



OFFICE OF RESEARCH
Sponsored Programs
1850 Research Park Drive, Ste. 300
Davis, CA 95618

Telephone: 530.754.7700
Facsimile: 530.752.0333
E-Mail: proposals@ucdavis.edu

April 15, 2015

California Landscape Conservation Cooperative
Ms. Rebecca Fris
3020 State University Dr. East # 2007
Sacramento, CA 95819-2632

Proposal entitled:

"Assessing the impacts of future climates and fire on hydrologic regimes in the Mediterranean-type ecosystems of southern California"

UC Davis Investigator: Emma Underwood

Total Requested Funds: \$150,327.00

Matching Funds: \$317,336.00

Project Period: 10/01/2015-09/30/2017

Dear Ms. Fris,

On behalf of The Regents of the University of California, Davis, it is our pleasure to forward institutional support and approval of the collaboration with the US Department of Agriculture under the referenced proposal being submitted to the California Landscape Conservation Cooperative.

At the time that this proposal results in an award, we shall expect to enter into an agreement which contains terms and conditions conducive to and consistent with a public educational institution performing fundamental research. It is expected that UC Davis will invoice in accordance with the University's accounting requirements and generally accepted accounting practices.

Please call on Dr. Underwood, UCD Principal Investigator, for scientific information. Administrative questions may be directed to me at the above contact information or at jssnyder@ucdavis.edu. We request that correspondence pertaining to this proposal and any ensuing award be sent to the Office of Research and to the principal investigator.

Send Award Notice to:

Office of Research
Sponsored Programs
1850 Research Park Drive
University of California
Davis, California 95618
(530) 747-3828/FAX (530) 747-3929

Send Checks (Payable to The Regents of the University of California) to:

Cashier's Office
University of California Davis
PO BOX 989026
West Sacramento, California 95798-9062

Sincerely,

A handwritten signature in blue ink that reads "Jinger Snyder".

Jinger Snyder
Contracts and Grants Analyst
jssnyder@ucdavis.edu
Tele: (530) 752-3767
Fax: (530) 752-0333
Enclosures

Project Title:

Assessing the impacts of future climates and fire on hydrologic regimes in the Mediterranean-type ecosystems of southern California

Project Lead and Co-Lead Contact Information:

Emma Underwood (Scientific Lead, Project Manager)
Department of Environmental Science and Policy
One Shields Avenue
Davis, CA 95616
Email: eunderwoodrussell@ucdavis.edu

Lorrie Flint (Scientific Lead)
Water Resources Discipline
U.S. Geological Survey
Placer Hall
6000 J Street, Sacramento, CA 95819-6129
Email: lflint@usgs.gov

Hugh Safford (Natural Resource Manager Lead)
Regional Ecologist
U.S. Forest Services
Pacific Southwest Region
1323 Club Drive, Vallejo, CA 94592
Email: hughsafford@fs.fed.us

Project Duration: 2 years**Total Requested Funding: \$120,596****Partners:**

(1) **US Fish and Wildlife Service;** Dr. Kaylene Keller, GIS and Data Manager R8 Refuges Inventory and Monitoring Program at US Fish and Wildlife Service (tel: 916-278-9419). The data and outcomes of the project are highly relevant for Dr. Keller's program. The modified hydrological models will be a direct input in FWS's work in National Wildlife Refuges in southern California (Hopper Mountain is in the watershed) and will allow managers to estimate the vulnerability of refuges and other managed lands to climate-driven changes in water supply. Dr. Keller will be involved in the development of output tools to ensure their potential utility for work within her program and for refuge management decisions.

(2) **US Forest Service;** (a) Dr. Nicole Molinari, Province Ecologist, USFS Pacific Southwest Region (tel: 805-961-5729). Dr. Molinari will provide background on existing plans and assessments that have been conducted for federal lands in the watershed, will advise on development of management workflow and tools, and organize a one-day workshop for tool conceptualization and use; (b) Dr. Pete Wohlgemuth, Physical Scientist, USFS Pacific Southwest Research Station (tel: 951-680-1538) and Dr. Robert Taylor, Hydrologist, San Bernadino National Forest (tel: 909-382-2660). Drs. Wohlgemuth and Taylor will provide input on the hydrologic modeling component based on his experience in the region;

(3) **The Nature Conservancy**; Dr. Sophie Parker, Los Angeles/Ventura Project Director (tel: 805-642-0345 ex. 4502). TNC has already established a network of natural resource managers working in the watershed who will be interested in the results of this work. TNC staff could also contribute to developing the output tool.

(4) **University of California Cooperative Extension**, Sabrina Drill, Natural Resources Advisor, Los Angeles and Ventura Counties (tel: 626-586-1975).

Geographic Scope: South Coast

Partner Contributions/Leveraging:

In-kind contributions:

(1) **UC Davis** (\$10,000) salary for Professor James Quinn for advisory role on all elements of the project; (\$5,000) non-monetary contribution for computers, equipment and archive media for project data.

(2) **US Forest Service** (\$25,836) salary for Hugh Safford, Regional Ecologist to provide advice and guidance relating to the vegetation and fire components of the project; (\$20,000) salary for USFS staff from Los Padres and Angeles National Forest to contribute technical expertise on the hydrologic model and natural resource staff to participate in a workshop to develop the output tool; (\$500) for workshop materials and incidentals; (\$1000) publication of project results in peer reviewed literature;

Leveraging other projects:

Our proposed project is highly complementary to other data development and cooperative ecosystem services work being supported by the US Forest Service and these combined efforts will produce more than the sum of the parts;

(1) **US Forest Service** (\$110,000) grant to UC Davis to develop methods to value ecosystem services (biodiversity, carbon storage, sediment erosion regulation, water provision, recreation) in the Santa Clara River Watershed and assess the impacts of fire on these services. Some of the data and analyses developed from this assessment will be of direct use for the proposed project; (\$100,000) grant to UC Davis to undertake a socio-economic vulnerability assessment of National Forests in California. This provides link between our work on federal lands in the watershed to the rest of the Pacific Southwest region.

(2) **USGS California Water Science Center, Pepperwood Preserve, Southwest Climate Science Center** (\$290,000) grant to develop Basin Characterization Model for California - downscaling hydrologic model and application of future climate projections. This model will be calibrated to the focal watershed in this proposed project.

Project Summary/Management Relevance:

We propose to further our understanding of hydrological regimes under current and future climates, and the interaction of fire on these regimes in the Mediterranean climate region of southern California. Through a collaborative core team consisting of the USGS, UC Davis, and natural resource managers within the US Forest Service, together with hydrologists, ecologists, and conservation partners on the ground in southern California we will; (1) quantify water recharge, runoff, and climatic water deficit by calibrating existing hydrologic models under current climates to a Mediterranean climate watershed; (2) project how the hydrologic regime is modified by future climates; (3) assess the impact of fire on hydrologic regimes and measure

their recovery post fire; and (4) develop an output tool that allows natural resource managers to easily query the hydrologic information under current and future conditions and visualize priority areas for water provision ecosystem services.

The proposed work will leverage two existing projects; (1) an on-going USFS-funded assessment of ecosystem services within the Santa Clara River watershed, and (2) the continued development of the statewide Basin Characterization Model (BCM) (Flint et al. 2013; Byrd et al. 2015). Here we seek two years of funding to enhance these efforts by expanding attention on hydrologic regimes and water provision services in a Mediterranean climate watershed. Initial work will focus on the Santa Clara River pilot watershed in Ventura and Los Angeles County and three major fires (Ranch, Piru, and Copper). One of the goals of this current project is to pilot a widely applicable scientific workflow for jointly managing water yield, fire risk, and vegetation recovery and a logical second phase would be to test the application of our findings to both other Mediterranean climate regions of southern California and other fire-dominated shrublands along much of the California coast and Sierra foothills and mid-elevations.

Outcomes of this project include; (1) spatial data on current and future hydrologic regimes in the Santa Clara River watershed; (2) a methodology for assessing the impact of fire on hydrologic regimes and measuring the recovery of the ecosystem post fire; (3) spatially explicit management-priority opportunities within the watershed for protecting water provision services and their overlap with other ecosystem services, such as sediment erosion regulation; (4) a best-practices package for assessing the interaction of water yield, fire risk, and vegetation recovery in managed Mediterranean chaparral-dominated watersheds, which will include a data library, printable maps, step-by-step instructions for land managers, and a tool for managers to assist in planning and decision making. These products will be of direct use for planning by the US Forest Service and tested immediately (e.g., Forest Plan Revision and the Climate Change Performance Scorecards) and for management (identifying priority areas on National Forests for water provision services). These outcomes will also assist partner organizations working in non-federal lands in the watershed, such as The Nature Conservancy, to identify priorities for land acquisition based on their water characteristics.

Capacity and Roles:

The project team is uniquely qualified to undertake the topic of this request for proposals. Collectively the team's experience captures hydrology and climate science, spatial ecology, vegetation and fire ecology, and natural resource management experience. Lead Scientist Lorrie Flint (Research Hydrologist, USGS) together with Alan Flint (Research Hydrologist, USGS) have developed the Basin Characterization Model (BCM) to characterize the hydrologic response to historical and future climate conditions. Funding to develop the BCM was provided by the USGS Water Science Center, Pepperwood Preserve, and SouthWest Climate Science Center (\$290,000). Regional applications of the BCM to date have included the Sierra Nevada, Klamath River, Central Valley, and the Russian River. Lead Scientist and Project Manager Emma Underwood (Research Scientist, University of California, Davis) has experience in landscape ecology, geospatial analysis, remote sensing technologies, and project management. She is currently PI on a USFS funded assessment of ecosystem services in the Santa Clara River Watershed (\$110,000), and has previously been involved with a conservation assessment of Global Mediterranean Habitat Types with The Nature Conservancy. Lead Natural Resource Manager Hugh Safford (Regional Ecologist, USFS Pacific Southwest Region) is a senior

vegetation and fire ecologist and provides expertise to land management on 18 national forests in California. He has also studied the impacts of future climates, including climate-fire interactions and impacts on invasive plants and native species.

Lorrie Flint will lead the hydrologic modeling component of the project which will incorporate future climates and recovery post fire. Emma Underwood will lead the development of data for informing post fire vegetation recovery, integrate information on the other ecosystem services in the watershed, and develop the management tool. She will also be responsible for overall project management. Hugh Safford will ensure the project is relevant to on-the-ground natural resource planning within the USFS, provide advice and guidance on the fire component and post fire vegetation recovery, collaborate with USFS staff to conceptualize the management framework, and convey findings from this project to other people within the USFS working on water modeling and water provision ecosystem services.

Approach and Scope of Work:

Background The Mediterranean climate region of southern and coastal California is a globally recognized biodiversity hotspot, in addition its natural landscapes provide a suite of ecosystem services including water provision to the high density urban populations and agricultural lands in close proximity. The provisioning of water is also critical to sustained ecological function, including habitat for endangered species like the southern California steelhead. Given the importance of water provisioning and other ecosystem services, there is surprisingly little known regarding their vulnerability to future climates and increasing fire in southern California. This is particularly concerning given the predicted impacts of climate change and altered fire regimes in southern California (Shaw et al., 2009, Keeley and Fotheringham, 2003). It is essential for natural resource managers and water managers in these chaparral-dominated systems to understand the spatial patterns of water provision services together with the interacting threats of climate change and fire, as a necessary step for managing for their long-term sustainability.

While our findings will be applicable to Mediterranean climate regions throughout southern California, the proposed work will focus on the Santa Clara River Watershed, located in Ventura County and Los Angeles County. Land ownership in the watershed is 59% federal (Los Padres and Angeles National Forests) with the remainder in private (37%) and state (2.5%) ownership. Vegetation in the watershed is predominantly chaparral (62%), and conifer and hardwood forests comprise 20%.

This project directly addresses *objective 2* of the LCC science management framework by using a multidisciplinary team of hydrologists, climate scientists, spatial ecologists, vegetation ecologists, and natural resource managers to bring appropriate skills and expertise to address water resources and the impact of climate change and fire in southern California. Ultimately, we will develop a readily replicated assessment protocol, including management tool and scientific workflow, to integrate existing and newly generated data on hydrologic regimes, climate change and fire to assist managers in decision making. The findings from this project range from online tools to peer-reviewed publications, and will help inform natural resource management in the watershed and will also be transferable to other Mediterranean climate regions in southern California, and beyond.

Calibrate the Basin Characterization Model to Mediterranean type climate regions

We will build on the existing Basin Characterization Model (BCM) at 270m resolution at monthly time intervals (Flint et al. 2013) and calibrate it to fire-exposed watersheds in the Santa Clara River basin and adjacent basins. Calibration will be done in locations with streamflow data available pre- and post-fire to assess the varying changes in water runoff and recharge. The model will be revised to incorporate a seasonal signature of potential evapotranspiration (PET) that can be scaled to the spatial intensity of fire and reduction of PET. The calibrated BCM data will be uploaded and accessible to land managers and the public through the Data Basin.

Assess the impact of fire on hydrological regimes and measuring post fire recovery

The hydrologic regime is defined as the relative proportions of runoff and recharge, including peak flows that may generate sediment transport, and baseflows that sustain dry season water supply, that are generated as a result of changes in climate. The hydrologic regime will likely change as a result of fire, and differ spatially according to soils, underlying geology, and burn intensity. It will also have different rates of recovery post-fire dependent on the regrowth of vegetation. Therefore, it is necessary to develop a post fire data layer to reflect vegetation recovery for input into the BCM. We will utilize pre and post fire Landsat TM imagery (30m resolution) and the Enhanced Vegetation Index (EVI) as a proxy for vegetation recovery post fire. The EVI is particularly well suited to mapping in semi-arid shrublands as it can detect variation in leaf area index, canopy type and architecture, and plant structure and, unlike other indices such as NDVI, it remains sensitive to vegetation at high biomass levels (Gao et al. 2000). We will generate the cumulative annual EVI pre fire and then each year post- fire (following approach by Kinoshita and Hogue 2011). These EVI values will be correlated with evapotranspiration rates from shrubland vegetation to develop and refine the scaling component of evapotranspiration that will enable matching post fire streamflow during recovery. Findings relating to the impact of fire on hydrologic regimes will be included in the management tool.

Assess the impact of future climates on hydrological regimes The calibrated BCM will be run for the southern California region for a selection of future climate projections from downscaled versions of the IPCC's CMIP5 set of Global Circulation Models. These results will be evaluated for watersheds used in the calibration stage to assess changes in the hydrologic regime as a result of projected changes in climate (and without consideration of fire). Maps of changes in hydrology as a result of projected climates will be developed for the southern California region and data will be available for inclusion in the management workflow and tool.

Develop a management workflow and tool to assist in natural resource decision making

We will perform sensitivity analyses to develop data and maps of hydrologic response to climate change for the southern California region. We will develop Geoweb modules that will assist managers in making natural resource decisions, such as identifying spatially explicit priority areas for management or restoration or for acquisition on private lands. The tool will integrate data on hydrologic regimes under current and future conditions with other data such as land ownership, vegetation, and spatial data on other ecosystem services such as sediment erosion in the watershed. The tool will allow managers to; (1) visualize and identify spatially explicit priorities for water provision services and their overlap with other ecosystem services in the watershed; (2) input the boundary of new fires and perform queries to estimate the impact of those fires on water runoff and recharge and how these are likely to recover over time; and (3)

visualize how hydrologic regimes change under future climate scenarios. The tool will allow users to; view the Santa Clara River watershed and zoom into particular areas, download the associated data, and find links to reports interpreting the data. To further conceptualize this tool and build it from the ground up we will hold a one-day workshop with USFS resource managers, TNC, and other conservation partners in the watershed. We will also look to participants to field test the final tool for us. This tool will be made available for use through the LCC's California Climate Commons website.

Deliverables/Timeline/Accessibility:

Please see Budget and Deliverables spreadsheet.

Measuring Results:).

We anticipate three main outcomes from this project;

- (1) Data and maps of hydrologic regimes under current and future climates calibrated to Mediterranean climate areas of southern California. Anticipated users of these data include natural resource staff within the Los Padres and Angeles National Forest, for example, for Forest Plan Revision, as well as conservation partners in the region, who can use these data for prioritizing their conservation efforts. One straightforward measure to assess the success of the project is the number of times these data are downloaded from the Data Basin website;
- (2) A methodology for assessing the impact of fire on hydrological regimes and their recovery over time. This information will be written up in a peer-reviewed literature and again, the number of citations of the article will indicate a measure of its success. It will also be written up in a non-technical manual for managers that will be accessible through the California Climate Commons website;
- (3) A management tool to support the manual will be hosted on the LCC's California Climate Commons website. We anticipate this will be used by USFS resource managers, water managers, and conservation practitioners in partner organizations for visualizing and querying hydrologic data under current and future climates and assessing the impact of fires of water resources. Furthermore, there will be an opportunity to engage with over 100 natural resource managers and practitioners to introduce and demonstrate the tool at a future California Chaparral Symposium, organized by Hugh Safford, the natural resource manager lead.

Value-added and Transferability:

Funding provided by the LCC will allow the BCM to be calibrated to Mediterranean type regions in southern California. Furthermore, the analytical steps and tools developed and tested in this pilot study should be broadly applicable, with slight modifications, to shrub and fire-dominated watersheds elsewhere in California and neighboring regions. Given the importance of water resources and the impacts of future climates this is essential information for natural resource managers working in the region.

A description of the workflow and how managers might utilize these data and our approach will be written up as a set of web pages on the California Climate Commons. Researcher Allan Hollander at UC Davis, who also serves as a resource librarian for the Climate Commons, will take the lead on developing these materials.

The BCM will be calibrated to the chaparral-dominated ecosystems of the Santa Clara River watershed but once completed, this modified BCM can be applied to all Mediterranean climate

areas in southern California. A logical second phase of this project would be to test the accuracy of this application using streamflow data from other basins in the south coast ecoregion.

Budget:

Please see Budget and Deliverables spreadsheet.

ATTACHMENTS

Citations:

- Byrd, K.B. et al. 2015. Integrated climate and land use change scenarios for California rangeland ecosystem services: wildlife habitat, soil carbon and water supply. *Landscape Ecol* 30(4):729-750.
- Flint, L.E. et al. 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. *Ecol Pro* 2:25.
- Gao, X. et al. 2000. Optical–biophysical relationships of vegetation spectra without background contamination. *Remote Sens Environ* 74, 609–620.
- Keeley, J.E. and Fotheringham, C.J. 2003. Impact of Past, Present, and Future Fire Regimes on North American Mediterranean Shrublands. *Ecol Studies* Vol 160, 2003, pp 218-22.
- Kinoshita, A.M. and Hogue, T.S. 2011. Spatial and temporal controls on post-fire hydrologic recovery in Southern California watersheds. *Catena* 87(2), 240-252.
- Shaw, M.R. et al. 2009. The Impact of Climate Change on California's Ecosystem Services. Report from the California Climate Change Center. CEC-500-2990-025-D.

California Landscape Conservation Cooperative 2015 Proposal Budgets

Budget Categories	CA LCC Request	Partner(s) Contribution(s) (monetary)	Partner(s) Contribution(s) (non- monetary value/in- kind)	Total
Salaries	\$ 48,736.00	\$ 55,836.00	\$ -	\$ 104,572.00
Supplies	\$ -	\$ 1,500.00	\$ -	\$ 1,500.00
Overhead	\$ 69,581.00	\$ -	\$ -	\$ 69,581.00
Equipment	\$ -	\$ -	\$ 5,000.00	\$ 5,000.00
Other	\$ 32,010.00	\$ -	\$ 255,000.00	\$ 287,010.00
Total	\$ 150,327.00	\$ 57,336.00	\$ 260,000.00	\$ 467,663.00

Other:

Budget Justification

Salaries and benefits for E. Underwood (UC Davis) calculated at 20% time year 1 and 2
 Salaries and benefits for A. Hollander (UC Davis) calculated at 5% time year 1 and 2
 Overhead for E. Underwood & A. Hollander (UC Davis) is calculated at 56.5% (9mth) & 57.% (3mth) for Year 1 and 57% for Year 2 (If fund
 Salaries and benefits for L. Flint and A. Flint (USGS California Water Science Center) calculated at 140 hours each
 Overhead for USGS calculated at 53%. Overhead also includes 17.5% on the first \$25,000 of subaward to USGS (\$4,375)
 Other (travel): 2 trips for meetings (Sacramento to Burbank, flight & hotel) @ \$1,000/pp for UCD & USGS leads each year

In kind / monetary contributions

Salaries: James Quinn, UC Davis salary and benefits 20 days @ \$500/day per year = \$10,000
 Salaries: Hugh Safford, USFS 20 days at \$645.92/day per year = \$25,836
 Salaries: USFS Los Padres and Angeles National Forest staff 5 days @ \$400/day*5 people per year = \$20,000
 Supplies: workshop materials and incidentals = \$500 ('monetary' as future costs)
 Supplies: publication costs 2 paper @ \$500 each = \$1,000 ('monetary' as future costs)

In kind / Non-monetary

Equipment: computer equipment, GIS software, archiving media @ \$2,500 per year = \$5,000
 Other: previous work which developed BCM data & downscaled climate projections = \$255,000 (NGO & state sources only)

Deliverable Name	Deliverable Type (select from pull-down)	Expected Delivery Date	Description	How will access to this product be provided? (See examples)	Target Audience (be as specific as possible)
Quarterly Financial and Progress Reports	Administrative	Quarterly	These are the quarterly reports required of all projects.	Quarterly Financial and Progress Reports should be emailed to CA LCC	Financial: CA LCC; Progress: CA LCC and Partners
Hydrologic regime data	Datasets: Raster geodata	Dec-15	Digital data and hard copy maps of the Basin Characterization Model (270m) calibrated to Mediterranean climate regions of southern California under current and future climates	Data will be uploaded to Data Basin website	Resource managers within the USFS responsible for Forest Plan revisions, conservation groups interested in planning or prioritizing water resources
Remote sensing analysis of post fire vegetation recovery	Methodology and Guidance document	Mar-16	Written document to describe methods, analyses, and findings relating to the use of remote sensing indices from Landsat TM data to estimate vegetation recovery post fire	Posted on LCC California Climate Commons website	Geospatial planners within USFS and partner organizations, academic researchers
Workshop	Training, Outreach, or Workshop	May-16	A one day workshop to discuss management workflow outputs and conceptualize visualization output tools	Meeting notes will be synthesized and available for all participants	Project team (USGS, UC Davis, USFS), partners (USFWS, TNC, UC Cooperative Extension) and other stakeholders in the watershed identified by partners
Measuring impacts of fire on hydrologic regimes	Publication and Guidance document	Dec-16	Methods and results assessing the impacts of fire on hydrologic regimes in the Santa Clara River Watershed and how water recharge and runoff recover with post fire vegetation recovery. A technical paper in a peer-reviewed journal as well as a less technical document for natural resource managers	Peer reviewed literature and guidance document posted on LCC California Climate Commons website	Geospatial planners within USFS and partner organizations, academic researchers
Management workflow and visualization tool	Application or Tool	Jun-17	Geoweb modules and visualization tools to help inform management decision making. The tool will allow exploration of hydrologic regime data under current and future climates and integrate data on other ecosystem services in the Santa Clara River watershed	LCC California Climate Commons website	Natural resource managers from federal partners working in the watershed (USFWS and the Los Padres and Angeles National Forests). Local partners and stakeholders working in the watershed.
Analysis of change in hydrological regimes under future climates	Publication	Jun-17	Manuscript that describes hydrologic regimes in Mediterranean Climate regions of southern California and predicted change under future climates and interacting pressures associated with fire in the landscape.	Peer reviewed literature	Scientists within federal partner organizations (USFS, USFWS) and in local organizations in Santa Clara River watershed