crops have relied on the use of soil fumigants, such as methyl bromide and chloropicrin, to manage a broad spectrum of soilborne diseases. Recent rise in soilborne diseases in strawberry production has been associated with the inability of alternative (non-methyl bromide) fumigants to consistently control them.

Rationale: The overall goal of this project is to enhance the utility of anaerobic soil disinfestation (ASD) for the management of soilborne diseases of strawberry.

Experimental Approach: A field trial during the summer of 2016 was conducted in the certified organic field located on the Cal Poly campus to evaluate the effects of cover crops and ASD on the soilborne pathogen *Verticillium dahliae*. Soil samples were collected before and after treatment application, and *V. dahliae* was quantified using the Andersen sampler technique. Strawberry plant mortality and yield over time were assessed.

A second experiment was established in the fall of 2016 in field 35b on the Cal Poly campus in an effort to identify more disease resistant cultivars to combine with ASD. A replicated field trial was conducted to evaluate 90 cultivars and elite selections for resistance to Macrophomina crown rot. Strawberry germplasm was selected from six public and private breeding programs: University California Davis, University of Florida, Driscoll's, Plant Sciences, Planasa and Lassen Canyon. Plant mortality was assessed every four weeks, then every two weeks once symptoms were observed.

Results: Cover cropping with wheat and barley without the use of ASD reduced *V. dahliae* populations from 39 colony forming units per gram (CFU/g) of soil to 13 CFU/g soil, but cover cropping with the use of rice bran ASD reduced *V. dahliae* populations from 33 CFU/g soil to 2 CFU/g soil. Strawberry plants grown after cover cropping without ASD ranged from 64-75% plant mortality by the end of the season; strawberry plants grown after cover cropping with rice bran ASD ranged from 37-45% plant mortality. Of the cultivars evaluated during the 2016-17 growing season, a wide range of susceptibility was observed. Elite selection UC-J and cultivar Ruby June where the most susceptible genotypes to crown rot, with more than 90% mortality by 24 Jul 2017. Elite selection UC-V and cultivars Manresa and Osceola were the most tolerant genotypes to Macrophomina crown rot, with less than 5% mortality by 24 Jul 2017.

Conclusions: The use of ASD with cover cropping significantly reduced plant mortality, however levels of 37-45% mortality is not an economically viable level for commercial growers. It is possible to reduce the amount of plant mortality if treatments are combined with more disease resistant cultivars. Host resistance will be a critical tool for managing this disease and guiding breeding programs in this post methyl bromide era. Field trials during the 2017-2018 production season will be incorporating a number of partially resistant cultivars with ASD for a more integrated management approach of Macrophomina crown rot.

GROWING GUAYULE AS AN ALTERNATIVE RUBBER-PRODUCING CROP FOR HIGH SALINITY AND BORON GROWING CONDITIONS IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY

Lone T.[1], Bushoven J.[2], Zoldoske D.[3], Banuelos G.[4], McMahan C.[5], Heinitz C.[6]

[1]Department of Agricultural Business, California State University, Fresno; [2]Department of Plant Science, California State University, Fresno; [3]Center for Irrigation Technology, California State University, Fresno; [4]USDA-ARS Water Management Research Laboratory, Parlier, California; [5]USDA-ARS Western Regional Research Center, Albany, California; [6]USDA-ARS National Clonal Germplasm Rep, Parlier, California

Contact: Todd A. Lone, tlone@mail.fresnostate.edu

Identification of Problem and Significance to California Agriculture: During California's drought, growers in the west side of the San Joaquin Valley (SJV) have lost access to high quality surface water and shallow groundwater. Consequently, an increasing number of farms have been forced to fallow or retire land and farmers are now more dependent on pumping groundwater. However, the availability and quality of groundwater is problematic due to over pumping and the presence of high levels of natural-occurring salts, including boron (B). Alternative drought tolerant and salt and B-tolerant crops must be identified to provide growers with economically acceptable and sustainable cropping options.

Rationale: Guayule, a drought tolerant plant, is a promising rubber-producing plant for arid/semi-arid areas. It can be grown on lands unsuitable for other crops and may bring retired lands back into profitable production. To secure ample supplies of naturally-produced rubber, prominent tire companies have recently invested millions in producing guayule in the southwestern United States. However, no information is available on attempting to grow guayule in saline/boron laden growing conditions in over 400,000 acres of available land in the west side of the SJV. Identification and successful establishment of stress tolerant guayule ecotypes in this region will certainly attract the attention of the tire and medical latex industries.

Experimental Approach: Initial greenhouse experiments are conducted to evaluate different guayule ecotypes exposed to salinity and boron (B) levels typically found in groundwater, drainage water, perched water tables, and soils in the west side of the SJV. The best performing ecotypes are planted in high saline and boron-laden soils under field conditions. These ecotypes are harvested, latex from plant parts is extracted, and the effects of salinity and boron on latex quantity and quality are evaluated and compared between ecotypes planted in non-saline and saline soils. Data collected from field experiments and latex analysis will be used to determine the economic feasibility of guayule production.

Results: Greenhouse evaluation of different guayule ecotypes exposed to different salinity and boron (B) levels indicate differences in ability to tolerate adverse conditions. It is not surprising none of the ecotypes survived the extreme high levels of salinity and B since most typical agronomic crops show toxicity symptoms at both 5 dS/m and 5 mg/L. The greenhouse evaluation provides a better idea of which ecotypes are more suited for planting in high saline and boron-laden soils under field conditions. The best performing ecotypes were planted in fields with a salinity range of 7-13 dS/m and a B range of 6 -14 mg/L. The field study is currently in progress and tissue culture mediums are being evaluated as a quicker means to evaluate ecotypes for salt and B tolerance.

Conclusions: Some guayule ecotypes appear to tolerate higher salinity and B conditions compared to most typical agronomic crop species. Effects of sustained field exposure to these adverse growing conditions on latex production and quality will be evaluated. Once latex is extracted and evaluated with maturing plants, economic estimations can be projected to determine the viability of guayule as an alternative crop for the west side of the SJV.

THE IMPACT OF PRODUCE PURCHASING ON HOUSEHOLD HEALTH OUTCOMES

Cai X., Schroeter C., Volpe R.[1]

[1]*Department of Agribusiness, California Polytechnic State University, San Luis Obispo*

Contact: Xiaowei Cai, cai@calpoly.edu

Identification of Problem and Significance to California Agriculture: Due to its effects on health outcomes, the nutritional quality of U.S. consumers' diets has increasingly become a concern for the nutritionists, government policy makers, economists, and healthcare providers. Our research provides a unique contribution by synthesizing the studies of food choices, health outcomes, market structure, and agricultural production. In the short term we provide a number of empirical estimates linking produce purchases with health outcomes, market structure with produce purchases, and consumers' food choices with the California agricultural production sector. In the long run, we aim to inform consumers' food choices, government food policy, and producers' decisions as dietary behavior changes.

Rationale: The health-related concerns can be linked at least partially to diet quality. Over the years, U.S. consumers purchase too few fruits and vegetables. Meanwhile, health care and other costs associated with obesity, overweight, diabetes, and other diet-related ailments continue to rise. Given these trends, we anticipate that federal and state agencies such as USDA and CDFA will intensify educational efforts and policy implementations aimed towards increasing fruit and vegetable intake among Americans. This project will help to inform such efforts by quantifying the potential impacts of increased fruit and vegetable expenditures on consumer health outcomes as well as the agricultural production sector, particularly in California. Additionally we plan to shed light on how changes in the food retail sector relate to fruit and vegetable expenditures.

Experimental Approach: We use advanced econometric methods to produce three outcomes: (1) estimates of the marginal impacts of increasing household expenditure shares on fruits and vegetables on health outcomes related to dietary quality, (2) estimates of the increased fruit and vegetable production, primarily in California and the western states, required such that supply is readily available for all households to meet the DGA with respect to produce intake, and (3) estimates of likely impacts of the increased diversification of the food retail sector in the U.S. on fruit and vegetable expenditures, ceteris paribus.

Results: Increasing household fruit and vegetable expenditure shares by one percent decreases the long-run multiyear incidence of adult obesity by 8.6 percent and average adult BMI by 1.6 percent, having controlled for a host of potential confounding factors. The results are robust to specification choice, though estimated impacts differ by gender. In addition, we find that increased retail market concentration is associated with decreased produce expenditures. In particular, the presence of most nontraditional store formats such as convenience stores and dollar stores is associated with decreased produce purchases. However, the opposite is true for club stores and natural/gourmet supermarkets.

Conclusions: We conclude that increased household purchases of fruit and vegetables can reduce the incidence of the incidence of adult type-2 diabetes, and reduce adult obesity incidence and BMI in the U.S. In addition, increased produce demand has impacts on the retail sector as well. As consumers increasingly demand foods that are organic, local, and easily prepared, responding to enhanced fruit and vegetable demand will require significant adjustments among retailers and producers.

UNMANNED AERIAL VEHICLES FOR PRECISION AGRICULTURE USING MULTISPECTRAL IMAGES AND MACHINE LEARNING

Bhandari S.[1], Raheja A.[2], Do D.[2], Ansari M.[3], Nordyke K.[4], Wolf J.[3], Sherman T.[1], Rashid A.[1], Pham F.[2]

[1]*Department of Aerospace Engineering;* [2]*Department of Computer Science;* [3]*Department of Plant Sciences;* [4]*Department of Mechanical Engineering, Cal Poly Pomona*

Contact: Subodh Bhandari, sbhandari@cpp.edu

Identification of Problem and Significance to California Agriculture: California is one of the world's largest agriculture producers and exporters. California's agriculture is also one of the largest users of chemicals and water resources. Any savings in chemicals and water will reduce the cost of production and environmental impact, and help conserve water. Near infrared (NIR) images obtained using remote sensing techniques help determine the crop performances and stresses of a large area in a short amount of time for precision agriculture, which aims to optimize the amount of water, fertilizers, and pesticides using site-specific management of crops. Conventional methods of remote sensing use satellites and manned aircraft. However, the images have low resolutions, and have large revisit periods. Also, these methods cost $8,000 to $10,000 per data capture for high of a 200 hectare farm. For remote sensing to play an important role for precision agriculture, the associated cost must be reduced.

Rationale: The overall goal of the project is to use UAV-based remote sensing technology and machine learning for precision agriculture. The main advantage of UAV-based remote sensing is the reduced cost and immediate availability of high resolution data. This helps detect crop stresses throughout the crop season. However, though the UAV-based remote sensing technology has made significant progress in recent years, much less has been done on validating the accuracy of the data. To be useful for the real-world applications, the accuracy of remote sensing data must be validated using the proven ground-based methods.

Experimental Approach: We have been using lettuce and citrus crops in our study. A test plot for growing lettuce at Cal Poly Pomona's Spadra farm was designed. Nitrogen and moisture content of the soil was determined prior to beginning the study. The plot was subject to different levels of nitrogen and water treatments. Two UAV platforms, one airplane and one multicopter, integrated with multispectral sensors and digital cameras, are being flown over the lettuce and existing citrus trees for remote sensing data. The ground truth sensors include Chlorophyll Meter, Water Potential Meter, and Handheld Spectroradiometer.

Results: The spectral data from the UAV and spectroradiometer were used in the determination of normalized differential vegetation index (NDVI) that is used to assess the plant health. The RGB images were used for the machine learning classifiers. Preliminary results indicate that the NDVI obtained using the Spectroradimoter compares well with the Chlorophyll Meter and Water Potential Meter data. A good correlation was obtained between the Chlorophyll Meter data and the chlorophyll measured in the lab. The machine learning classifiers seem to predict the qualityof plants reasonably well. We are currently working on establishing a correlation between the remote sensing data and ground truth data.

Conclusions: With the data collected so far, the NDVI obtained using the Spectroradiometer has shown good correlation with Chlorophyll Meter and Water Potential Meter Data. Accuracy of the machine learning algorithm in predicting the plant health is satisfactory. The remote sensing data is currently being analyzed, and the findings will be disseminated soon.