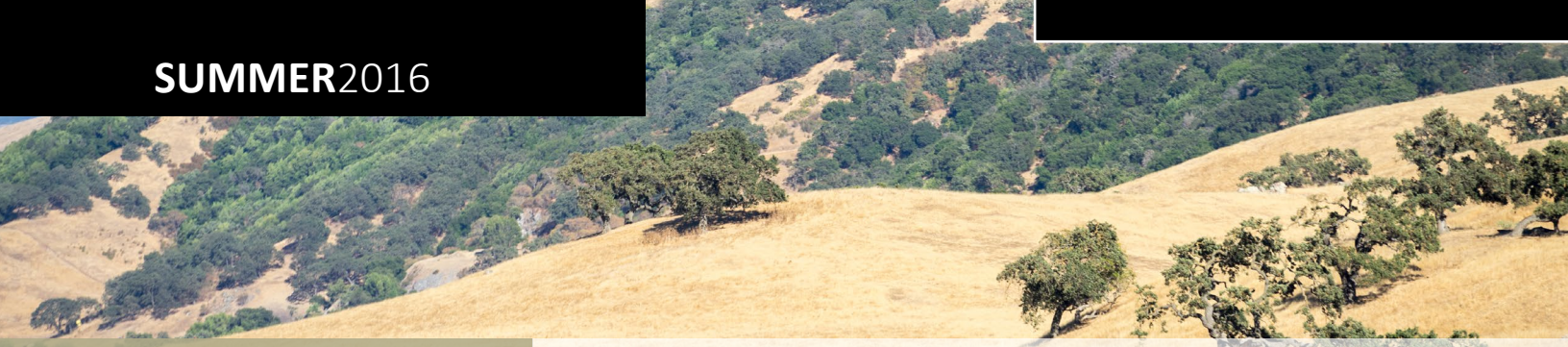
SUMMER2016



National Drought Mitigation Center

DROUGHTSCAPE

The Newsletter of the National Drought Mitigation Center

CONTENTS

About the photo

The colors of drought are evident July 8 at Santa Teresa County Park in San Jose, California. The state has been experiencing drought conditions for five years. Despite normal rainfall over the winter, the state has not yet recovered.

Photo by Xynalia/Flickr

DIRECTOR'S REPORT

Don Wilhite retired from the University of Nebraska-Lincoln on June 30, 2016. This was particularly noteworthy within the university community because he had based almost his entire career at Nebraska.

Michael J. Hayes

I have always known him to be a tremendous ambassador for the university and state: He even tried to get me to purchase my first bright red Cornhusker shirt before he had offered me the job for which I was interviewing.

But Don's retirement also is noteworthy throughout the global drought community, where he was known as a true pioneer. Within this community, he will be leaving behind an incredible legacy promoting proactive drought risk management approaches at all scales around the world. Prior to Don's career-long work, little understanding existed to encourage officials to prepare for future drought events. Now, this topic is addressed in discussions or with research regularly. In addition, the Integrated Drought Management Programme co-chaired by the World Meteorological Organization and Global Water Partnership promotes these concepts worldwide. This is a huge accomplishment that can be attributed directly to Don.

For me, it has been amazing to see that Don's passion for drought issues has never wavered. I've learned so much from him during my career with the National Drought Mitigation Center. Don and I boarded a plane for Australia shortly after my arrival in 1995 to learn about drought management strategies there, and I have been learning from Don, and with Don, ever since. As the NDMC evolved and grew, Don stressed again and again that the most important key to the development of a successful team was finding the right people to be on it. When I became NDMC director in 2007, I was the recipient of the strong team Don had created, and I attribute the NDMC's long-term success to Don's team-oriented philosophy.

More recently, Don has become much more of a colleague and friend; it has been an honor to work with him. He still passionately advocates for proactive drought risk management, but he also has led multiple efforts to investigate how climate change might impact Nebraska and the central United States. The good news is that Don will continue some of his work with several international drought management activities. That is great because, without action to reduce risk, droughts will continue to pose an increasing threat to food and water security around the world.

Michael J. Hayes

Meet our newest employees

John Swigart joined the National Drought Mitigation Center in June 2016 as a geospatial analyst. He spent the previous nine years as the GIS coordinator for the Valles Caldera National Preserve in northern New Mexico. Here he analyzed and managed spatial data in support of a full range of natural resource management undertakings including landscape restoration, ecological monitoring, land-use planning and wildland fire management. A licensed teacher, he also taught and tutored secondary mathematics and science while in New Mexico.

John Swigart

Prior to that, Swigart was employed as an archaeologist/GIS specialist with the Nebraska State Historical Society. In addition to archaeological compliance work for highway construction, he designed and developed the Nebraska Cultural Resource GIS. This is a comprehensive spatial database of all known archaeological sites and surveys in the state with a customized user interface so the non-specialist can easily access, query and map the data. Swigart received the 2014 Asa T. Hill award for this effort.

Swigart enjoys being outdoors, mountain biking, camping, hiking and gardening. He is very interested in mathematics and hopes to pursue an advanced degree in the discipline. He was born and raised in Nebraska and is thrilled to be back home and bringing his experience to the NDMC and his alma mater, the University of Nebraska.

Swigart earned a master's degree in anthropology from the University of Nebraska-Lincoln in 2001 and a bachelor's in anthropology from the University of Nebraska-Lincoln in 1992.

■■■

Curtis Riganti joined the National Drought Mitigation Center as a climatologist in the summer of 2016 after completing a master's degree in Earth and Atmospheric Sciences with a meteorology/climatology specialization from the University of Nebraska-Lincoln in the fall of 2015.

Curtis Riganti

Riganti is analyzing drought trends in the United States and is helping to investigate statistical distributions used for the Standardized Streamflow Index.

In addition to his master's degree, RIganti has a bachelor's degree in meteorology from the University of Oklahoma, earned in spring 2013.

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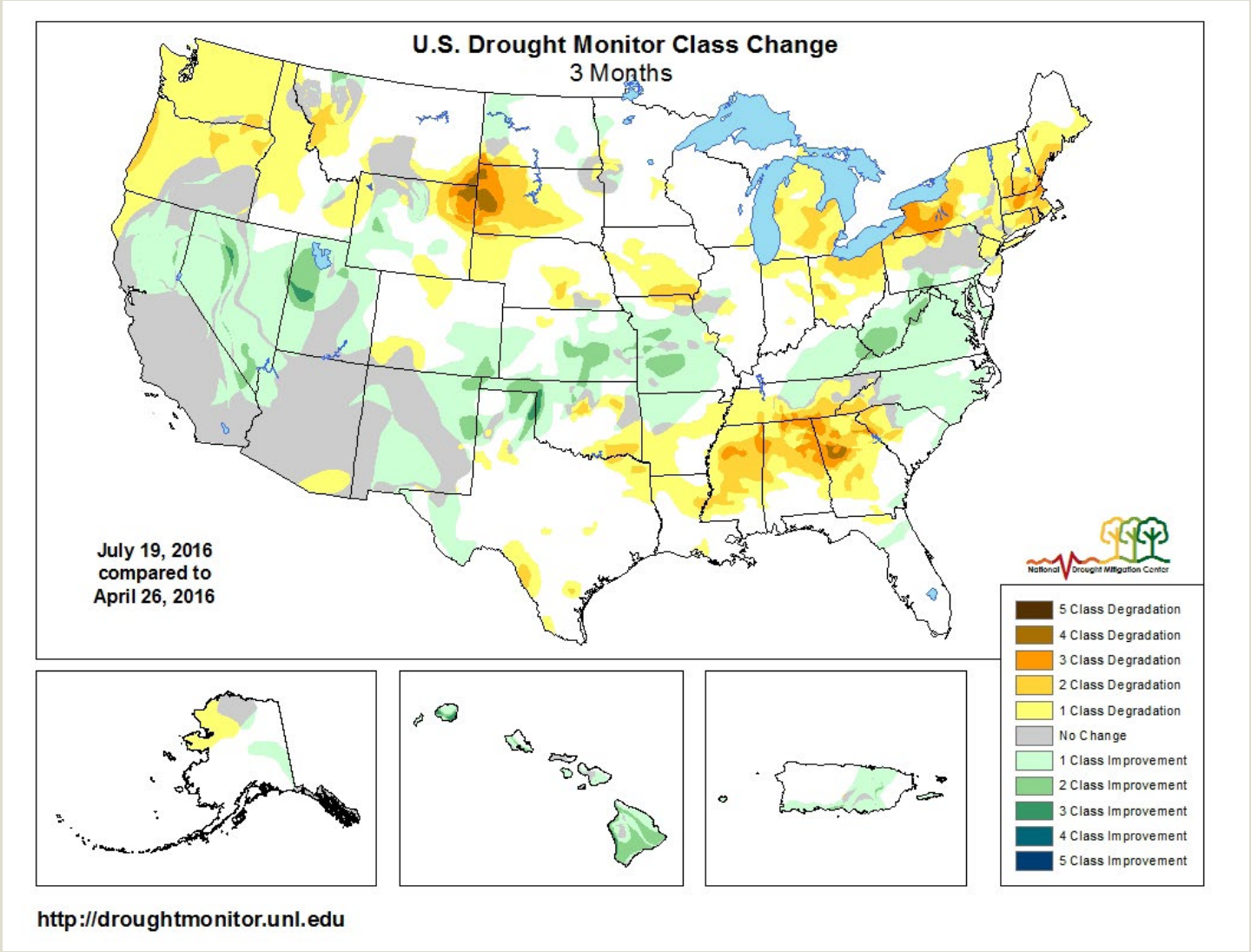

Drought slowly spreads, while severe drought improves slightly

BY BRIAN FUCHS
NATIONAL DROUGHT MITIGATION CENTER CLIMATOLOGIST

Drought classifications are based on the U.S. Drought Monitor. Details on the extent and severity of drought are online: ***droughtmonitor.unl.edu****.*

The outlook integrates existing conditions with forecasts from the National Oceanic and Atmospheric Administration's Climate Prediction Center: ***www.cpc.ncep.noaa.gov.***

Drought

Drought has expanded slowly with new areas of drought developing in the Southeast, Northeast, and High Plains while improving slightly over the West. During this quarter, drought expanded to cover 13.60 percent of the United States compared to 12.76 percent at the end of March. Severe drought improved slightly, and now covers 4.56 percent of the country compared to 4.92 percent in the first quarter. The severe drought improvements were mainly over the West and Rocky Mountains. Extreme drought improved from 3.14 to 1.97 percent while exceptional drought improved from 1.56 to 0.92 percent of the country. Like severe drought, most of these improvements were in the West. At the end of June, drought was affecting more than 81.7 million people, compared to 32.3 million people at the end of March.

Temperatures

Temperatures during this time period were near normal for most areas east of the Missouri River Valley. Some departures in the Northeast were up to 2 degrees

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below normal. Areas of the West, Great Basin, and Northern Rocky Mountains were warmer than normal with departures of 2 to 4 degrees above normal. For both Alaska and Hawaii, temperatures were above normal during the quarter.

Precipitation

Precipitation was abundant during the period, with areas of Texas recording 10 to 15 inches above normal. Near-normal to above-normal precipitation was recorded over much of the Plains, Mid-Atlantic, Southwest, and along the Atlantic coast of the Southeast. Dryness was evident over portions of the Upper Mississippi River Valley, Tennessee River Valley, and New England with departures of up to 10 inches below normal. Most of Hawaii and Alaska were above normal for precipitation as well.

Outlook

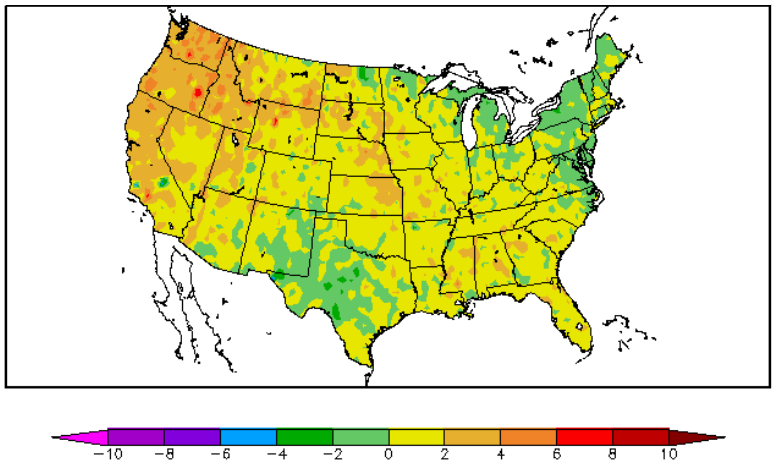
For the West, drought will persist and develop over eastern Washington and northern Idaho. In the Southwest, some improvements may be possible over Arizona and New Mexico. Drought development is anticipated over portions of central Texas while drought will persist and expand over much of the Southeast. Over the High Plains, drought will continue over portions of South Dakota, Wyoming and Montana and will persist over much of New England and Hawaii.

MONTHLY DROUGHT AND IMPACT SUMMARIES

For a more detailed review of conditions, please see the NDMC's Drought and Impact Summaries for April, May, and June:
drought.unl.edu/newsoutreach/monthlysummary.aspx

Departure from normal temperature (F)

April 1 to June 30, 2016

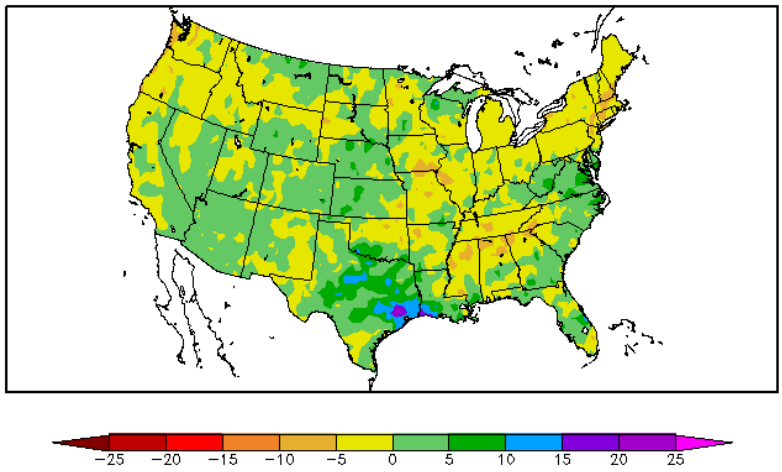


Generated 7/11/2016 at HPRCC using provisional data.

Source: High Plains Regional Climate Center

Departure from normal precipitation (in)

April 1 to June 30, 2016



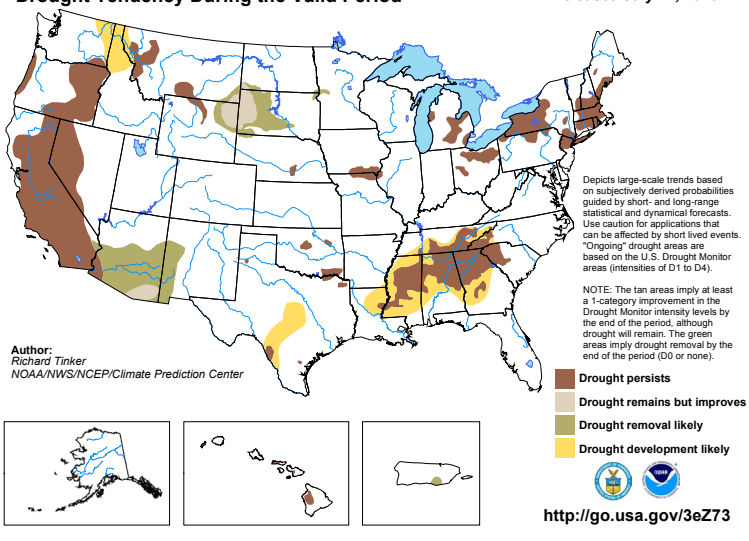
Generated 7/11/2016 at HPRCC using provisional data.

Source: High Plains Regional Climate Center

U.S. Seasonal Drought Outlook

Drought Tendency During the Valid Period

Valid for July 21 - October 31, 2016
Released July 21, 2016

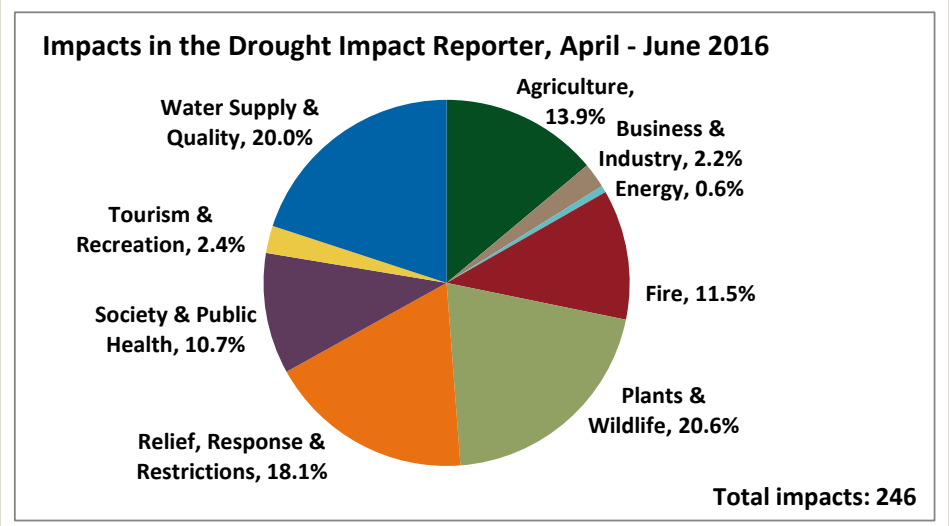


Author:
Richard Tinker
NOAA/NWS/NCEP/Climate Prediction Center

http://go.usa.gov/3eZ73

Drought spreads, intensifies across US

BY DENISE GUTZMER
NATIONAL DROUGHT MITIGATION CENTER DROUGHT IMPACT SPECIALIST



Source: National Drought Mitigation Center

As the growing season got underway and drought took hold in new areas and intensified in others, more reports of impacts emerged in the Northeast, Southeast, Midwest, South Dakota and the Pacific Northwest. The Drought Impact Reporter recorded many descriptions of slowed crop growth and damage to plants across the country, and California, which has been in drought for five years, reported concerns about water supply and restrictions, or the absence of them after a winter of near-normal snowfall.

Overall, 246 impacts were added to the DIR during the second quarter of 2016, with 71 of those for California, 20 for North Carolina, 14 for Missouri and 10 for New Mexico. Eighteen of North Carolina's impacts came from members of the Community Collaborative Rain, Hail & Snow Network, documenting issues near their homes, and in Missouri, 11 of the impacts were from CoCoRaHS contributors and other individual observers, driving the impact counts higher than would be expected, given the drought conditions in each state, and reflecting efforts to cultivate a denser network of observations, particularly during potential emerging drought conditions. New Mexico had entries from three CoCoRaHS volunteers.

California's ongoing drought

Toward the end of California's wet season, which extends through the winter and early spring months, the snowpack in the state's Sierra Nevada amounted to near-average, leading the state's water providers to increase allocations. Warm weather melted the snow quickly, leading to early runoff and lower flows later in the season when runoff would normally be stronger. The California Department of Water Resources revised its water supply estimate and predicted just three-quarters of the normal runoff during the months of heaviest snowmelt, short-changing the rivers and reservoirs that usually receive a third of the state's water. Much of the West saw the same early snowmelt and early runoff, leaving rivers and streams on the low side as summer began.

The average snowfall boosted reservoir levels, making Californians feel like the drought was not as intense as it had been. That led to calls for an end to the mandatory restrictions on water use that had been in place since June 2015 and more local control of water use, which Gov. Jerry Brown granted on May 9. He offered a new framework for water use efficiency, making permanent the emergency drought regulations set forth in January 2014 and warning water providers to prepare for a drier future. The State Water Resources Control Board finally dropped its mandatory conservation targets later in May, allowing water districts to set their own conservation standards, provided that they had a three-year supply of water.

"California braces for unending drought," by Ian Lovett, The New York Times, May 9, 2016 and San Jose Mercury News, May 9, 2016

"California drops mandatory water cutbacks for cities and towns," by Kurtis Alexander, San Francisco Chronicle (SFGate.com), May 18, 2016

El Niño is done, La Niña on the way?

Last winter's strong El Niño was a disappointment in that it didn't bring the series of wet, drought-easing storms to all areas. In addition, the National Oceanic and Atmospheric Administration's Climate Prediction Center (CPC) forecasts a La Niña to develop in the fall, which would potentially mean more dry weather for the Southwest and parts of California.

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Plenty of firewood in California

The lengthy stretch of drought has left the landscape exceedingly dry and inflicted intense damage on California's trees. In a six-county region of central and southern Sierra Nevada most severely affected by the drought, roughly 66 million trees have died since 2010, due to a bark beetle epidemic and warm temperatures, according to the U.S. Forest Service. The tree mortality from Tuolumne to Kern counties rose by 65 percent since the last mortality figures were announced in October 2015, when the count was numbered at 40 million. Officials are taking action to reduce the incredible amount of dead wood that could fuel catastrophic wildfires and endanger people's lives.

"Feds: Drought kills 66 million trees in California's Sierra," by Scott Smith, Associated Press, San Francisco Chronicle (SFGate.com), June 22, 2016

http://www.sfgate.com/news/us/article/Feds-Drought-kills-66-million-trees-in-8319935.php

Emerging crop damage/loss in eastern two-thirds of the U.S.

Pockets of drought have developed in parts of the eastern U.S., causing stress and damage to crops, increasing fire activity and leading to water restrictions for some communities.

Southeast

By the end of June, crop damage was apparent in northern Alabama, where crops were withering and may be past the point of recovery. Corn was already stunted in early June and yields were thought to be diminishing. Conditions were similar in northern Georgia where the lack of rain increased the fire danger and dry pastures meant that growers would be feeding their livestock hay if rain did not fall soon. Hay growth was slow in western North Carolina, too, and vegetation and gardens required watering to keep them alive.

"The drought continues to affect crops," WZDX-TV Huntsville (Ala.), June 28, 2016
http://www.rocketcitynow.com/news/the-drought-continues-to-affect-crops

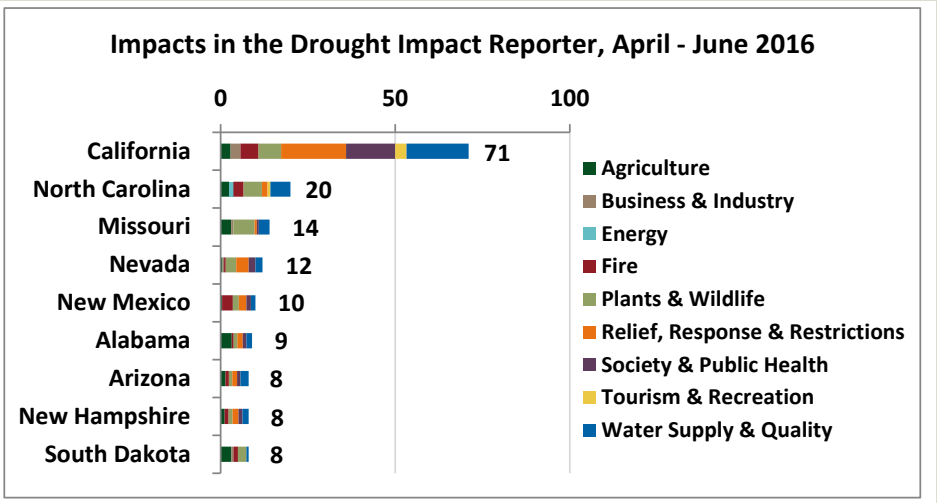
"Lack of rain is hurting corn crops in North Alabama," by Scott Sheahen, WZDX-TV Huntsville (Ala.), June 6, 2016
http://www.rocketcitynow.com/news/drought-hurting-local-corn-crops

CoCoRaHS Report from Station #Athens 7.6 SE on 6/27/2016

"Officials warn of wildfire conditions," by Ben Benton, Chattanooga Times Free Press (Tenn.), June 2, 2016
http://www.timesfreepress.com/news/local/story/2016/jun/02/officials-warn-wildfire-conditions/368906/

"Today's Topic: Weather hurting NC crops," North Carolina Department of Agriculture and Consumer Services, June 14, 2016
http://info.ncagr.gov/blog/2016/06/14/todays-topic-weather-hurting-nc-crops/

CoCoRaHS Report from Station #Battleboro 7.2 W on 6/20/2016



Source: National Drought Mitigation Center

DROUGHT IMPACT REPORTER

For more detailed reports, please see the NDMC's Drought Impact Reporter for April, May and June:
droughtreporter.unl.edu

Midwest

The lack of rainfall was felt across the Midwest as growers irrigated where they could and saw crop damage where they could not. A Christmas tree grower in Mason in south central Michigan expressed dismay that even established trees were manifesting signs of damage from the lack of rain. Dozens of burn bans were enacted around Lansing, Michigan, to prevent fires from July fireworks and ordinary outdoor burning. In parts of Indiana and Illinois, corn growth was stunted and leaves were curling severely from the lack of rain. Hot, dry weather in Missouri stressed crops, and corn stalks began to take on a grayish hue, with leaves growing close to the stalks. Grasses stopped growing, and farmers in southwestern Missouri were selling cattle.

"Dry weather hurting Christmas tree farms," by WILX-TV Lansing NBC 10 (Mich.), June 30, 2016
http://www.wilx.com/news/localnews/headlines/Dry-weather-hurting-Christmas-tree-farms-384925281.html

"Burning bans could impact area fireworks," by Ken Palmer, Lansing State Journal (Mich.), June 30, 2016
http://www.lansingstatejournal.com/story/news/local/2016/06/27/burning-bans-effect-throughout-lansing-area/86446974/

CoCoRaHS Report from Station #Holland 6.3 NW on 6/25/2016

"We need rain: Michiana showing signs of drought." by Tom Coomes, ABC 57 WBND-TV South Bend News (Ind.), June 13, 2016
http://www.abc57.com/story/32212718/we-need-rain-michiana-showing-signs-of-drought

"Heat, lack rain hurting some crops," by Greg Olson, Jacksonville Journal-Courier (Ill.), June 22, 2016

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http://myjournalcourier.com/news/96896/heat-lack-rain-hurting-some-crops

"Weather poses lower than average crop yield," by Hope Lecchi, Sedalia Democrat (Mo.), June 17, 2016
http://sedaliademocrat.com/news/13126/weather-poses-lower-than-average-crop-yield

Northeast

The Northeast was dry during the latter half of 2015 and early 2016, but received enough moisture to pull the region out of drought for a while before the landscaped dried out again. Dry weather in Maine put some crops weeks behind schedule, and growers were irrigating if they had the capability. Irrigation was the saving grace in New Hampshire, too, where as many as 70 towns and water systems had restricted or banned outdoor water use to conserve water. A couple of Massachusetts communities were also restricting water use until rains returned. Connecticut's Department of Public Health declared a drought advisory on June 27 and urged residents to follow guidelines for conserving water. In New York, seeds had not germinated well, irrigation was needed and lawns were turning brown.

"Dry spell has Maine growers going with the flow," by Beth Quimby, Portland Press Herald (Maine), June 27, 2016
http://www.pressherald.com/2016/06/26/gardeners-getting-ready-for-a-rain-dance/

"Dry spell means more work down on the farm," by Don Himsel, Nashua Telegraph (N.H.), June 29, 2016
http://www.nashuatelegraph.com/news/1082449-469/dry-spell-means-more-work-down-on.html

"As dry weather continues, water restrictions spring up," by Eli Okun and Melissa Proulx, Manchester Union Leader (N.H.), June 28, 2016
http://www.unionleader.com/article/20160629/NEWS11/160629267&source=RSS

"Southampton enacting voluntary water bans," by Jennifer Pagliei, WWLP-TV Springfield (Mass.), June 27, 2016
http://wwlp.com/2016/06/27/southampton-enacting-voluntary-water-bans/

"State Issues 'Drought Advisory,' Farmers Worried Lack of Rainfall Damaging Crops," by Gregory B. Hladky, Hartford Courant (Conn.), June 27, 2016
http://www.courant.com/news/connecticut/hc-ct-drought-worries-20160627-story.html

"PARCHED! Farmers dealing with near drought," by Steve Buchiere, Geneva Finger Lakes Times (N.Y.), June 29, 2016
http://www.fltimes.com/news/parched-farmers-dealing-with-near-drought/article_d7154498-3e06-11e6-8653-031e1c91db87.html

CoCoRaHS Report from Station #Skaneateles 0.8 NNW on 6/30/2016

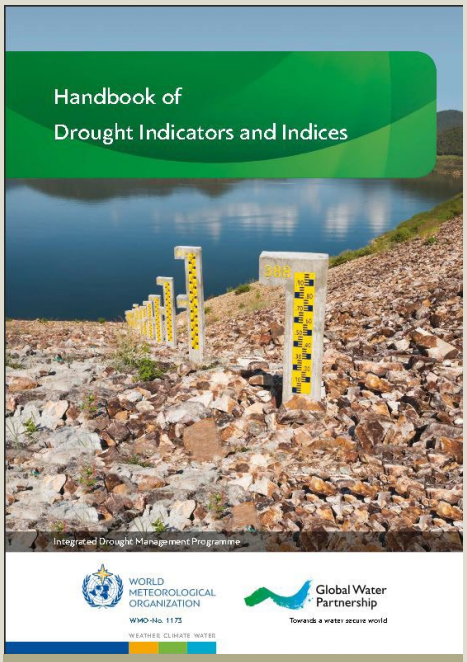
Drought guidebook most comprehensive catalog of indicators available

BY SHAWNA RICHTER-RYERSON
NDMC COMMUNICATIONS ASSOCIATE

The Handbook of Drought Indicators and Indices brings into one resource guide 50 drought tools being used by planners and policymakers around the world.

The guidebook, written by Mark Svoboda and Brian Fuchs, climatologists with the National Drought Mitigation Center at University of Nebraska-Lincoln, and released by the Integrated Drought Management Programme (IDMP), is available online here. It is a part of the Integrated Management Tools and Guidelines Series compiled by the IDMP, a partnership by the World Meteorological Organization and Global Water Partnership, and it will be translated into Arabic, Chinese, Spanish, French and Russian.

"For a long time now, users of drought indicators for operational or research needs have been asking for a catalog of the most widely used indicators around the world," Svoboda said. "I believe we have put together one of the most thorough and up-to-date catalogs of indicators being applied today."



Courtesy image

The Handbook of Drought Indicators and Indices, recently released, is available in English through the Integrated Drought Management Programme website, www.droughtmanagement.info.

The publication gives an overview of available tools, programs and literature being used in drought-prone regions and includes where it originated and what data it utilizes. Each is further broken into classification – meteorology, soil moisture, hydrology, remote-sensing and composite or modelled – and then given an ease-of-use category, green being the easiest to access or use and red being the most data-intensive and complex.

Indicators and indices provide options for identifying the severity, location, onset, duration and cessation

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of drought conditions, according to the guidebook, and it's important to remember impacts vary by region and by season. It's also important to remember there is no one-size-fits-all definition of drought, Svoboda and Fuchs write. No single index or indicator can be applied to all types or areas affected by drought.

"The list of indices and indicators is a great starting point on what can be done with data available to a user and also where to go to find out more information," Fuchs said. "Starting with the Palmer Drought Severity Index in the 1960's to all of those currently listed in the guidebook, the science behind drought has come a long way and offers many opportunities to those wishing to do more in the way of monitoring as part of an early warning or planning system."

The "living document" will allow users to leave comments about what indicators they use in an online database, which could provide guidance to others battling drought. Their comments can highlight the strengths or weaknesses of tools, helping decision-makers choose the ones best-suited to their planning and drought mitigation needs. That interactive version of the drought guidebook is here: *http://www.droughtmanagement.info/indices/.*

"These are the building blocks," Svoboda said about the tools presented in the publication. "How they can be applied is the next step."

Both Svoboda and Fuchs say this book is intended to be a reference, and both are looking to the future and the possibility of creating an application guide – maybe even a smartphone application – to accompany it. They want to see the tools available at people's fingertips.

Perhaps literally.

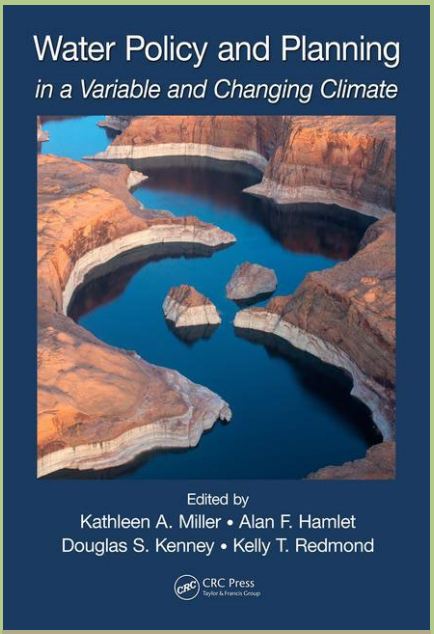
OTHER RECENT PUBLICATIONS

Water Policy and Planning in a Variable and Changing Climate

Water Policy and Planning in a Variable and Changing Climate, edited by Kathleen A. Miller, Alan F. Hamlet, Douglas S. Kenney, and Kelly T. Redmond, CRC Press, Taylor & Francis Group, May 2016, part of the Drought and Water Crises series, edited by Don Wilhite.

Chapter 7, "Support for Drought Response and Community Preparedness: Filling the Gaps between Plans and Action," is by Kelly Helm Smith, Crystal J. Stiles, Michael J. Hayes, and Christopher J. Carparelli.

Publisher's description: This is an edited volume that will serve as a comprehensive resource for both students and practitioners in fields related to water policy and environmental management in the Western United States. The 480-page volume includes 21 chapters written by highly-regarded experts on their respective topics. The book describes the physical, socioeconomic and institutional setting for water resource planning and policy development in the Western United States. It explains the processes driving climate variability in the region as well as the potential impacts of climate change on water availability, water quality and water-related hazards. It highlights the relevance of climate variability and change for addressing the major ongoing water policy challenges confronting Western water planners and policy makers and provides case studies that document both emerging challenges and creative approaches to planning for managing climate-related risks.



The National Drought Mitigation Center contributed a chapter to Water Policy and Planning in a Variable and Changing Climate, available from CRC Press.

Learn more: *https://www.crcpress.com/Water-Policy-and-Planning-in-a-Variable-and-Changing-Climate/Miller-Hamlet-Kenney-Redmond/p/book/9781482227970*

Drought indicators revisited

"Drought indicators revisited: The need for a wider consideration of environment and society," by Sophie Bachmair, Kerstin Stahl, Kevin Collins, Jamie Hannaford, Mike Acreman, Mark Svoboda, Cody Knutson, Kelly Helm Smith, Nicole Wall, Brian Fuchs, Neville D. Crossman, and Ian C. Overton, in WIRES (Wiley Interdisciplinary Reviews: Water), Vol. 3, No. 4, July-August 2016, pages 516-536.

Find it here: *http://onlinelibrary.wiley.com/doi/10.1002/wat2.1154/full*

DIR updates make finding local data easier

Recent changes to the Drought Impact Reporter make it much easier for users to find information about how drought has affected a specific location. Impacts are now aggregated by jurisdictional scale – city, county, state, multi-state, or the whole country, and users can specify a location.

Previously, the web-based tool allowed users to specify a location, but provided impacts at all scales simultaneously, which made it difficult for users to zero in on impacts affecting a single area. Now, if users want impacts for a specific location at all relevant scales, they can do separate searches for each scale.

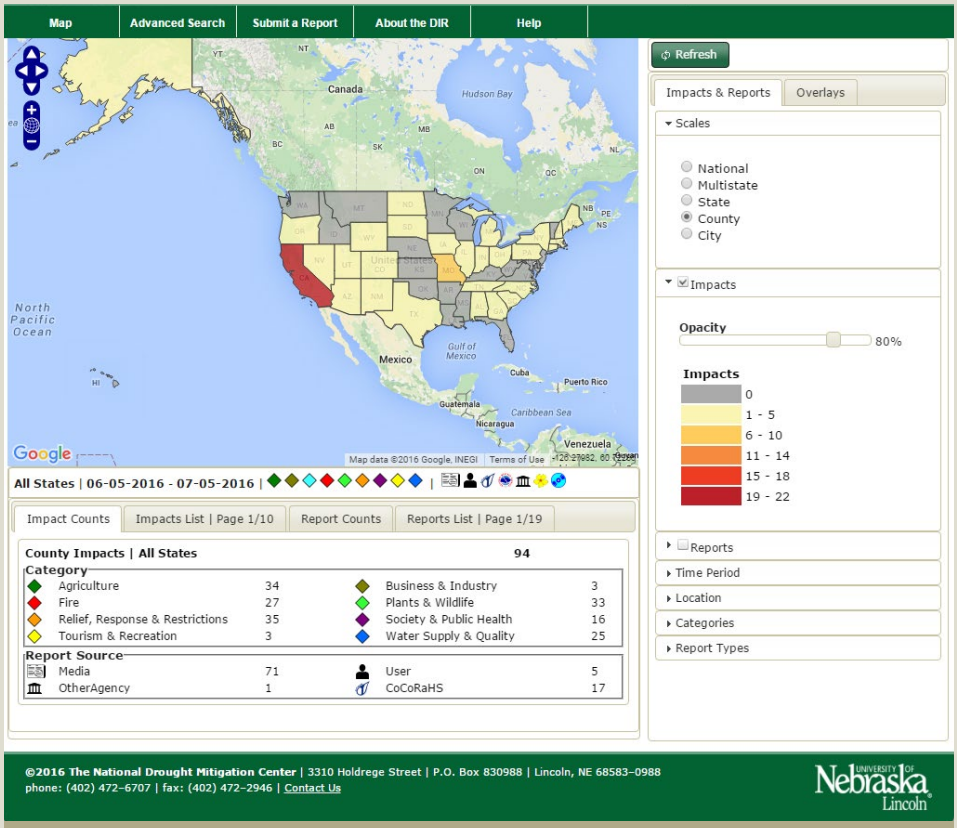
Other enhancements are:

- A more useful view of counties that helps people to find the location of a county within a state.
- A system for letting users navigate directly to a customized view of the Drought Impact Reporter, specifying a state, jurisdictional scale, temporal scale, and one or all categories. This allows webpage administrators to provide users with a live, customized display of the Drought Impact Reporter.
- New overlays, which as of July 2016 included Weather Forecast Offices, Tribal Lands, Regional Drought Early Warning Systems, and USDA Climate Hubs. More are in the works, including a layer that will display USDA Secretarial Disaster Declarations.

And, the Drought Impact Reporter still allows people to submit observations related to drought via the Submit a Report tab. See Condition Monitoring Reports for ideas about what to report.

The National Drought Mitigation Center launched the Drought Impact Reporter in July 2005, in response to an identified need for a comprehensive national archive of drought impacts. The impact reporter has been supported over the years by a variety of competitive grants and contracts, notably from the U.S. Department of Agriculture's Risk Management Agency and from the National Oceanic and Atmospheric Administration's Sectoral Applications Research Program. These latest improvements were made possible by a contract with the U.S. Department of Agriculture's Office of the Chief Economist, and incorporates user feedback gathered in partnership with the National Integrated Drought Information System.

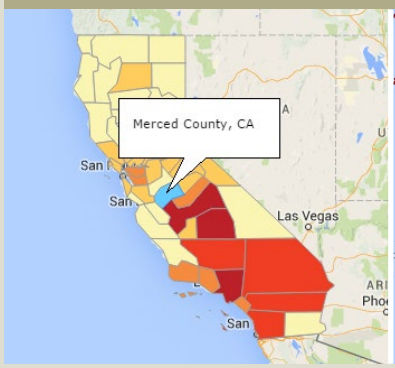
For more information about the capabilities of the Drought Impact Reporter, including detailed help on how to use it, please visit *droughtreporter.unl.edu*.

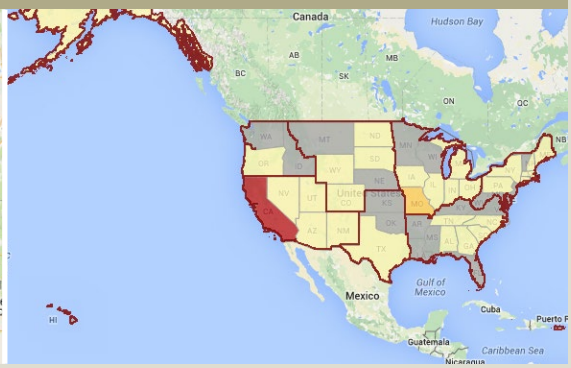


National Drought Mitigation Center

(ABOVE) The default view of the Drought Impact Reporter shows impacts associated with counties, for the past 30 days, for the whole country. The panel below the map counts impacts by category and by source.

(BELOW LEFT) One of the new functions of the DIR is to show impacts reported at a county level. The function includes a hover label showing county and state names, shown in this close-up of California. (BELOW RIGHT) The latest functions also include overlays, including the USDA Climate Hub regions shown here.



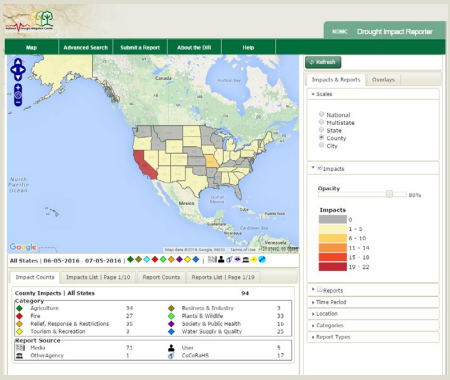


Create a custom view in the DIR

How to link to a custom view of the Drought Impact Reporter

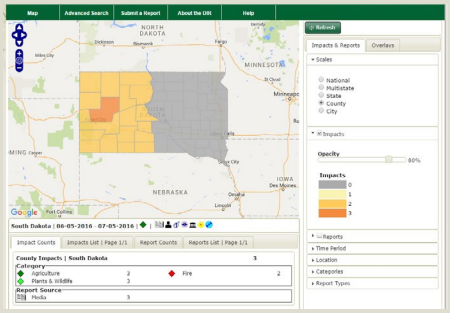
The base URL structure is always the same:

droughtreporter.unl.edu/map/?[state FIPS],[category number]



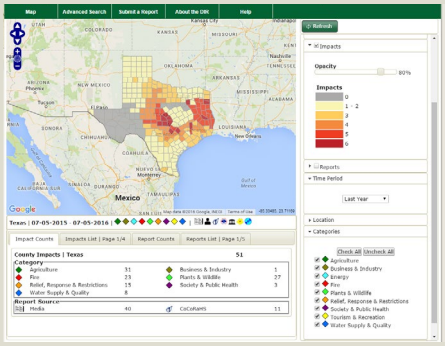
So for example, South Dakota has a state number of 46 and Agriculture is category number 2:

droughtreporter.unl.edu/map/?46,2



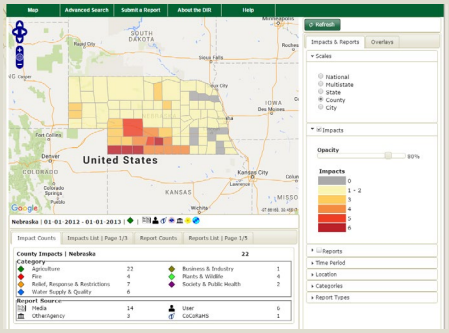
To show all categories, omit the number but leave the commas:

droughtreporter.unl.edu/map/?48,



Users can also set a scale and a time period. For example, this URL shows county level, ag impacts for Nebraska between 1/1/2012 and 1/1/2013:

droughtreporter.unl.edu/map/?31,2,counties,01012012-01012013



NOTE:
If no scale is selected, "county" is the default.
If no time period is selected, the map will show the most recent 30 days.

The Codes

JURISDICTIONAL SCALE OPTIONS

- national
- multistate
- singlestate
- counties
- cities

TIME SCALE OPTIONS

- lw = last week
- lm = last month
- l6 = last 6 months
- ly = last year

CATEGORIES

ID	*Name*
0	All
2	Agriculture
3	Business & Industry
4	Energy
5	Fire
13	Fruits and Nuts (orchard)*
1	General Awareness
12	Ornamentals*
15	Other Agriculture*
6	Plants & Wildlife
14	Produce (fruits and vegetables)*
11	Ranching*
7	Relief, Response & Restrictions
8	Society & Public Health
9	Tourism & Recreation
10	Water Supply & Quality

** Categories for Hawaii only*

STATES

State	*FIPS*		
Alabama	01	Montana	30
Alaska	02	Nebraska	31
Arizona	04	Nevada	32
Arkansas	05	New Hampshire	33
California	06	New Jersey	34
Colorado	08	New Mexico	35
Connecticut	09	New York	36
Delaware	10	North Carolina	37
District of Columbia	11	North Dakota	38
Florida	12	Ohio	39
Georgia	13	Oklahoma	40
Hawaii	15	Oregon	41
Idaho	16	Pennsylvania	42
Illinois	17	Puerto Rico	72
Indiana	18	Rhode Island	44
Iowa	19	South Carolina	45
Kansas	20	South Dakota	46
Kentucky	21	Tennessee	47
Louisiana	22	Texas	48
Maine	23	Utah	49
Maryland	24	Vermont	50
Massachusetts	25	Virginia	51
Michigan	26	Washington	53
Minnesota	27	West Virginia	54
Mississippi	28	Wisconsin	55
Missouri	29	Wyoming	56

Questions or suggestions?
Please contact Jeff Nothwehr at jnothwehr2@unl.edu or Kelly Smith at ksmith2@unl.edu.

NU centers lead project to help MENA region respond to drought

BY SHAWNA RICHTER-RYERSON
NDMC COMMUNICATIONS ASSOCIATE

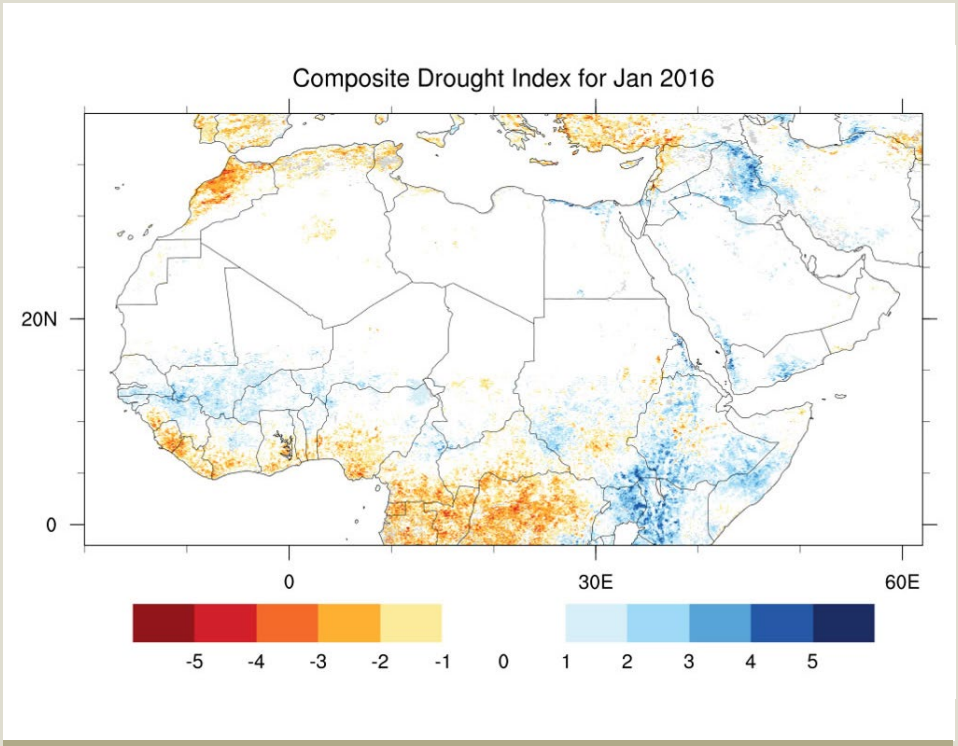
The National Drought Mitigation Center at the University of Nebraska-Lincoln is co-leading a $4-million research effort with the Dubai-based International Center for Biosaline Agriculture. The project is designed to help the Middle East and North Africa region develop a Regional Drought Management System.

The U.S. Agency for International Development is funding the one-year project through March 2017. One million dollars of the total grant is designated for the research activities conducted by the NDMC, which has partnered with UNL's Center for Advanced Land Management Information Technologies and the Robert B. Daugherty Water for Food Global Institute at the University of Nebraska.

The project has two major parts: improved drought monitoring information and working with stakeholders across the water-scarce region to understand how this information can improve decision-making, said Michael Hayes, drought center director and principal investigator for the project.

"This project is a great opportunity for the University of Nebraska to capitalize on our strengths related to drought, water efficiency and remote sensing in the region," Hayes said.

Researchers include several teams of drought center experts, and working with them are Brian Wardlow, CALMIT director; Christopher Neale, institute director of research; and collaborators from the University of Maryland and the USDA Agriculture Research Service. Together they are developing composite drought indices for the region to improve planning. For their part, scientists at the international agriculture research center are generating monthly maps.



National Drought Mitigation Center

Three University of Nebraska groups have worked together to create the Composite Drought Index for the Middle East and North African region as part of a research project funded by the Dubai-based International Center for Biosaline Agriculture. The three centers are: the National Drought Mitigation Center at University of Nebraska-Lincoln; the Robert B. Daugherty Water for Food Global Institute at the University of Nebraska; and UNL's Center for Advanced Land Management Information Technologies.

Building on the regional version completed earlier this year, climatologists Mark Svoboda, Brian Fuchs, Tsegaye Tadesse and Deborah Bathke are working on creating, implementing and improving country-specific composite drought indices for Tunisia, Morocco, Lebanon and Jordan. The indices incorporate data collected from satellite remote sensors with data collected on the ground. Those used in the composite include the existing Standardized Precipitation Index, Land Surface Temperature differences and the Normalized Difference Vegetation Index, as well as an evapotranspiration product being created for the region as a part of the MENA project.

Neale, NDMC's Hatim Geli and UNM's Chris Hain are working on that tool, which will produce a daily, satellite-based evapotranspiration product: the Evaporate Stress Index. With support from UNL's Holland Computing Center, they are analyzing the data and providing it to planners who will use it to calculate the water balance within watersheds and estimate water productivity at field scales. Learning to predict crop yields based on field-level evapotranspiration and to improve

Continued on **page 12**

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water productivity is an urgent need for agriculture in areas of the world that are chronically water-stressed.

All that information, combined with climate change modeling data by NDMC's Azar Muhammad, will provide the region with a set of comprehensive, usable drought planning tools for the first time.

While monitoring tools are being developed, the project centers are focused on helping governmental agencies and commodity groups better understand the drought needs of the MENA region as well as its vulnerabilities. Stakeholder interviews are being conducted by ICBA, while NDMC faculty and staff Theresa Jedd, Cody Knutson and Nicole Wall are developing reports to help determine what drought looks like in each country, what sources of information planners are using to identify drought and where there are gaps in resources.

Answers to these questions and findings drawn from them will be presented at town hall-style forums planned for Tunisia, Morocco, Lebanon and Jordan from September through November. Insights gained from those meetings will help improve the effectiveness of tools developed during the project.

"The intent long term is for the MENA region to incorporate the three pillars of drought policy," Hayes said. The three pillars of drought policy are monitoring and early warning; vulnerability and impact assessment; and mitigation and response. "These are the first steps."

They are steps that can empower local decision makers.

"The partnership between the University of Nebraska-Lincoln and ICBA is invaluable in bringing together international and MENA regional expertise to empower local decision makers to better manage droughts in these water-insecure countries," said Rachael McDonnell, head of Climate Change Modeling and Adaptation Section at the agriculture research center.

Community Capitals researchers explore drought resilience in McCook, Nebraska

BY DEBORAH BATHKE, NICOLE WALL, THERESA JEDD AND TONYA BERNADT

NDMC RESEARCHERS

Natural disasters affect scores of towns across the Great Plains each year. Media accounts describe the devastating impacts of these disasters and the initial attempts toward recovery. These accounts of disaster recovery regularly emphasize the importance of volunteer help from neighboring communities, services and materials provided by local governments and faith-based organizations, and financial assistance from federal agencies.

Now, in a project funded by the North Central Regional Center for Rural Development, a group of researchers is taking a scientific approach to assess the internal and external resources available to rural communities to help them successfully respond to and recover from natural disasters.

Courtesy photo

This multi-disciplinary team, comprised of faculty research associates, extension specialists and nonprofit facilitators from North Dakota State University, University of Nebraska-Lincoln, South Dakota State University, Kansas State University, Oklahoma State University, and the Heartland Center for Leadership Development, is conducting a series of case studies to analyze and document how three communities have responded and recovered from natural disasters. The three rural communities are: Breckenridge, Minnesota, which experienced devastating flooding in 1997; McCook, Nebraska, affected by the widespread severe- to extreme-drought of 2012; and Pilger, Nebraska,

Continued on **page 13**

National Drought Mitigation Center

NDMC research team (Nicole Wall, Deborah Bathke, and Tony Mucia) listening to stakeholders discussing the impacts on health during times of drought. Photo taken by Jake Petr (NDMC), at the Southwest Nebraska Public Health Department.

Continued from **page 12**

which was destroyed by an EF-4 tornado in 2014.

The researchers have been conducting in-depth and focus-group interviews, photographing the communities, and analyzing community documents, government data and reports to discover how community leaders have used their assets to respond to and recover from the shocks their communities faced. The study applies the Community Capitals Framework, an analytical tool used in disaster recovery, to inventory each community's assets and the impacts natural disasters had. In this study, CFF is being used to help communities mitigate, respond to and recover from the negative impacts of a disaster.

IN MAY 2016, THE RESEARCH TEAM TRAVELLED TO MCCOOK AND SPENT TWO DAYS GETTING FAMILIAR WITH THE COMMUNITY, GATHERING INFORMATION AND CONDUCTING INTERVIEWS. … FOCUS GROUP INTERVIEWS WERE USED TO GAIN PERSPECTIVES FROM KEY COMMUNITY MEMBERS ON DROUGHT MANAGEMENT.

In McCook, researchers worked with a stakeholder advisory team to identify key community members important in making decisions related to the negative impacts of drought. Those impacts include water shortages, agriculture and livestock losses, water main breaks, heat and respiratory illnesses in vulnerable populations, and wildfires.

In May 2016, the research team travelled to McCook and spent two days getting familiar with the community, gathering information and conducting interviews. Based on recommendations from the advisory team, focus group interviews were used to gain perspectives from key community members on drought management as it relates to municipal utilities, natural resource management and public health. To collect more detailed information, in-depth interviews were conducted with the mayor, community and economic development personnel, emergency management and 4-H extension representatives. Follow-up interviews may continue through the summer.

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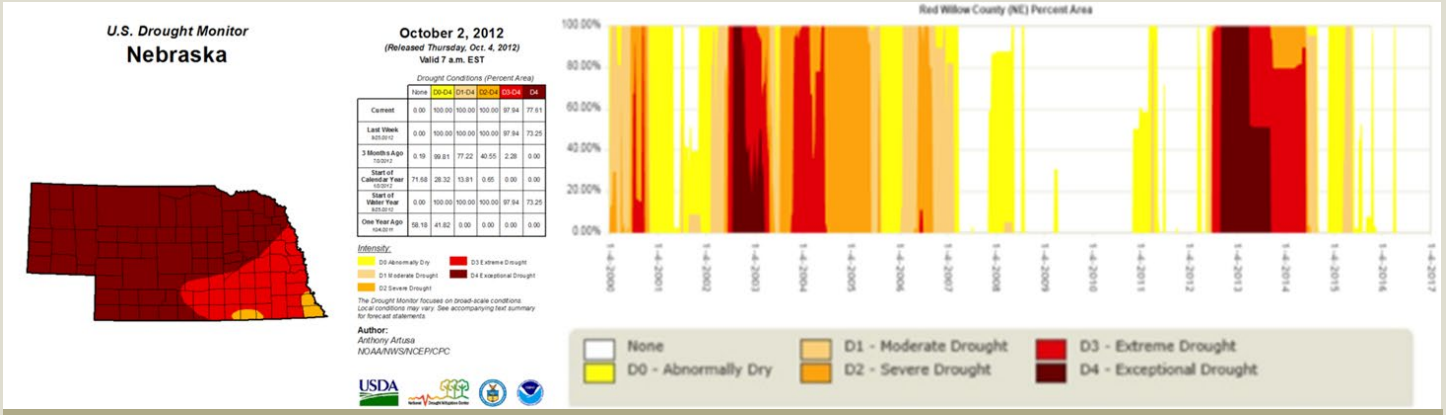
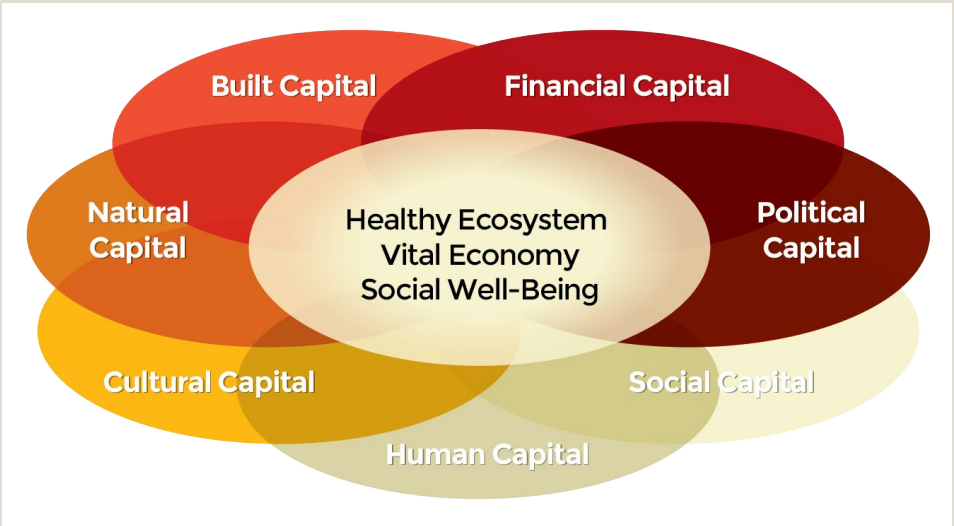


Figure 1: Monthly PDSI for Red Willow County (April 1962-December 2012). Source: National Drought Mitigation Center (droughtatlas.unl.edu).

Continued from **page 13**

Case study results are being framed according to the type of community asset — built, cultural, financial, human, natural, political and social — and how these assets contribute to McCook's resilience and vulnerability, how they were impacted during the 2012-2014 drought, and how they were used in response to and recovery from drought.

As an example, McCook lies within the Republican River Basin that provides it with natural capital such as fertile soils, clean air, available surface and groundwater supplies, and abundant wildlife. This natural capital allows agricultural producers, businesses and tourism outlets to build financial capital, and increases the community's resilience to natural hazards. Extended droughts diminish natural capitals by reducing lake and pond levels, which can then have ripple effects such as reducing surface water supplies, increasing toxic blue algae and decreasing fish and wildlife populations. To respond to and recover from drought, McCook drew from its human capital — Nebraska Game and Parks and Emergency management personnel — to monitor drought closely, provide educational and pond management materials, and implement tailored habitat and wildlife protection to shorten recovery times.



The Community Capital Framework Model is a lens that researchers and communities can use to understand the full complexity of what helps a community be healthy and resilient.

In terms of built capital, the city has up-to-date water-and-utility infrastructure that enables it to provide a safe and consistent supply of water to its residents. The McCook Public Water System receives its water from numerous wells in the Republican River Valley. The recent drought challenged the city's ability to meet user demands for water. The city was able to respond to the drought and successfully maintain a safe water supply by using a variety of capitals such as a mitigation-based water conservation, drought and emergency plan that triggered drought stages (evidence of political capital); a strong sense of community and voluntary water restrictions (social capital); and effective leaders and highly trained utility personnel (human capital).

The project team plans to share their findings with community officials and leaders in early fall to incorporate their feedback before releasing a final report to the general public. In addition to research findings, this report will include methods and materials to assist the officials and leaders in creating an inventory of their assets for use in building resilience for other natural disasters such as floods and tornadoes and community development efforts. A public webinar, arranged by NCRCRD, will disseminate the findings and allow these and other communities to learn from each other's experiences.

PART III

Groups co-developing approaches to improve planning for drought on public lands

BY JULIE BRUGGER, MIKE CRIMMINS AND MITCHEL MCCLARAN
UNIVERSITY OF ARIZONA

Forest Service personnel and ranchers with grazing permits on the Tonto National Forest in Arizona recently participated in a workshop to increase their preparation for drought by planning and implementing livestock management in the National Forests of the Southwestern US. The workshop, the third of three in a series, was Feb. 17, 2016.

Thirty-eight people participated, including 16 ranchers; 11 Forest Service personnel from the Tonto NF; one National Drought Mitigation Center researcher, Tonya Haigh; the Desert Landscape Conservation Cooperative director, who was asked to observe; and seven of the eight members of the research team from the University of Arizona. The first two workshops were featured in the Summer 2015 and Winter 2016 issues of DroughtScape.

In response to preferences expressed by Workshop II participants and the outcomes of the drought scenario planning exercises in that workshop, we designed activities that would continue to provide interaction and problem-solving among participants, as well as more exposure to new tools that provide local climate information and more in-depth understanding of the Forest Service decision process. The main activities for Workshop III were:

1. Exploring how online tools that provide information on the Standardized Precipitation Index for drought monitoring and NOAA Climate Prediction Center Three-Month Precipitation Outlooks can be used during annual operating Instructions meetings so that ranchers and Forest Service personnel are looking at the same drought/climate information.
2. Developing realistic expectations about the complexity and duration of the Forest Service decision process used to approve installation of infrastructure used to increase preparation for the next drought.

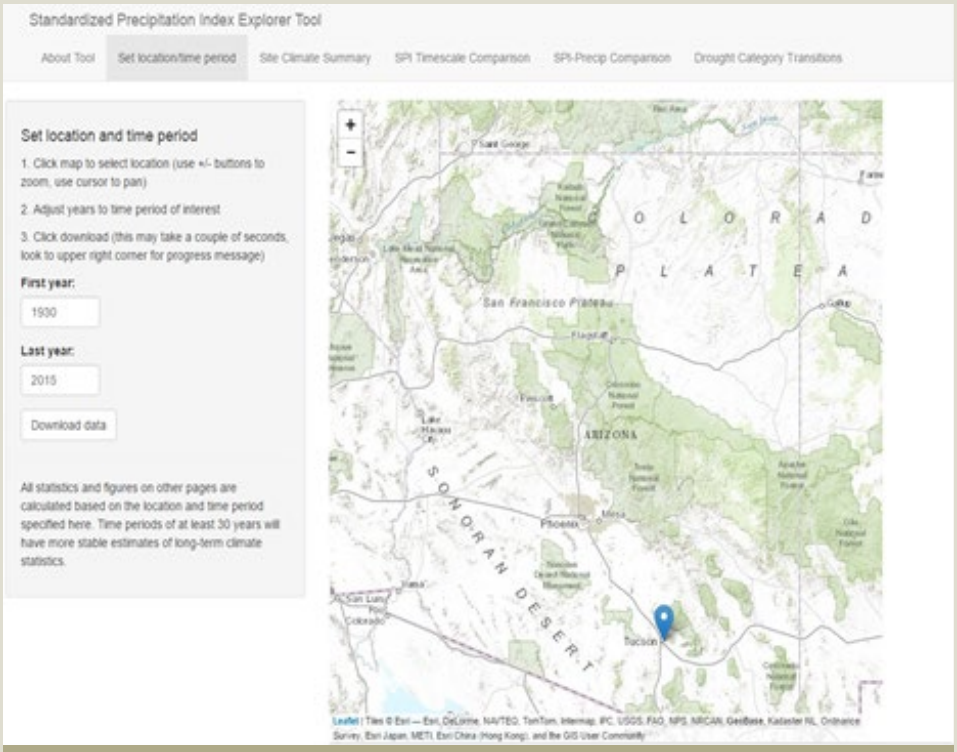


Figure 1: Set location/time period tab of SPI Explorer

Standardized Precipitation Index

Our attention to SPI is based on the policy for Forest Service Region 3, in which the Tonto National Forest lies, that states "anytime the SPI reaches a value of minus 1.00 or less for the preceding 12 month period, grazing allotments should be evaluated for existing drought conditions" (R3 Manual Supplement to 2209.13.19.1). Our attention to decision points faced by ranchers and the Forest Service focused on the traditional mid-winter (January to February) AOI that sets parameters of grazing intensity and timing for the coming year and the schedule of infrastructure maintenance and construction. We also explored the adoption of a separate decision-point in early summer to address the drought conditions associated with the summer rains from the North American Monsoon because they are critical for about 75 percent of the forage production in a year.

Mike Crimmins developed the SPI Explorer Tool to view and analyze local-scale estimates of historic precipitation variability. The tool (*https://cals.arizona.edu/droughtandgrazing/dashboard*,

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direct link *https://uaclimateextension.shinyapps.io/SPItool/*) was built using R programming language (*https://www.r-project.org/*) and a web application framework called Shiny (*http://shiny.rstudio.com/*), and draws upon online climate datasets offered up through web services by the Applied Climate Information System *(http://www.rcc-acis.org/*). Specifically, the SPI Explorer Tool uses the Parameter-elevation Relationships on Independent Slopes Model (*http://www.prism.oregonstate.edu/*) climate dataset which is a gridded, interpolation of monthly temperature and precipitation observations on a 4-by-4 kilometer elevation grid.

The tool is organized into tabs represented across the top of the page (Figure 1). They include:

- Set Location/Time Period: Map interface to download precipitation data for specific locations and time periods.
- Site Climate Summary: Quick look at annual precipitation totals for the selected site in graphical and table form.
- SPI Timescale Comparison: Single figure of one, three and twelve month SPI values plotted on common time axis.
- SPI-Precip Comparison: Interactive tool that allows for the exploration of precipitation statistics and SPI values for specific months and SPI timescales.
- Drought Category Transitions: Interactive tools that calculate and display the probability of transitioning from one SPI-based category to another based on historical occurrences.

The precipitation time series loaded into the tool based on the selections on the Set Location/Time Period tab determines the dataset used on all other tabs.

The SPI-Precip Comparison tab (Figure 2) produces several statistical

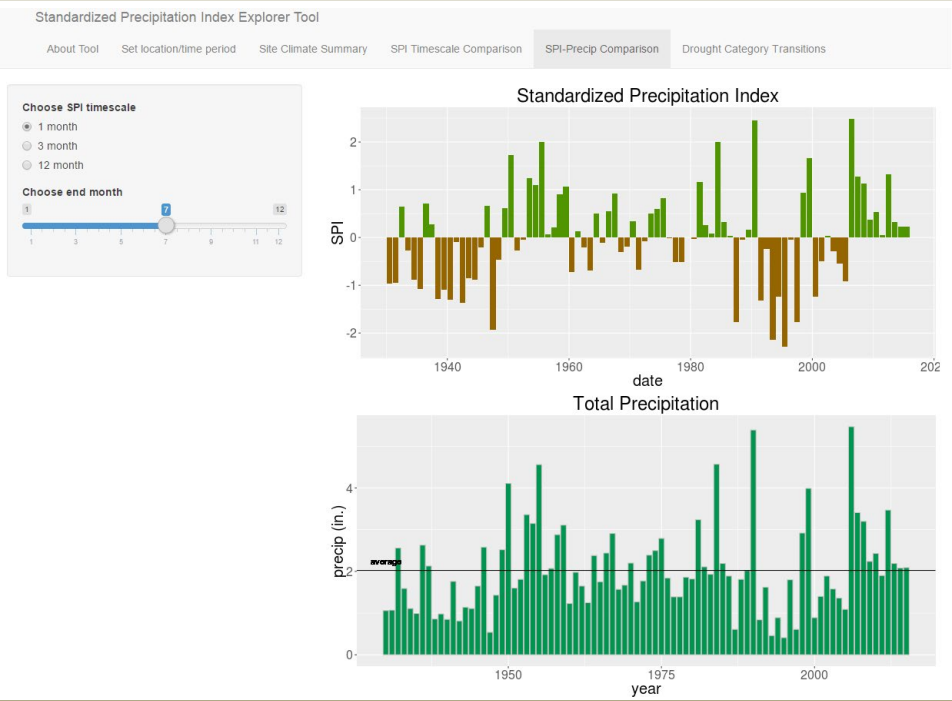

Figure 2: SPI- Precip Comparison tab

summaries of precipitation based on selecting a specific starting month and SPI window (1, 3 or 12 months). For example, selecting 1 month SPI and July produces summary statistics and historical plots of July precipitation for the period of record selected on the first tab. The full output includes:

1. Time series plot of SPI values for selected month and timescale;
2. Raw, total precipitation values based on SPI timescale and month selection;
3. Histogram of raw precipitation values based on SPI timescale and month selection;
4. Cumulative probability distribution of the same precipitation values displayed in the histogram;
5. General precipitation statistics including extremes and terciles; and
6. Precipitation and SPI table of values that can be sorted/reordered.

The Drought Category Transitions tab (Figure 3) using the historical record to describe the likelihood of future conditions given current conditions. This is particularly useful for estimating end of summer (through September) conditions based on the condition at the start of summer (through July). Users select the month and SPI timescale for Period 1- start month and Period 2- end month. The tool provides likelihood of transition among four SPI categories: very dry (<-1), dry (-1 to 0) wet (0 to 1), and very wet (1 to 2). For example, Figure 3 shows that historically there is a 38.5 percent chance that very dry (<-1 SPI) conditions in July will persist through September, and a 15.4 percent chance that wet (0-1 SPI) conditions will follow a very dry July.

Drought Assessment and Climate Prediction Activities

During Workshop III, Mike Crimmins introduced Activity 1 by explaining how SPI is calculated and why this method makes it possible to compare the SPI between places with different average amounts of rainfall, as well as to calculate SPI over different time scales. He also explained how CPC Precipitation Forecasts are created and the significance of the color-coded maps. The group as a whole then

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completed two exercises using SPI, CPC Precipitation Outlooks, and the SPI Explorer Tool together: 1) for a February 2016 AOI meeting in Globe, Arizona, and 2) for an early monsoon check-up in August 2015. Afterward, they split into four groups, including at least one District Ranger and Range Staff and four to five ranchers, to work through the exercises for Payson, Arizona. To encourage open discussion, District Rangers, Range Staff, and ranchers from different districts were grouped together to the extent possible. Each group gathered around a separate table and was provided with a computer, projector, and screen large enough that participants could view the climate tools together. A member from the project team operated the tools for each group and each participant filled out their own exercise sheet as the group progressed through the exercise. The team member also provided additional interpretation and guidance about the operation of the SPI Tool and the completion of the exercises.

For the February AOI meeting, current drought conditions were determined from the 12-month SPI for Arizona (*http://www.wrcc.dri.edu/wwdt/index.php?region=az*). Next, seasonal precipitation outlooks were determined from the NOAA CPC Precipitation Outlook forecast (*http://www.cpc.ncep.noaa.gov/products/predictions/long_range/*). Participants then used the SPI Explorer Tool to determine the high-low values for the terciles being projected in the seasonal outlook. This provided hands-on practice to access the forecast and to evaluate just how much rain is within each tercile, as well as the likelihood of that tercile occurring in the next three months. For the August AOI meeting, instead of the CPC Precipitation Outlook, drought likelihoods based on the historic record were generated using the Drought Category Transition tab in the SPI tool. This information could be more valuable during discussions in summer about what types of preparations should be made for possible drought conditions because in the Southwest, three-month summer precipitation outlooks are typically "equal chances" of falling within each of the three terciles.

Figure 3: Drought category transitions tab, with example of Period 1 set to July and 1-month SPI, and Period 2 set to September and a 3-month SPI.

Realistic Expectations about the Forest Service Decision Process

This second major activity asked participants to develop realistic expectations about the nature and duration of project reviews performed by the Forest Service. This is critical for drought preparations because it determines how long it will take to get a project approved before installation. Longer review durations make it more likely that the next drought will occur before the installation is approved and available to provide greater flexibility to respond to drought conditions.

To begin, the entire group discussed and provided input describing the most likely type and duration of decision given a variety of characteristics such as presence of endangered species, arrival of a new district ranger, and previous completion of an impact analysis. That information was used during small group exercises in which groups filled out worksheets for two scenarios for a water development project which asked participants to identify:

1. What type of decision is most likely given the characteristics of the project;
2. The steps in the decision process;
3. How long it would take to complete the decision process;
4. Who was going to track the progress of the decision process;
5. How was that progress going to be communicated;
6. What events might occur to lengthen the process;
7. How much longer would the process take with that event; and
8. How you would respond to the new event that slowed the process.

Overall, the workshop met its objectives. Evaluations indicated that all respondents felt that the workshop

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improved their understanding of how drought information could be used to increase their ability to prepare for drought, and that their understanding has increased considerably throughout the series of workshops. Ranchers' understanding of the Forest Service decision process, how long it takes, and how to become more engaged in Forest Service decision processes for long-term drought planning has also improved. Analysis of workshop recordings, notes, and evaluations indicates that workshop activities continued to promote communication, joint problem-solving, and development of a common framework for looking at drought information and co-developing decisions among ranchers and Forest Service personnel.

The research team continues to work to translate the success of the project into the "Guide to Drought Preparation for Livestock Grazing Allotments on Southwest National Forests" to conduct follow-up research to determine longer-term impact of the project, and to promote further activities that will continue productive interactions and improve drought planning and preparedness on the Tonto NF and the region.

Reach the writers

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- Mike Crimmins, Soil, Water, and Environmental Sciences at the University of Arizona: *crimmins@email.arizona.edu*
- Mitchel McClaran, School of Natural Resources and the Environment at University of Arizona: *mcclaran@u.arizona.edu*

NDMC founder, drought legend retires

BY SHAWNA RICHTER-RYERSON
NDMC COMMUNICATIONS ASSOCIATE

After nearly 40 years with the University of Nebraska-Lincoln, Don Wilhite, founding director of the National Drought Mitigation Center, former School of Natural Resources director and dedicated applied climate professor, has retired and will shift to emeritus status.

June 30 was his official last day.

"It's been a great honor to work with the university since I joined the faculty in 1977," Wilhite said. "On both the domestic and international side, it has been very rewarding to see my emphasis on drought preparedness and drought policy as well as my emphasis on the development of drought early warning systems and vulnerability assessments being adopted as part of NOAA's National Integrated Drought Information System and by agencies of the United Nations such as the World Meteorological Organization, the U.N.'s Convention to Combat Desertification and the U.N.'s Food and Agriculture Organization.

"I have really enjoyed working with all of the faculty and staff in SNR over the years and wish the unit nothing but success in the years ahead."

Wilhite was the founding director of the International Drought Information Center in 1989, which focused at an international level on reducing vulnerability to drought through projects directed at planning, early warning and mitigation. The center created a guidebook on drought preparedness for developing countries, organized training seminars and conferences related to drought and water resource management, and helped shape drought policy.

This work took him to Africa, Brazil, Thailand, China, Switzerland and Uruguay, among dozens of others countries that were seeking advice for drought planning. The IDIC was active until 2002.

In 1995, Wilhite founded the National Drought Mitigation Center, whose focus has been on reducing societal vulnerability to drought, nationally and internationally, through the development of preparedness plans that emphasize proactive mitigation measures and the adoption of national drought policies that are focused on risk reduction. When Wilhite began working with U.S. states, only three had drought plans. Today, 47 do. The NDMC may best be known for its work on the U.S. Drought Monitor, a weekly map of drought conditions, of which Wilhite and the NDMC were instrumental in getting created. Countries around the world have sought to emulate the map for their own drought response.

Wilhite served as the director of the NDMC until 2007, when he was appointed director of the School of Natural Resources. He stepped down from that post in 2012 to rejoin the Applied Climate Science faculty. His focus since has been on fostering drought management policy internationally and on climate change and its impacts on the state, and in September 2014, he was one of four authors that published "Understanding and Assessing Climate Change: Implications for Nebraska."

"This report has attracted a great deal of attention across the state and has resulted in numerous initiatives on- and off-campus to identify adaptation and mitigation actions for specific sectors," he wrote in his faculty profile. Sector-based roundtable discussions that followed resulted in a summary report, released in early 2016, which Wilhite hopes will

Continued on **page 19**

Courtesy image

Don Wilhite, founding director of the National Drought Mitigation Center, former School of Natural Resources director and dedicated applied climate professor, retired June 30, 2016.

Continued from **page 18**

lead to additional action on climate change adaptation and mitigation for Nebraska.

Results of that already are in progress. In April, the Nebraska Legislature passed a resolution establishing a committee composed of state senators to examine the impacts of climate change on the state and to determine appropriate and necessary actions. On June 1, Wilhite, along with Sen. Ken Haar's office, organized a one-day seminar to familiarize senators on the science and implications of climate change. (Watch the presentations here.)

Some of his other posts over the years have included:

• Co-organizer of a November 2015 workshop on the Implications of a Changing Arctic on the Water Resources and Agriculture of the Central United States. This workshop was sponsored by NOAA, USDA and the University of Nebraska and is associated with the U.S. chairmanship of the Arctic Council, which began in April 2015.

• Co-chair of the organizing committee for the 2014 annual symposium of the Center for Great Plains Studies, Drought in the Life, Cultures, and Landscapes of the Great Plains.

• Fellow at the Daugherty Water for Food Global Institute at the University of Nebraska, 2013 to present.

• Chairman of the Management and Advisory Committees of the newly formed Integrated Drought Management Program launched by the World Meteorological Organization and the Global Water Partnership in 2013.

• Chairman of the International Organizing Committee for a High-Level Meeting on National Drought Policy sponsored by the World Meteorological Organization, the Food and Agriculture Organization and the United Nations Convention to Combat Desertification, July 2011 to March 2013.

• Co-chair of the executive council for the National Integrated Drought Information System, NOAA, 2007 to present.

"Don has made tremendous contributions throughout his career here at UNL," said Michael Hayes, current director of the NDMC. "He has been a vital member of the climate group first within the Department of Agricultural Meteorology and then the School of Natural Resources. However, one achievement forever credited to Don will be his vision for proactive drought risk management. Don's vision has spread around the entire world, leaving behind both national and international legacies, as well as leading to the creation of the National Drought Mitigation Center with its mission to support drought risk management."

Since Wilhite began his work at UNL in 1977, he has brought in more than $20 million in grants and published more than 130 journal articles, technical reports, book chapters and books.

For the next year, Wilhite will utilize an emeritus office while he completes several projects.

NDMC answers questions on climate change and drought in the western United States

Q Are we seeing signs of a warming climate in the West?

A Undoubtedly. Temperatures have been warming over the West by a rate of more than 0.2 degrees Fahrenheit per decade over the last 100-plus years. In the early 1900's, the average annual temperature over the West was 53 degrees and that has increased to about 55.5 degrees.

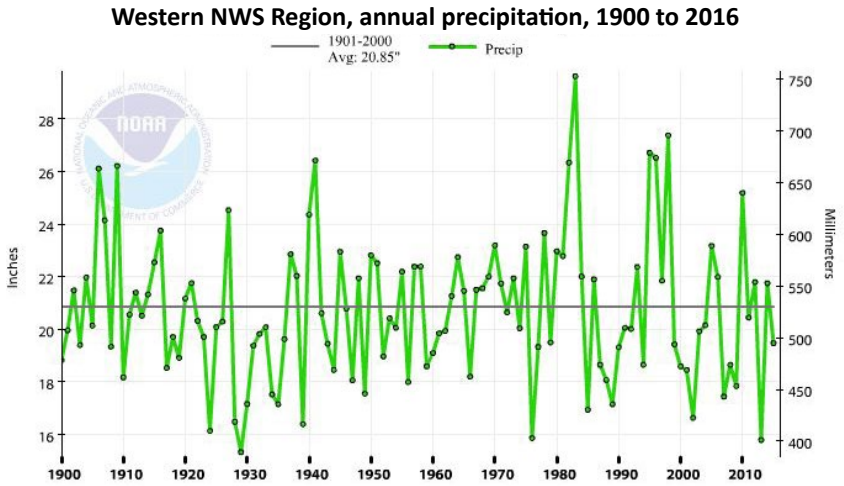
Q How does a warming climate affect drought?

A The temperature increase changes many aspects of the water cycle and the natural ecosystems that are part of the complex Western region. When there are warmer temperatures, there is more water demand by plants, animals and humans, and more water evaporates. Warmer temperatures also affect snow during the important winter "wet season," which is where much of the water used in the West comes from. If it's too warm, potential snow will fall as rain, and snow will evaporate before it has a chance to melt. Snowmelt is the source of as much as 75 percent of the water supply in the West, according to the U.S. Geological Survey. A warmer climate also affects the timing of precipitation, bringing more rain later in the fall and earlier in the spring.

Q Are there any special considerations related to mountains?

A Yes, elevation is important. Warmer temperatures at higher elevations also will result in more rain and less snow. Warmer temperatures could affect the tree line and other features of the ecosystem.

Q We heard somewhere that hotter temperatures speed up the water cycle and actually make it rain more. Wouldn't that balance out the drying effect of heat?



National Oceanic and Atmospheric Administration

A In some climate regimes, as temperatures have warmed over the last century, the amount of precipitation has also increased, which helps to alleviate the impact of the warmer temperatures. The data from National Centers for Environmental Information show that this is not the case in the western United States. The data show that annual precipitation is declining by 0.03 inches per decade throughout the West. This amount does not seem to be large, but coupled with the increased temperatures, the region is drier now than it was 100 years ago.

Q Is climate change causing the drought that's still going on in parts of California?

A This is a tough question and is the subject of ongoing research. Temperatures are higher now than they were during the 1950s and 1970s droughts, and this is showing up in the impacts. For example, there has been a tremendous amount of die-off to pine trees across the West. This has likely been due to a combination of both drought and high temperatures, and it has not been seen during the past 100

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years until now. Warmer temperatures are making drought impacts worse, but we don't know how much climate change is contributing to the lack of precipitation.

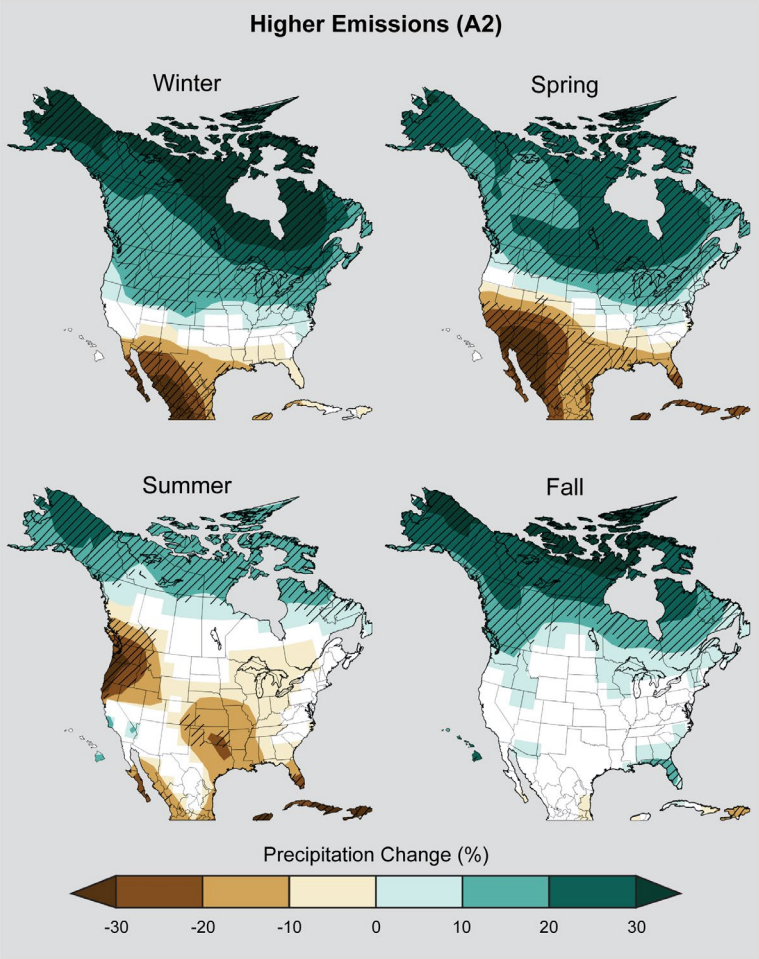
Q What do you recommend for further reading on drought and climate change in the West?

A Glad you asked. We recommend the following:

- Berghuijs, W. R., R. A. Woods, and M. Hrachowitz. "A precipitation shift from snow towards rain leads to a decrease in streamflow." Nat. Clim. Change 4.7 (2014): 583-586.
- Diffenbaugh, Noah S., Daniel L. Swain, and Danielle Touma. "Anthropogenic warming has increased drought risk in California." Proceedings of the National Academy of Sciences 112.13 (2015): 3931-3936. The authors "find that human emissions have increased the probability that low-precipitation years are also warm, suggesting that anthropogenic warming is increasing the probability of the co-occurring warm–dry conditions that have created the current California drought."
- Griffin, Daniel, and Kevin J. Anchukaitis. "How unusual is the 2012–2014 California drought?" Geophysical Research Letters 41.24 (2014): 9017-9023. The authors find, based on tree ring chronology, that, "The current California drought is exceptionally severe in the context of at least the last millennium and is driven by reduced though not unprecedented precipitation and record high temperatures."
- Hatchett, Benjamin J., et al. "Placing the 2012–2015 California-Nevada drought into a paleoclimatic context: Insights from Walker Lake, California-Nevada, USA." Geophysical Research Letters 42.20 (2015): 8632-8640. The authors developed estimates of Walker Lake behaviors during the Medieval Climate Anomaly, a time of documented extremes, and "simulated the current 2012–2015 California-Nevada drought and found that the current drought exceeds MCA droughts in mean severity but not duration."
- Mann, Michael E., and Peter H. Gleick. "Climate change and California drought in the 21st century." Proceedings of the National Academy of Sciences 112.13 (2015): 3858-3859.
- Margulis, S. A., G. Cortés, M. Girotto, L. S. Huning, D. Li, and M. Durand (2016). Characterizing the extreme 2015 snowpack deficit in the Sierra Nevada (USA) and the implications for drought recovery, Geophysical Research Letters, 43, 6341-6349. "The 2015 Sierra Nevada range-wide snow volume was characterized by a return period of over 600 years with a strong elevational gradient; the accumulated snowpack drought deficit volume ending in 2015 was the largest over the 65 year record analyzed; despite historically strong 2016 El Niño conditions, it is highly likely that recovery to predrought conditions will take about 4 years."
- Wang, S.Y., et al. "Probable causes of the abnormal ridge accompanying the 2013–2014 California drought: ENSO precursor and anthropogenic warming footprint." Geophysical Research Letters 41.9 (2014): 3220-3226. The authors detected "a traceable anthropogenic warming footprint in the enormous intensity of the anomalous ridge during winter 2013–2014 and the associated drought."
- Williams, A. Park, et al. "Contribution of anthropogenic warming to California drought during 2012–2014." Geophysical Research Letters 42.16 (2015): 6819-6828. "Precipitation is the primary driver of drought variability but anthropogenic warming is estimated to have accounted for 8–27% of the observed drought anomaly in 2012–2014 and 5–18% in 2014."
- Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014. "Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment" U.S. Global Change Research Program.

— COMPILED BY BRIAN FUCHS, MARK SVOBODA, MIKE HAYES AND KELLY HELM SMITH, NATIONAL DROUGHT MITIGATION CENTER

Projected Precipitation Change by Season



nca2014.globalchange.gov

The National Climate Assessment released in 2014 forecast the change in precipitation by season if emissions continued to increase.