NOAA – RPPR – due by 6/30/23

Linking Indicators of Drought Hazard to Multi-Sectoral Impacts: An Application to California

Period of performance: September 1, 2020 – June 30, 2023

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## **What were the major goals and objectives of this project?**

The overall goal of this project is to develop a framework for linking drought hazard indicators with sector-specific impacts in highly managed water storage and conveyance systems, such as those of the American West. To achieve this goal—building on existing NIDIS indicators—we are developing sector-specific drought hazard indicators for California that take into account water availability from both local and more distant sources. With these indicators we are going to develop drought impact risk profiles that reflect the capacity of different sectors to respond and adapt to drought conditions. Working with stakeholder advisory groups, we are also going to identify thresholds and triggers that can be useful for local, state, and federal drought response. We are developing a suite of sectoral drought hazard indicator maps, which are going to convey different stages of drought hazard across locations, and propose metrics for mapping drought impact risk.

**The project has four interrelated scientific objectives (Figure 1):**

1. **Incorporation of the water grid into drought hazard indicators.** An important innovation is the inclusion of the water storage and conveyance system—or “water grid” (Escriva-Bou et al. 2019)—into drought hazard indicators. The grid’s capacity to store and convey water plays a dominant role in the magnitude, timing, and geographic variability of drought impacts. We are going to use California’s water grid and 2012–16 drought impacts to inform this work, with the goal of building a framework that can be scalable to other western states.
2. **Multi-sectoral assessment of drought hazard indicators.** A second innovation is the development of sector-specific drought hazard indicators. For any given drought in any given region, different sectors can face different levels of scarcity, depending on the composition of their water supply portfolio and other factors, such as timing of flows and sensitivity to water temperatures. We are initially focusing on urban communities, rural communities, irrigated agriculture, and freshwater ecosystems. Other relevant sectors—such as hydroelectricity, forests, and rangeland management—could eventually be added.
3. **Linkage of drought hazard indicators and impacts for different sectors.** Drought impacts depend not only on the severity of drought conditions, but also on the level of vulnerability and exposure of the affected system (Cardona et al. 2012). These impacts will vary within and across sectors, depending on baseline conditions, adaptive capacity (e.g., financial resources and the costliness of reducing water demands), and the way the drought’s timing and duration interact with sector-specific demands. In general, more natural systems—such as rural rivers that lack dams—might be impacted earlier in a drought than systems where water is more intensively managed—such as managed wetlands, irrigated agriculture, or cities with water supply redundancies. One of our main goals is to explore the linkages between drought hazard indicators and impacts, by assessing specific sector- and water management system conditions that can affect sector exposure and vulnerability and contribute to a region’s overall drought risk. We are going to explore the development of drought impact risk profiles that help characterize areas and sectors at greatest risk. We are also going to identify thresholds between risk stages and triggers that result in impacts and policy responses.
4. **Co-development of decision support tools.** The project aims to develop readily updatable map-based decision support tools building on current NIDIS platforms to improve drought management and response. To make the results of the research relevant and useful for decision makers, we are using a science-to-action approach (Vano et al. 2017) throughout the research process. We are working closely with NIDIS staff and convene stakeholder advisory groups to gather advice and feedback and to ensure that the project outputs are easily digestible and transferable to other geographic regions.

To achieve these goals, we have organized the project into the following six activities:

* Activity 1. Review drought impacts and responses during California’s 2012–16 drought.
* Activity 2. Develop sector-specific drought hazard indicators considering the water grid.
* Activity 3. Link sector-specific drought hazard indicators and impacts.
* Activity 4. Assess thresholds and triggers to inform decision making.
* Activity 5. Develop a suite of drought hazard indicator maps and other visualization tools.
* Activity 6. Engagement and Workshops with Scientific and Stakeholder Partners.

## **What was accomplished under these goals?**

A picture containing calendar

Description automatically generatedFigure : Adjusted project timeline

* **Activity 1: Review drought impacts and responses during California’s 2012–16 drought.**
* **Activity 2: Develop sector-specific drought hazard indicators considering the water grid.**
* **Activity 3: Link sector-specific drought hazard indicators and impacts.**
* **Activity 5: Develop a suite of drought hazard indicator maps and other visualization tools.**
* **Activity 6: Engagement and Workshops with Scientific and Stakeholder Partners.**

As part of our efforts to engage with sectoral and scientific stakeholders throughout our project, we established five stakeholder advisory groups made up of 62 participants. These groups include a scientific advisory group and four sectoral groups: the environment, agriculture, urban communities, and small communities (note: we have renamed rural communities, small communities following the guidance of our stakeholder group members). The science group is led by Mike Dettinger and is made up of11 members that include representatives from DWR, SWRCB, USBR, USGS, NIDIS, alongside additional climate and environmental scientists. The environment group is led by Ted Grantham and Jeff Mount, and includes 12 representatives from DWR, SWRCB, CalTrout, NOAA, Fish & Wildlife, TNC, EDF, and academia. The agriculture group is led by Josué Medellín-Azura, consists of 12 members, and includes growers alongside representatives from CDFA, USBR, NRCS, EDF, and various county water authorities. Kurt Schwabe leads the urban communities group, which includes 11 members from various urban water districts, DWR, SWRCB, and CUWA. Finally, our small communities group consists of 13 members, including individuals from DWR, SWRCB, Indian Health Services, environmental justice organizations, and county governments, and is led by Alvar Escriva-Bou.

After establishing each group in quarter one, we convened virtual kickoff meetings in quarter two between December 2020 and January 2021. During these kickoff meetings, we introduced members to one another, the core research team, and the project goals and objectives. We also presented our preliminary methodological framework and gathered feedback about how to make our results most effective for stakeholder use. The following is a list of when each kickoff workshop was convened:

1. Science SAG meeting #1: December 7th 2020
2. Environment SAG meeting #1: December 8th 2020
3. Small communities SAG meeting #1: January 19th 2021
4. Agriculture SAG meeting #1: January 25th 2021
5. Urban communities SAG meeting #1: January 29th 2021

Following our kickoff meetings, the core research team also followed up with individual stakeholders for interviews to delve deeper into questions and topics that arose during the kickoffs.

The first group of project workshops began in May 2021 with the Environmental stakeholder advisory group workshop. During this meeting, group leaders presented initial results for our environment specific drought hazard indicators, including the details of a two part methodology for aggregating hydro-climatic data into a regional, environment specific, drought index. In August 2021, the science advisory group met to provide feedback on the composite hydro-climatic indicators we have developed as part of Activity 2. Then towards the end of 2021 we convened stakeholder workshops with the agriculture, urban, and small communities advisory groups. Our environmental stakeholder advisory group met additionally in February 2022 to provide feedback on the environmental drought indicators our team, led by Ted Grantham, has been developing. During these meetings we discussed the respective sectoral impacts of drought and presented our methodological approach for integrating the water grid into indicators of drought. The following is a list of when each of the aforementioned workshops took place:

1. Environment SAG meeting #2 – May 2021
2. Science SAG meeting #2 – August 30th 2021
3. Agriculture SAG meeting #2 – November 29th 2021
4. Urban SAG meeting #2 – December 9th 2021
5. Small communities SAG meeting #2 – December 14th 2021
6. Environment SAG meeting #3 – February 23rd 2022

In addition to our stakeholder group workshops, the core research team also followed up with interested stakeholders to more thoroughly discuss questions and ideas that came up during those meetings. These stakeholders include state officials from the California Department of Water Resources, the State Water Resources Control Board (April 2022), the California Water Data Consortium (May 2022), the California Urban Water Agencies (CUWA) (January 2022), and the California Water Commission (March 2023). For more academic dissemination of the results, we have also presented our results at various conferences in the last year including the American Geoscience Union (AGU) Fall Meetings in December 2021 and 2022, the Salmonide Restoration Federation’s Annual Meeting in April 2022, and the E&J Gallo Water Summit in May 2022.

*Finally, in May 2023 we convened a final project workshop with all five stakeholder groups….[summary of workshop].*

## **What opportunities for training and professional development has the project provided?**

NA

## **How were the results disseminated to communities of interest?**

In addition to our ongoing engagement with the project’s stakeholder groups, we have disseminated initial project results to the public through the circulation a new policy brief on agricultural drought impacts, a virtual public event on farming in drought, and two blog posts. First, in November we published an update the current drought conditions in California, “[The Current Drought: Time to Hope for the Best, Prepare for the Worst](https://www.ppic.org/blog/the-current-drought-time-to-hope-for-the-best-prepare-for-the-worst/).” This publication included a current analysis of conditions and a forecast of potential scenarios moving forward, alongside policy recommendations for various sectors across the state. Later in December we published a review of urban water conservation efforts, “[Are California’s Cities Conserving Enough Water?](https://www.ppic.org/blog/are-californias-cities-conserving-enough-water/)”, which compared present day water saving efforts to those made in the previous drought. Then in April, we published a new policy brief, [Drought and California’s Agriculture](https://www.ppic.org/publication/policy-brief-drought-and-californias-agriculture/) , which assesses the economic impacts the 2021 drought conditions had on California farmers. Upon release, we also organized a virtual event on April 21st 2022, [Farming in a State of Extremes](https://www.ppic.org/event/farming-in-a-state-of-extremes/?utm_source=ppic&utm_medium=email&utm_campaign=event), with panelists from representatives from the Governor’s Office, local irrigation districts, and a local farmer. Beyond these formal results of the project, as mentioned above, the project is including many informal engagement opportunities with many interested parties.

## **What do you plan to do during the next reporting period to accomplish the goals and objectives?**

Not applicable

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# OPTIONAL CATEGORIES

## PRODUCTS

### **Publications, conference papers, and presentations**

* We published an updated fact sheet on “[Droughts in California](https://www.ppic.org/publication/droughts-in-california/)” (April 2021) that includes a high level review of the 2012-16 drought and its impacts.
* We also published a two-part blog series and hosted an event on the state’s immediate drought conditions:
  + Blog #1: “[California’s Latest Drought in 4 Charts](https://www.ppic.org/blog/californias-latest-drought-in-4-charts/)” (May 3rd, 2021)
  + Blog #2:– “[Anticipating and Addressing the Impacts of Drought](https://www.ppic.org/blog/anticipating-and-addressing-the-impacts-of-the-drought/)” (May 4th, 2021)
  + Event: “[Is California Ready for Drought?](https://www.ppic.org/event/is-california-ready-for-drought/)” (May 6th, 2021)
  + Event [recording and summary](https://www.ppic.org/blog/video-is-california-ready-for-drought/) (May 10th, 2021)
* Finally, we recently published a commentarywith Cal Matterson groundwater levels and wells at risk of going dry in the Central Valley, “[How better data can help California avoid a drinking water crisis](https://calmatters.org/commentary/my-turn/2021/06/how-better-data-can-help-california-avoid-a-drinking-water-crisis/)” (June 14th, 2021).
* We published an update on current drought impacts “[The Current Drought: Time to Hope for the Best, Prepare for the Worst](https://www.ppic.org/blog/the-current-drought-time-to-hope-for-the-best-prepare-for-the-worst/)” (Nov 2021)
* We also published a review of water management decisions and their impact on the environment in times of drought with the California WaterBlog “[Managing Water Stored for the Environment During Drought](https://californiawaterblog.com/2021/11/07/managing-water-stored-for-the-environment-during-drought/)” (Nov 2021)
* We also published a review of urban conservation efforts across the state, “[Are California’s Cities Conserving Enough Water?](https://www.ppic.org/blog/are-californias-cities-conserving-enough-water/)” (Dec 2021)
* In February, we published a review of the [Economic Impacts of the 2021 Drought to California Agriculture](https://wsm.ucmerced.edu/drought_impact_2021/) (Feb 2022)
* Most recently in April 2022 we published a policy brief on the impacts of drought on California’s agricultural sector, and hosted a public event discussing the contents of the brief:
  + Policy brief: [Drought and California’s Agriculture](https://www.ppic.org/publication/policy-brief-drought-and-californias-agriculture/)
  + Event: [Farming in a State of Extremes](https://www.ppic.org/event/farming-in-a-state-of-extremes/?utm_source=ppic&utm_medium=email&utm_campaign=event)
* In April 2022, Jeff Mount and Ted Grantham presented their work on environmental drought hazard at the 39th [Annual Salmonid Restoration Conference](https://www.calsalmon.org/conferences/39th-annual-salmonid-restoration-conference) in Santa Cruz, California.
* In December 2022, Alvar Escriva-Bou presented preliminary project results at the Fall AGU [meeting](https://www.agu.org/Events/Meetings/Fall-Meeting-2022) in Chicago, Illinois.
* Jeff Mount and Ted Grantham also submitted a paper in [Water Resources IMPACT magazine](https://www.awra.org/AWRA/Members/Publications/IMPACT.aspx).
* *Additional blogs/conferences/publications*
  + *Should include probably the three methodology papers in here once they’re submitted.*

### **Technologies or techniques**

NA

### **Inventions, patent applications, and/or licenses**

NA

### **Other products**

NA

## PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

### **What individuals have worked on this project?**

The core research team includes Alvar Escriva-Bou, Ellen Hanak, Jeff Mount, Andrew Ayres, Annabelle Rosser, Skyler Lewis, and Spencer Cole from PPIC’s Water Policy Center, alongside four external partners, Michael Dettinger from Scripps Institute of Oceanography, Ted Grantham from UC Berkeley, Josué Medellín-Azuara from UC Merced, and Kurt Schwabe from UC Riverside.

### **Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

NA

### **What other organizations have been involved as partners?**

NA

### **Have other collaborators or contacts been involved?**

We have also been collaborating with 62 stakeholders as part of our five sectoral advisory groups. These members include:

1. Michael Anderson, California State Climatologist at DWR
2. Amanda Sheffield, Regional Drought Information Coordinator at NIDIS (CA-NV)
3. Dennis Lettenmaier, Distinguished Professor Geography at UCLA
4. Justin Huntington, Research Professor at Desert Research Institute
5. Noah Molotch, Associate Professor of Geography at INSTAAR CU Boulder
6. Alan Haynes, Service Coordination Hydrologist at California Nevada River Forecast Center
7. Liz Kiteck, Water Operations Division Manager at USBR
8. Claudia Faunt, Program Chief, Groundwater Availability and Use Assessments at USGS
9. Erik Ekdahl, Deputy Director at SWRCB
10. HB Zeff, Post-Doctoral Researcher at University of North Carolina
11. Molly White, Principal Engineer at DWR
12. Julie Zimmerman, Freshwater Lead Scientist at the Nature Conservancy, California Chapter
13. Ann Hayden, Senior Director, Western Water and Resilient Landscapes at Environmental Defense Fund
14. Sandra Jacobson, South Coast Regional Director at CalTrout
15. Rachel Johnson, Southwest Fisheries Science Center Program Lead at NOAA
16. Ted Sommer, Lead Scientist at DWR
17. Peter Moyle, Distinguished Professor Emeritus at UC Davis
18. David Herbst, Research Biologist, Sierra Nevada Aquatic Research Laboratory, and Marine Science Institute at UC Santa Barbara
19. Avril Horne, Arc Discovery Early Career Researcher at U. Melbourne
20. Sarah Null, Associate Professor, Watershed Sciences at Utah State
21. Kristal Fad, Environmental Program Manager at Department of Fish and Wildlife
22. Les Grober, Retired Annuitant at SWRCB
23. Ali Forsythe, Consultant at Sites Reservoir Project (Former USBR)
24. Cindy Paulson, Executive Director at California Urban Water Agencies (CUWA)
25. Brad Coffey, Group Manager at Metropolitan Water District of Southern California
26. Kelley Gage, Water Resources Director at SDCWA
27. Jeff Stephenson, Water Resources Principal & Specialist at San Diego County Water Authority
28. Richard Atwater, Director at Foothill Municipal Water District
29. Ken Jenkins, Director of Drought Management and Conservation at Cal-Water
30. David Mitchell, Consultant at Mitch and Associates LLC
31. Rosemary Menard, Water Director at City of Santa Cruz
32. Joshua Haggmark, Water Resources Manager at City of Santa Barbara
33. Katie Evans, Director of Communications and Conservation at Coachella Valley Water District
34. James Nachbaur, Director of Research, Planning and Performance at SWRCB
35. Julia Eckstrom, Senior Environmental Scientist at DWR
36. Jessi Snyder, Community Development Manager at Self-Help Enterprises
37. Mary Pitto, Regulatory Affairs Advocate at Rural County Representatives of California (RCRC)
38. Jonathan Nelson, Policy Director at The Community Water Center (CWC)
39. Stephanie Anagnoson, Director of Water and Natural Resources at Madera County
40. Ross W. Miller, Chief Engineer at Tulare county resource management agency
41. Natalie Stork, Groundwater Management Program Supervisor at SWRCB
42. Andrew Altevogt, Deputy Director at SWRCB - SAFER Program
43. Courtney Howard, Divison Manager at County of San Luis Obispo
44. Adan Ortega, Executive Director at California Association of Mutual Water Companies
45. Sarge Green, Consultant at Fresno State
46. Jonathan Rash, Deputy Director at Indian Health Services (CA)
47. Erick Orellana, Policy Advocate at Indian Health Services (CA)
48. Joe Boy, Office of Emergency Management Director at Tule River Indian Tribe of California
49. Dave Puglia, President and CEO at Western Growers Association
50. Karen Ross, Secretary at California Department of Food & Agriculture
51. Amrith Gunasekara, Science Advisor at California Department of Food & Agriculture
52. Kristin White, Operations Manager, Central Valley Operations Office at USBR
53. Wendy Rash, State Water Quality Specialist at Natural Resources Conservation Service
54. David Guy, President at Northern California Water Association
55. Tom McCarthy, General Manager at Kern County Water Agency
56. Scott Petersen, Water Policy Director at San Luis Delta Mendota Water Agency
57. Dan Sumner, Director, UC Agricultural Issues Center and Frank Buck Jr. Chair Professor at University of California Agriculture and Natural Resources
58. Tom O'Brien, Senior Vice President and General Counsel at Driscoll's
59. Kim Brown, Senior Director at the Wonderful Company
60. Robynn Grimm, Senior Manager, Water Information Systems at EDF
61. Jon Reiter, Principal Consultant at Cavalrei

## IMPACT

### **What was the impact on the development of the principal discipline(s) of the project?**

The project is still ongoing and the main impacts are expected to be realized during the final part of the project. But during the ongoing engagement activities, many stakeholders have expressed their interest in the completion of our project because they think it might be an important advance in the characterization of droughts in California.

### **What was the impact on other disciplines?**

NA

### **What was the impact on the development of human resources?**

NA

### **What was the impact on teaching and educational experiences?**

NA

### **What was the impact on physical, institutional, and information resources that form infrastructure?**

The project is going to impact informational resources (by expanding on the current drought early warning systems in highly managed water systems) which might help the planning and management of water infrastructure.

* *Could expand more on the specific contributions Alvar’s results might make*

### **What was the impact on technology transfer?**

NA

### **What was the impact on society beyond science and technology?**

So far, the publications and events described above have helped improved public understanding of the sectoral impacts of drought and informed policymakers about how to best mitigate those impacts. ~~As the project progresses, we expect our results to contribute to NIDIS’s ongoing work communicating drought risk to decision makers, policymakers, and the general public.~~

* *Summarize the impact of three methodology papers once they’ve progressed*
* *Summarize the impact of the final stakeholder workshop*

### **What percentage of the award’s budget was spent in foreign country(ies)?**

0%

## CHANGES/PROBLEMS

### **Changes in approach and reasons for change**

Some unanticipated challenges due to the pandemic and the drought – particularly the way remote work has affected our internal collaboration with the core research team and the availability of key stakeholders to provide feedback on our work – caused some delays in our progress. As a result, we requested a one year no-cost extension and revised our research activity timeline and deliverables accordingly. While we’ve made some adjustments to the project’s timeline, these changes have not significantly altered our approach, and rather simply extend the work over a lengthier period of time.

### **Actual or anticipated problems or delays and actions or plans to resolve them**

The Covid-19 pandemic and the respective shift to socially distanced, remote work has had a significant impact on how the core research team collaborates with one another as well as with stakeholders. These challenges have been further compounded by the current drought over the past year, as the vast majority of our partners and stakeholders are actively working to respond to conditions. As a result, it has been difficult to convene folks at times, especially during periods where drought conditions are at their most extreme. Consequently, we applied for and were granted a no-cost extension, which adds an additional year to the project timeline, giving us more flexibility to connect with stakeholders that are juggling competing priorities.

### **Changes that had a significant impact on expenditures**

Due to the Covid-19 pandemic, all outreach with stakeholders, core research team meetings, and advisory group workshops have been convened virtually, which has significantly reduced our expenditures for project meetings and travel for the first year.

### **Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents**

Nothing to Report

### **Change of primary performance site location from that originally proposed**

NA

## PROJECT OUTCOMES

### **What were the outcomes of the award?**

The five expected outputs of this project include:

1. A framework to develop multi-sectoral drought hazard indicators, taking into account the water grid
2. An innovative methodology for linking drought hazard indicators and impacts
3. Open access data and methods for drought hazard indicators and impacts
4. Exploratory mapping tools, including sector-specific drought hazard indicator maps and drought risk profiles
5. An engagement process that could be useful for ongoing tracking of drought impacts

These outputs will be encapsulated in the following deliverables:

* 1. Three methodology papers that include a description of our framework, to integrate the grid into indicators of drought, detailed descriptions of our developed methodology for linking indicators and impacts, and numerous exploratory maps and figures applying our methodology to sectoral case studies.
  2. A public github data repository that can be used to access and reproduce the data as described in our publications.
  3. Four additional stakeholder advisory group workshops, and one final project workshops or public event.

After the first seven quarters of the project, we are on track to deliver these outcomes by the end of the project (which has been extended to August 2023).

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