California Institute for Water Resources
University of California

Annual Technical Report
2018

General Information

Products

Shukla, S., D. McEvoy, M. Hobbins, G. Husak, J. Huntington, C. Funk, D. Macharia, and J. Verdin, 2017: Examining the Value of Global Seasonal Reference Evapotranspiration Forecasts to Support FEWS NET's Food Insecurity Outlooks. J. Appl. Meteor. Climatol., 56, 2941–2949, https://doi.org/10.1175/JAMC-D-17-0104.1

Shukla S, D McEvoy, M Hobbins, G Husak, J Huntington, C Funk, J Verdin, 2017.Examining the value of global seasonal reference evapotranspiration forecasts to support FEWS NET's food insecurity outlooks. Journal of Applied Meteorology and Climatology. 56(11):2941-2949. doi: 10.1175/JAMC-D-17-0104.1

Aukema, JE, NG Pricope, GJ Husak, D Lopez-Carr, 2017. Biodiversity Areas under Threat: Overlap of Climate Change and Population Pressures on the World's Biodiversity Priorities. PLoS ONE 12(1): e0170615.doi:10.1371/journal.pone.0170615

California Sea Grant Science Fellowship Spotlight: Megan Sabal 2018 https://www.swc.org/in-the-news/2718/california-sea-grant-science-fellowship-spotlight-megan-sabal

Sabal, Megan C. 2018. How to Scare a Salmon? https://www.youtube.com/watch?v=uB7d7J0PqoQ

Cheung, K., Pourreza, A., Zuniga-Ramirez, G., Reiter, M., Haghverdi, A. (2019). Identification of drought stress in turfgrass using hyperspectral and multispectral remote sensing, 2019 ASABE Annual International Meeting, Boston, MA

Cheung, K., Pourreza, A., Zuniga-Ramirez, G., Reiter, M., Haghverdi, A. (2019). Identification of drought stress in turfgrass using hyperspectral and multispectral remote sensing, ASABE CA/NV Sectional Meeting, Tulare, CA

Haghverdi, A., Reiter, M., Ghodsi, S., Singh, A. (2019). Evaluating the Performance of Smart Evapotranspiration-Based Controllers in Southern and Central California. Soil Science Society of America International Soils Meeting, Jan 6-9, San Diego, California.

Haghverdi, Amir; Somayeh, Ghodsi., (2017), Developing Urban Irrigation Water Conservation Strategies Using Smart Soil Moisture Sensor-Based Controllers, "ASA, CSSA, and SSSA Annual Meeting". ASA ASA, CSSA, and SSSA. Tampa, FL https://scisoc.confex.com/crops/2017am/webprogram/Paper107651.html.

Pourreza, A., Zuniga-Ramirez, G., Reiter, M., Haghverdi, A. (2019). Identification of Drought Injury in Turfgrass Using Hyperspectral and Multispectral Remote Sensing. Soil Science Society of America International Soils Meeting, Jan 6-9, San Diego, California

Reiter, M., Pourreza, A., Zuniga-Ramirez, G., and Haghverdi., A. (2018). Multispectral and Thermal Remote Sensing of Turfgrass Response to Deficit Irrigation in Central California. 2018 ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD

Singh, A., Sharifi, M., Ghodsi, S., Haghverdi, A. (2019). Monitoring the Impact of Multiple Water Conservation Strategies on Turfgrass Using Ground Based Remote Sensing Tools. Soil Science Society of America International Soils Meeting, Jan 6-9, San Diego, California

Rossi, Gabriel, Weston Slaughter, and Theodore Grantham, 2018, "A study of aquatic habitat and fish behavior in a Russian River Tributary" in Proceedings of the 36th Annual Salmonid Restoration Conference, April 11-14, 2018, Fortuna, CA, pg 23, available at: https://www.calsalmon.org/sites/default/files/SRF_2018_Proceedings.pdf

Slaughter, Weston, Keane Flynn, Gabriel Rossi, and Theodore Grantham, 2019, "The effects of flow augmentation on intvertebrate drift, salmonid foraging behavior, and inter-pool movement in a Mediterranean stream" in Proceedings of the 37th Annual Salmonid Restoration Conference, April 23-26, 2019, Santa Rosa, CA, pg 23, available at: https://www.calsalmon.org/sites/default/files/2019_SRF_Conference_Proceedings.pdf

Leah Stokes & Patrick Hunnicutt; Presented by Leah Stokes at the Environmental Politics and Governance Conference at the School of Public and Environmental Affairs at Indiana University.Friday June 23 2017. “Evaluating Water Conservation Policy in California.”

Leah Stokes & Patrick Hunnicutt; Presented by Leah Stokes at ETH Zurich. Thursday May 24, 2018.“Evaluating Water Conservation Policy in California.”

George, Austin, 2019, Using Natural Tracers and Water Chemistry to Quantify Recharge and Aquifer Dynamics in East Sacramento, California, MS Dissertation, Geology Department, California State University, Sacramento, Sacramento, CA. 52 pages.

George, Austin; Amelia Vankeuren; Ate Visser; Marissa Loustale. Using Natural Tracers and Water Chemistry to Quantify Recharge and Aquifer Dynamics in East Sacramento, California. Groundwater Resources Association of California Western Groundwater Congress, Poster, 9/25/2018, Sacramento, CA.

George, Austin; Amelia Vankeuren; Ate Visser; Marissa Loustale. Quantifying Recharge and Aquifer Dynamics in East Sacramento, California. Groundwater Resources Association of California Sacramento Branch Student Night, 3/13/2019, Sacramento, CA.

Hutmacher, Bob, Steve Wright, Jeffery Dahlberg, et al, 2017. Sorghum
Irrigation Management Field Evaluations. https://ucanr.edu/sites/CEStanislausCo/files/258566.pdf

Hutmacher, Bob, Steve Wright, Jeffery Dahlberg, et al, 2017. Sorghum Irrigation Management Field Evaluations. https://ucanr.edu/sites/CEStanislausCo/files/258566.pdf

Clark, Nick, Robert Hutmacher, Jeffery Dahlberg, & Steven Wright, 2017. Effects of nitrogen fertility and irrigation level on yield and quality of corn and sorghum forages in the San Joaquin Valley in 2017 Conference Proceedings: California Plant and Soil Conference. http://calasa.ucdavis.edu/files/257056.pdf

Hutmacher, Bob, Steve Wright, Jeffery Dahlberg, Nicholas Clark, et al. Sorghum Irrigation Management Studies. http://agric.ucdavis.edu/Alfalfa__Forage_Field_Day_September_20th_2017/

Hutmacher, Robert, Nicholas Clark, Jeff Dahlberg, et al., 2019. Sorghum and Corn Cultivar Yield Responses to Irrgation and Nitrogen Amounts under Sub-Surface Drip Irrigation in the Western San Joaquin Valley at International Plant Nutrition Institute: 13th Western Nutrient Management Conference, Reno, NV.

Kendrick, Alexander; Rosemary, Knight, 2018, Quantifying porosity domains in geological materials using displacement-T2 data, "in" The 14th International Bologna Conference on Magnetic Resonance in Porous Media, Group ement Ampere, Gainesville, FL, 45.

Information Transfer Program

Science communication: We continue to grow an already strong web presence. Our Twitter followers, numbering over 9,000, are composed of journalists, academics from across the country and world, non-profits, agencies, and concerned communities. We continue to work to communicate University based science to our stakeholders, with a renewed focus on highlighting the work of a diversity of researchers across the UC and CSU systems.

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. In October, 2018 we hosted over 50 participants and speakers at a Forum on Sustainable Groundwater Management in San Jose, California.
http://ciwr.ucanr.edu/Programs/rosenberg/

Findings of various project activities were shared with landowners, consultants, agency staff, ngos, and academic researchers.

Student Support

Masters Students
Federal Funds: 1 Matching Funds: 2 Total: 3

PhD. Students
Federal Funds: 5 Matching Funds: 2 Total: 7

Other Acad./Researchers
Federal Funds: 10 Matching Funds: 1 Total: 11

Professor/Summer
Federal Funds: 0 Matching Funds: 1 Total: 1

Totals
Federal Funds: 16 Matching Funds: 6 GRAND TOTAL: 22

Notable Achievements and Awards

This research has created a new collaboration with the San Joaquin Valley Agricultural Sciences Center of the USDA Agricultural Research Service (USDA ARS) in Parlier, CA.

Alex Kendrick, the PhD student supported by this work, received an ARCS (Achievement Rewards for College Scientists) Foundation fellowship for 2018-2019.

The research team was awarded two extramural funds (by USGA through Turfgrass and Environmental Research Grant and by UC ANR through Competitive Grants Program) to expand the work initiated using this seed grant.

2019 M. Sabal, J. Frances Allen Award, AFS
2019 M. Sabal, Skinner Travel Award AFS Honorable Mention
2018-2020 M. Sabal, Delta Science Fellowship
2018 M. Sabal, Best Student Oral Presentation, Cal-Neva AFS
2018 M. Sabal, Travel Award, American Society of Naturalists

Undergraduate student research project analyzing dissolved inorganic carbon in these samples was funded by the Groundwater Resources Association of California Sacramento Branch through a CSUS Geology Student Research Grant.

One masters student presented research at the Groundwater Resources Association of California Western Groundwater Congress and received that conference’s award for “Best Student Research Presentation".

Projects

Can Habitat Restoration Mediate Predator-Prey Interactions to Increase Juvenile Salmon Survival in California's Central Valley?

Project Type: Annual Base Grant **Project ID:** 2017CA369B

Project Impact: Juvenile salmon are ecologically and economically important and encounter many predators while traveling. Scientists and managers have focused on the consumption of migrating salmon, but how those predators may affect prey behavior is unclear. Predation risk can drastically alter non-migrating prey behavior with consequences on populations and communities. Our goal was to examine predator effects on migrating juvenile salmon behavior and evaluate population consequences to the prey. We developed a conceptual framework to predict how migrating prey perceive and respond to predation risk, a direct extension of classic economic escape theory. Next, we tested this theory empirically using behavioral assays where we timed juvenile salmon swimming downstream with & without predator cues. In two experiments, juvenile salmon changed behavior (speed) in response to predator cues, but the pattern of response was context-dependent on previous predator experience and habitat. Wild salmon with more previous predator experience reacted more strongly to predation risk than hatchery salmon. Salmon also responded more strongly to predation risk in the shade compared to the sun and varied their escape strategy—slowing down in the shade and speeding up in the sun. Ongoing research will link these fine-scale decisions and responses to known ecological tradeoffs in juvenile salmon through a dynamic model. This model will explore optimal antipredator decisions for migrating salmon and relate those decisions to survival of juveniles and adults under various management scenarios. This work evaluates an under-studied mechanism potentially contributing to migratory salmon declines—non-consumptive effects of predators on prey behavior.

Evaluating Water Conservation Policy in California

Project Type: Annual Base Grant **Project ID:** 2017CA373

Project Impact: What explains variation in California’s urban water districts’ ability to conserve water? In this project, I am evaluating the effectiveness of a number of conservation strategies: pricing, messaging and penalties. Using funds from this grant, I have collected data from urban water districts. Using funds from another grant, I have supplemented this data with a public opinion poll of Californians to understand their views on water conservation. Among the top 15 best performing districts, compared to the bottom 15 districts, very different water conservation strategies are used. The best districts are using rebates, drought information to a much greater extent. In addition, the best performing districts are charging more than twice as much on average than the worst performing districts for an average water bill. This also holds for each unit of water sold. We have also undertaken fixed effects regressions to understand the relationship between different strategies and water conservation. As this shows, increasing bills does not appear to drive conservation. Instead, the use of social penalties appears to be the most effective water conservation strategy. These results are also confirmed in the public opinion poll we undertook, using research funding from a separate grant. Overall, we do not find that increasing water bills drives water conservation. This is a surprising finding, perhaps suggesting that water use is fairly inelastic.

Fish Habitat Response to Streamflow Augmentation in Support of Salmon Recovery in the Russian River Basin

Project Type: Annual Base Grant **Project ID:** 2017CA370B

Project Impact: We evaluated the ecological benefits of a Sonoma County, CA streamflow augmentation project, in which stored water was released into a stream to sustain habitat conditions for endangered salmon. We implemented a before-after-control-impact (BACI) to evaluate how stream flow, water depths, water quality, and fish behavior responded to different rates of water releases from the augmentation system. The field study was implemented between June and September in 2017 and 2018. We found that flow augmentation increased the length and duration of stream connectivity and had a beneficial effect on water depths and fish health. Flow augmentation did not have a strong effect on water quality in the first month of the study, but improved water quality in the last month of the study. The flow treatments definitively prevented the mortality of endangered fish trapped in isolated pools that would have

dried up in the late summer season. Findings of the study are being used to develop an operations plan which will establish recommendations for the timing and rate of flow releases in future years. The study also guided the development of a successful proposal ($530k) to the California Wildlife Conservation Board, to continue research at the project site through 2021. Research products from this project include an undergraduate thesis, abstracts in conference proceedings, and two manuscripts as part of a PhD dissertation that will be submitted to peer-reviewed journals for publication in fall 2019.

Groundwater Dynamics in Sacramento Aquifers Following California's Historic Drought

Project Type: Annual Base Grant **Project ID:** 2017CA374B

Project Impact: This year, we developed a model for groundwater-surface water interaction in the Sacramento area to investigate how groundwater recharge could be altered by climate change. The model was calibrated with field data collected for this project (mean groundwater ages, recharge temperatures, etc.) and historic groundwater level data. The model simulated groundwater recharge through the year 2100 for four different climate change scenarios used by the State of California (Cal-Adapt.org). Results indicate that recharge from precipitation varies by 30% depending on the climate change scenario, while recharge from the lower American River varies by 2.5%, with an overall recharge difference of 4.5%. Though groundwater levels did not show declining trends over the course of the model, there were many years where groundwater levels were 2 meters lower in the hotter-drier climate scenario. This indicates a loss of groundwater storage and is equivalent to the change in groundwater levels measured during California’s historic 5-year drought during 2012-2016. These results suggest that climate change could create challenges for groundwater sustainability in the Sacramento area over the next century. In an already tight groundwater budget, a 4.5% decrease in recharge would require offsets by other measures such as demand reduction through reduced groundwater pumping. Benefits from this project include hands-on training for students in field sampling, laboratory analysis, and presentation skills, as well as networking with local groundwater professionals. The project has also led to a new collaboration between research scientists at Lawrence Livermore National Laboratory and the CSUS Geology Department.

Identification of Seasonal and Decadal Drought though Monitoring and Modeling

Project Type: National Competitive Grant **Project ID:** G14AC00042

Project Impact: This work built on previous agreements that identified and established relationships with individuals and institutions concerning agroclimatology in food insecure regions to facilitate the sharing of information among analysts and decision-makers with U.S. and foreign government agencies, UN organizations, and humanitarian NGOs. Research collaborations with USGS EROS covered a wide range of projects including modeling and mapping precipitation and precipitation-related fields to support drought and flood mitigation, analyzing the impacts of sea surface temperatures (SSTs) on global atmospheric circulation and rainfall, estimating crop area in developing countries, and the development of user tools to create and explore datasets reflecting aspects of agroclimatology. These activities were carried out by a team of researchers, graduate students and technicians at the University of California, Santa Barbara (UCSB) as well as field scientists stationed in Africa and Central America. This team forms the heart of the Climate Hazards Center (CHC).

Optical and Thermal Remote Sensing of Turfgrass Response to Different Deficit Irrigation Strategies in Central and Southern California

Project Type: Annual Base Grant **Project ID:** 2017CA377B

Project Impact: The US west is generally arid and subject to droughts, yet some of the largest cities across the nation are in this region. Irrigation demand is usually the most significant component of total outdoor water use in urban sectors in southern California. The main objectives of this study were to develop water conservation strategies for irrigated turfgrass in southern California and to quantify the impact of different deficit irrigation regimes on turf health and quality using remote sensing technologies. Bermudagrass showed much higher performance under deficit irrigation compared to tall fescue. Consequently, bermudagrass is recommended for Southern and Central California where improving irrigation water use efficiency of urban landscapes is crucial for maintaining urban green infrastructure while conserving water resources. We found no remarkable water savings due to limiting watering days

to only multiple days per week as compared with a no watering restriction scenario. There was on average 12% over-irrigation relative to the desired irrigation level by the smart irrigation controller when data compared to CIMIS stations near the experimental sites. Therefore, the smart ET based controller showed promising performance for autonomous landscape irrigation in urban settings. Our results showed that multispectral imagery (using adrone-mounted camera and handheld sensors) is an effective way to detect drought injury in irrigated landscape. On the other hand, cellphone attached thermal cameras showed lower accuracy and their application is not suggested for precise monitoring of landscape health and its response to drought.

Program Admin

Project Type: Annual Base Grant **Project ID:** 2018CA-ADMIN

Project Impact: The California Institute for Water Resources (CIWR) was created in 1957 and 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. The Institute has affiliate faculty from ANR, the different UC and California State University campuses and other universities. The CIWR Director and Academic Coordinator serve as key spokespeople on California water issues and work with federal, state, regional, nonprofit, and campus stakeholders to improve the understanding of water issues through advocacy and outreach programs. The CIWR receives funds from USGS that are used to support the operations of the Institute, our Information Transfer and our Competitive Grants Program. In 2018, we continue to work with our advisory committee to administer the junior investigator competitive grants program. We solicited proposals for California water related research, education, and extension projects from academics at qualified institutions statewide to be funded under the WRRA (contingent on funding). We supported several new projects on topics ranging from groundwater recharge to water conservation policy – all topics of concern in the state. We also completed a strategic planning process for the water institute, guided by a committee of water experts from the UC system as well as state agencies and the private sector. The plan can be found here: http://ciwr.ucanr.edu/files/295460.pdf

Program Administration

Project Type: Annual Base Grant **Project ID:** 2018CA-ADMIN

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Suitability of Alfalfa Forage Crops for Winter Groundwater Recharge

Project Type: Annual Base Grant **Project ID:** 2017CA357B

Project Impact: Agricultural managed aquifer recharge (AgMAR), where farmland is flooded during winter using surface water to recharge underlying groundwater, is a promising technology currently tested on alfalfa. We

evaluated the effect of two different flooding durations and frequencies for groundwater recharge on 2-year alfalfa (Medicago sativa L.) stand, variety Ameristand 835NT RR with fall dormancy rating of 8 at the Kearney REC in Parlier, CA. We implemented three treatments: i) 4 days of flooding and 10 days off (low frequency), ii) 3 days of flooding and 4 days off (high frequency), and iii) control in a randomized complete plot design with three replicates on nine 20x44 sqft plots. AgMAR treatments applied for a total of 6 weeks between Feb 11 and March 24, 2019. Low frequency treatment, a total of 5.4 feet of water (106,059 gallons) was applied in addition to 2.32 inches of precipitation during experiment. High frequency treatment received a total of 11.9 ft (234,926 gallons) of water. The statistical analysis of variance revealed, alfalfa yield of the first and second cutting of the growing season did not show significant differences between treatments and varied between 3150 – 3284 lbs. per acre for the first and 3393 -3762 lbs. per acre (12% moisture content alfalfa) for the second cutting. Analysis of alfalfa forage quality indicated a significant difference in crude protein (CP) content (p-value = 0.036), which varied between 20.17% and 21.56% and neutral detergent fiber (aNDF) content, which varied between 39.75% and 40.72% between flood treatments and the control.

The Use of NMR Logging Measurements to Estimate Hydraulic Conductivity in Glacial Aquifers

Project Type: National Competitive Grant **Project ID:** G17AP00134

Project Impact: Glacial aquifers are an important source of groundwater in the United States and require accurate characterization of aquifer properties to make informed management decisions. One parameter that is crucial for understanding the movement of water is hydraulic conductivity, K. We use nuclear magnetic resonance (NMR) logging to estimate K at submeter resolution at two different sites in Wisconsin. The challenge to be addressed is that of transforming the NMR parameters acquired through NMR logging to accurate estimates of K. In two wells at each site, we collected NMR logs and measurements of K using a direct push permeameter. Using a bootstrap algorithm to calibrate four different NMR models of K to the measurements of K, we were able to estimate K to within an order of magnitude. Using our logging data, we evaluated previous NMR calibrations of the Schlumberger-Doll Research equation for estimating K in different aquifers. The previous calibration for the High Plains Aquifer estimated K almost as well as our local calibration. We found the NMR K model calibration varied with K, suggesting the range of K measured in an aquifer could impact the calibration. We also developed laboratory NMR methods to characterize the connected pathways that transport water through porous materials. These methods will be used to investigate NMR models of K. This study establishes NMR logging as an effective tool for estimating K in glacial aquifers and provides further evidence there may be a standard range of NMR K model calibration values for different aquifers.

Water and Nitrogen Use Efficiencies of Sub-Surface Drip Irrigated and Fertilized Forage Corn and Sorghum in the San Joaquin Valley

Project Type: Annual Base Grant **Project ID:** 2018CA3477

Project Impact: Our objectives were: (1) determine two forage corn and four sorghum cultivar (cvr) yield responses to three irrigation water (IW) amounts from 60-100% of corn evapotranspiration; and (2) evaluate yield within each IW level to three nitrogen (N) fertilizer split-application injection rates ranging from zero to full estimated N requirements across years and cvr. From 2016-18 we conducted a subsurface drip irrigated (SDI) field study to achieve these objectives at UC Westside Research and Extension Center in Five Points, CA. Crop year, IW, N, and cvr all had significant effects on yield (p