The Missing Piece:
Drought Impacts Monitoring

Report from a Workshop in Tucson, AZ
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Executive Summary

Based on a shared interest to better understand the impacts of drought and the potential utility of using drought impacts reporting as a tool for monitoring conditions, researchers from the Carolinas RISA (Dow, Lackstrom, and Brennan), the Climate Assessment for the Southwest (Crimmins and Ferguson), and the Southwest Climate Science Center (Meadow) decided to convene a workshop in Tucson in March 2013. The primary goal was to assemble a small group of university and agency scientists involved with drought impacts monitoring to discuss opportunities and barriers associated with drought impacts reporting, recommend best practices for implementing a drought impacts reporting system, and develop a path forward for addressing or overcoming barriers. The longer-term objective of the initial meeting was to explore the feasibility of creating a community of practice that could share information and integrate activities related to drought impacts research and reporting.

Over the course of one-and-a-half days of discussion, the group touched on several topics related to drought impacts and approaches to monitoring them. From those discussions we have distilled the following key themes:

1. Understanding the full range of drought impacts is important for planning and mitigation.

While it is relatively easy to quantify precipitation (and deviations from normal), our current understanding of the full range of drought impacts is limited. The relative paucity of information about the actual impacts of drought conditions—such as infrastructure damage and economic losses—adversely affects society's ability to prepare for, monitor, and respond to drought.

2. There are numerous challenges in collecting and synthesizing drought impacts information for use in planning and mitigation.

While there are many existing efforts to collect impacts information, they vary across scale and sectors, resulting in a patchwork of coverage. Defining and characterizing second-order impacts, assessing the cumulative effects of multiple stresses, and determining drought onset and recovery are critical activities that continue to need attention and improvement.

3. Many opportunities and potential strategies exist to advance drought impacts reporting and the integration of impacts information into decision making.

Successful efforts will require committed communication and coordination across multiple levels and sectors. Next steps might include evaluating existing tools to identify effective approaches and gaps to be filled; investigating ways to integrate environmental, economic, and social datasets and information into drought impact assessments; and providing resources to local and regional field experts to collect and synthesize both baseline and impacts information.

4. Individual projects and programs have amassed valuable lessons about drought impact research and reporting, though greater coordination and cooperative development is needed.

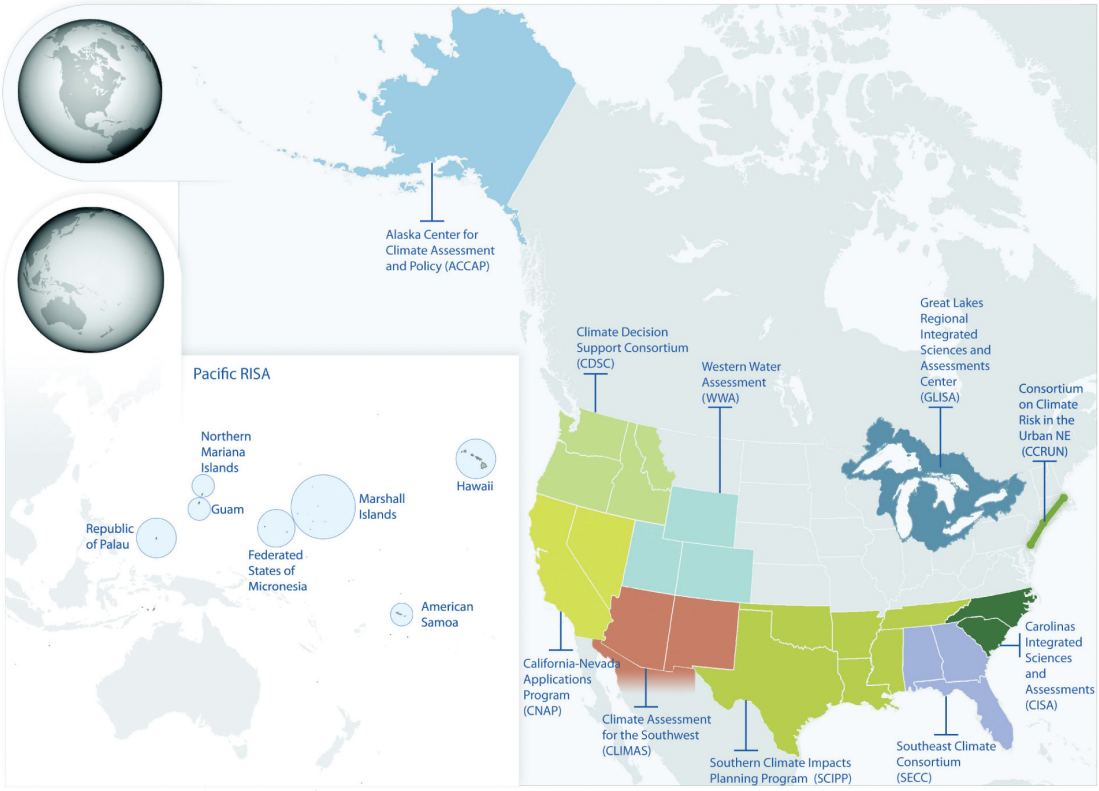
A more comprehensive effort is necessary to build upon and improve our collective understanding of drought impacts and impacts reporting—including best practices, barriers and challenges, and strategies for moving forward.

Introduction

While the importance of identifying, reporting, and assessing drought impacts is recognized as a component of a comprehensive Drought Early Warning System (DEWS), drought impact information collection strategies and assessments often are not well integrated into drought monitoring and management strategies (Hayes et al. 2011). Across the US, several organizations are involved in efforts related to drought impacts reporting, but these activities are often not connected, which limits opportunities for leveraging knowledge and resources.

Regional Integrated Sciences and Assessments (RISA)

The Regional Integrated Sciences and Assessments (RISA) research teams, funded by the National Oceanic and Atmospheric Administration (NOAA), are in a unique position to help coordinate efforts around this issue. The RISA program supports teams that help build the nation's capacity to prepare for and adapt to climate variability and change. Many are involved with the National Integrated Drought Information System's (NIDIS) Coping with Drought initiative to study drought issues in different regions and sectors and to develop information and decision support resources for drought risk management. The impetus for a meeting focused on drought impacts reporting was the recognition that RISA teams currently have limited opportunities to interact—and coordinate—with other RISAs and entities working on drought impacts projects. To facilitate communications and integration, researchers from the Carolinas Integrated Sciences and Assessments (CISA) and Climate Assessment for the Southwest (CLIMAS) proposed an initial meeting to form a drought impacts working group. The vision of the workshop planning committee was to form a small group that



As of summer 2013, the RISA network is made up of eleven teams across the US.

can provide a forum for RISAs working on Coping with Drought projects to share information and integrate activities related to drought impacts research and reporting. The overarching goal is to form a community of practice and build a body of knowledge that can be used to inform existing and future RISA projects as well as broader efforts, such as those conducted by NIDIS, the National Drought Mitigation Center (NDMC), the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS), and others that may be interested.

As a first step, the working group met at the University of Arizona in March 2013 to discuss existing drought impacts research and reporting efforts, the challenges and successes associated with such efforts, and ways to develop a path forward for integrating efforts and addressing or overcoming barriers. Discussions drew on the experiences of the RISAs (CISA, CLIMAS, Southeast Climate Consortium [SECC], and Southern Climate Impacts Planning Program [SCIPP]) and partners (CoCoRaHS, NDMC, NIDIS, SW CSC) represented. This report summarizes those discussions, highlighting individual and collective lessons learned, recommendations for advancing drought impacts reporting efforts, and a preliminary action plan for the community of practice.

Background

Building a Drought Early Warning System in the US

An early warning system refers to "a system of data collection and analysis to monitor people's well-being (including security), in order to provide timely notice when an emergency threatens [and] to elicit an appropriate response" (Food and Agricultural Organization of the United Nations 2001, 3). In the United States, efforts to develop a DEWS have centered on improving the nation's capacity to monitor and respond to drought by providing monitoring, forecasting, and outlook tools; developing management plans and appropriate response actions; and communicating information about drought conditions and anticipated impacts. Many of these efforts have been spearheaded by the NDMC and NIDIS.

The NDMC was established in 1995 at the University of Nebraska-Lincoln to assist communities, states, and tribal governments in developing and implementing strategies to reduce vulnerability to drought. Efforts focus on drought monitoring and proactive preparedness and risk management planning. The NDMC is also home to the U.S. Drought Monitor (USDM). Since 1999 the USDM map has been used as a tool to summarize drought conditions across the US and Puerto Rico on a weekly basis. It is produced in partnership with the U.S. Department of Agriculture (USDA), NOAA, and expert observers from around the country. NIDIS is an interagency and multi-partner effort established to create a national DEWS (NIDIS Program Implementation Team 2007). The aim of the program is to support drought communications and education; coordinate drought monitoring, forecasting, and impacts assessments at multiple levels; and develop decision support tools.

Despite considerable effort and success in improving drought early warning and communications, many opportunities exist to further improve drought resilience. In response to the historic drought of 2012, the National Drought Forum was convened by NIDIS and its partners to identify priority actions and opportunities for advancing drought preparedness and response. One priority includes improving the characterization and assessment of drought conditions, as well as the socioeconomic and environment impacts of drought across temporal and spatial scales (NIDIS 2012).

Drought Impact Monitoring and Assessment as a Component of a Drought Early Warning System

Impacts data can help improve understanding of drought vulnerabilities and can therefore be used for developing and targeting mitigation strategies (Hayes et al. 2011; Wilhite, Svoboda, and Hayes 2007). Impacts information can also be used to support more precise relief allocation decisions and inform policy and planning priorities. In the agriculture sector, for example, drought impact reports are provided to USDM authors by the Farm Service Agency (FSA) field personnel and county extension agents, both seen as credible and professional sources of information. USDA, in turn, uses the USDM as a tool to trigger the distribution of financial assistance for those affected by drought. A county receives an emergency disaster designation from USDA if a portion of a county is designated as D2 (severe drought) on the USDM for eight consecutive weeks, or if any portion of a county is designated as D3 or higher. Because the distinctions in where USDA relief funds will go are tied directly to the USDM, agricultural drought impact reports can contribute important information to support these critical decisions.

The Need for Improved Drought Impact Data and Information

Despite this example from agriculture—and although drought impacts information is frequently cited as an important element of a DEWS—our experience reflects what we have seen in the literature, which is that "often impact assessment is forgotten, or not included, within the discussion of various drought monitoring tools and how all fit into a DEWS" (Hayes et al. 2011, 486). Preparedness and response plans are often developed with agriculture or water supply in mind, or focus primarily on developing triggers, monitoring drought indicators, and prescribing response actions. Impacts data from sectors other than agriculture and water resources are not currently a robust part of planning and response at regional, state, and local levels.

Furthermore, our experience has been that the story revealed by drought impacts can be at odds with what commonly used drought indicators show, suggesting that indicators based solely on hydrometeorological data do not sufficiently capture the complexity of actual drought conditions. USDM authors primarily rely on indicators derived from hydrometeorological data and input from local and regional expert assessments of conditions from around the US to classify drought severity for the country. Standard drought indices used to help inform the USDM include the Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI), and the Keetch-Byram Drought Index. Measures of soil moisture, vegetation health, and hydrological conditions such as streamflows, ground water levels, and reservoir storage also are used. (See "Drought Monitor: State-of-the-Art Blend of Science and Subjectivity" at droughtmonitor.unl.edu/classify.htm.)

The USDM is widely referenced and useful for seeing large-scale drought patterns, but one concern about the USDM's broad coverage is that it does not always accurately reflect on-the-ground conditions. Drought index values often have diverse and complex connections to impacts that can emerge in local systems (e.g., ecosystems) and sectors (e.g., agriculture) based on local adaptations and unique regional climates (e.g., semiarid climate of the Southwest). Impacts specific to different regions, sectors, and locales are difficult to capture and depict on a national map, which thereby limits the usefulness of the map for many decision-making and resource management applications.

We identified several examples where common drought indicators, such as those used in developing the USDM, do not fully capture drought impacts:

- In Arkansas in 2012 crops suffered from drought conditions although standard drought indices and the USDM did not indicate a drought. Further investigation showed this mismatch was the result of high evapotranspiration levels, a factor not commonly considered in assessing drought severity.

- Some areas, such as the Four Corners region in the Southwest, have limited climatological data collection systems, complex semiarid climates, and highly diverse topography, severely constraining the ability of traditional drought indices to capture drought conditions at either a regional or local scale. In addition, the semiarid character of the Southwest and a unique seasonal-transitional climate make the operational use of typical drought monitoring indices (e.g., SPI) challenging because the particular timescale of the index and the trigger point chosen substantially influences the degree to which the index reflects actual drought conditions.

- The absence of large tropical storms ("drought busters") in southeast Florida over recent years may lead to increasingly drought-stressed ecosystems, although environmental monitoring information that would reveal these stresses is not frequently included in drought monitoring processes.

- Coastal ecosystems in the Carolinas are sensitive to changes in salinity levels, which are influenced by drought (among other processes), but there is no drought indicator that includes salinity measures.

Cypress bay during 2008 drought, Brunswick County, North Carolina.
CREDIT: DAN TUFFORD, CISA

Examples like these demonstrate that near real-time streams of drought impacts data could provide critical information to operational drought monitoring, providing context for drought indices currently based largely on hydroclimatic monitoring. Without a comprehensive understanding

of impacts, it is likely that state and community response plans do not fully address and mitigate impacts to sectors and resources that are exposed to and impacted by drought, but that do not have readily available data for monitoring the way that the agriculture and water resources sectors typically do. Furthermore, efforts to integrate impacts data into monitoring and planning activities are hindered by limited knowledge of drought impacts reporting best practices such as how to collect impact data, link data and information across different levels of management, and provide useful impact information to decision makers.

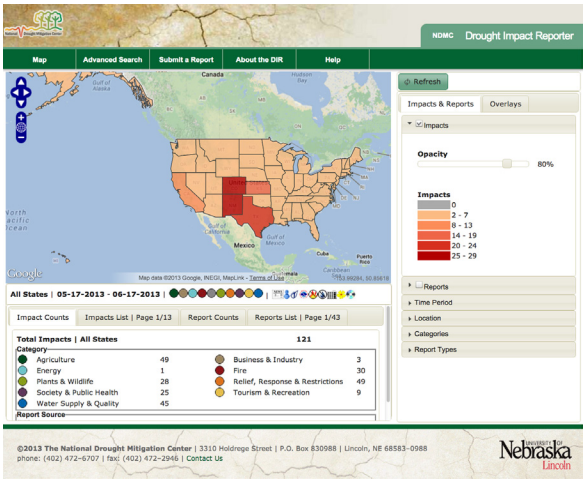
We believe that enhancing understanding about drought impacts and efforts to develop a more robust system of collecting data will contribute to improved drought monitoring, planning, and response decisions. The following sections discuss overarching challenges that limit our ability to comprehensively monitor and understand the full range of drought impacts and lessons learned from our experiences with drought impacts reporting efforts.

Overarching Challenges

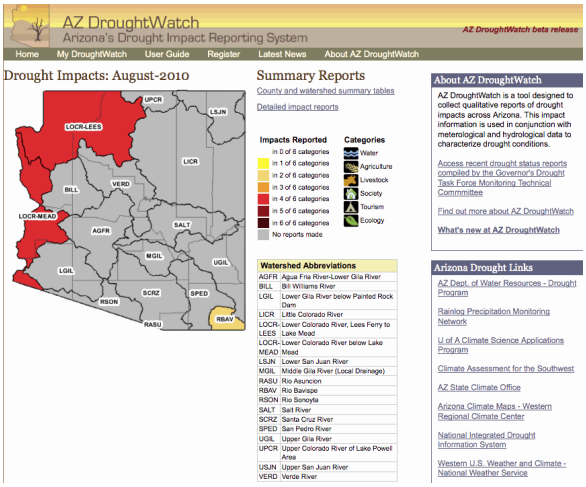
Existing Efforts are Disparate, Diverse, and Fragmented

Collectively, we have been engaged in several drought impacts reporting efforts, including the national Drought Impact Reporter (DIR), CoCoRaHS drought impacts reporting, NIDIS pilot projects, and Arizona DroughtWatch. While this report reflects the experiences and expertise of the meeting participants, we recognize other efforts to collect impacts data exist. Table 1 provides examples of drought impact data collection and communication efforts.

These activities represent a diverse cross-section of scales and data collection approaches. Each of the initiatives—and others not listed here—has been developed with a goal of improving data collection and understanding of drought impacts. However, each effort targets different audiences, defines and characterizes drought impacts in different ways, and accepts impact reports in varying formats. To our knowledge, only the Arizona DroughtWatch system has been formally evaluated (Meadow, Crimmins, and Ferguson 2013), thus limiting the availability of information about best practices and successful strategies. At this stage in the development of drought impacts reporting systems, coordinated efforts to share such information also has been limited.



Drought Impact Reporter (DIR) droughtreporter.unl.edu



Arizona DroughtWatch azdroughtwatch.org

Table 1: Examples of drought impact data collection and communication efforts

NDMC manages the Drought Impact Reporter (DIR), a Web-based mapping tool that compiles and provides drought impact information from across the US. This tool represents a broad, national effort to gather information about drought impacts, defined as "an observable loss or change that occurred at a specific time and place because of drought." This includes changes in human behavior, ecosystems, and air quality, in addition to more obvious losses such as agricultural productivity. One objective of the DIR is to ensure that impact information comes from the wide range of sectors and communities that are affected by drought. The DIR accepts impact reports from a variety of sources including the media, government agencies, and citizen observers.

The Arizona DroughtWatch (AZDW) system was developed as a component of the state of Arizona's Drought Preparedness Plan. A network of county-level drought impact reporters submits information that the Arizona Governor's Drought Task Force can then use when making recommendations regarding drought status. Unlike the DIR system, AZDW was designed to have dedicated observers regularly reporting the status of different sectors and systems to help support operational drought monitoring in the state and more broadly in the USDM. The system was designed to support state-level drought monitoring and planning and to inform and support larger-scale data collection and monitoring efforts like the USDM and DIR.

The Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) is a national network of volunteers who measure precipitation data. With the NDMC, CoCoRaHS has developed a form for volunteers to provide drought impact information directly to the DIR. CoCoRaHS has developed several training tools to inform observers about the process of creating a report and the importance of documenting drought impacts. This effort represents a promising strategy for leveraging an existing network of environmental observers to contribute to drought impacts data and information.

University of Wisconsin-Extension developed an online impacts reporting tool to track conditions so that response resources could be deployed most effectively. This tool collects state-level and sector-specific impact data across Wisconsin using a free, open-source crowdmapping platform. South Dakota State University Extension established a similar effort in 2012.

USDA National Agricultural Statistics Service (NASS) and Farm Service Agency (FSA) collect information about agricultural and crop impacts. Summary information about crop and weather conditions is available through USDA's Weekly Weather and Crop Bulletin.

National Weather Service (NWS) Weather Forecast Offices (WFOs) issue Drought Information Statements when an area is in severe (D2) or worse drought on the USDM. These reports are reviewed and included in the national DIR.

Defining Drought Impacts

One of the most challenging issues is clarifying what is meant by drought impacts. While the development of drought indicators that represent the diversity and complexity of drought has substantially evolved over the last two decades (Botterill and Hayes 2012), there has not been a complementary evolution in thinking about the complexity of monitoring drought impacts. The characteristics of drought make it a particularly difficult environmental hazard to monitor, prepare for, and respond to. These characteristics include the multi-scale nature of drought (both temporal and spatial), the relative nature of drought given a particular climate regime (i.e., what is considered deficient precipitation in the tropical Pacific Islands is orders of magnitude different than an equivalent shortage in the desert Southwest), and the diverse ways that human and ecological systems are buffered against the full force of precipitation shortages. Although these issues are well known (e.g., Redmond 2002), drought is still typically defined by climatologists in terms of hydrometeorological data which, in certain contexts, simply cannot capture the full complexity of drought as experienced by human and ecological systems (Meadow, Ferguson, and Crimmins 2013). One result of this physical science-derived understanding of drought is that we have not considered the full range of what might be considered drought impacts and how an accounting of a fuller set of impacts data could be best used in dealing with drought.

Persistent drought, seasonal winds, and land use all contribute to sand dune migration onto the rangelands of the Hopi Tribe in northeast Arizona.
CREDIT: DANIEL FERGUSON AND MICHAEL CRIMMINS, CLIMAS

Much of the work that has been done on drought impacts reporting to this point has relied on relatively straightforward metrics that often are associated with below-average precipitation. For example, the agricultural sector has multiple reliable economic metrics (e.g., crop yields) that already are consistently collected and provide a steady stream of drought impacts information. Similarly, many water resource management agencies across the US have robust metrics to assess the state of water systems relative to drought conditions. Identifying, quantifying, and collecting less obvious drought impacts are challenges that often are not tackled. For example, second-order or more distant drought impacts typically are not considered when assessing drought conditions. These more distant impacts include degradation of water quality during extended drought periods, public health events that may arise from dry and dusty conditions, impacts to infrastructure such as well pumps that become overtaxed with reduced surface water availability, and many others that are unique to the diverse geographies of the US. The complexity of dealing with impacts resulting from multiple stressors also can make reporting difficult.

For example, sinkhole formation in Florida may be linked to both groundwater extraction and drought. Drought vulnerability could also play a role in the distribution and type of impacts, although we know very little about vulnerability outside standard sectors, such as agriculture and water resources. A better understanding of these indirect drought impacts is vital for the next generation of drought planning and response.

A home falls into a large sinkhole in Florida.
CREDIT: SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

One hurdle that must be overcome as we work to better characterize drought impacts for the purposes of drought monitoring and assessment is the temporally complex nature of a drought impact. As we begin to better categorize drought impacts, we will need to confront two important questions: 1) Is a drought "over" when precipitation resumes or when impacted systems begin to recover? 2) How do we deal with state changes that may result from long-term drought conditions? Declaring the end of a drought is, in many ways, much more complex than declaring the onset. A moisture-deprived system may take a very long time to return to a state that we may consider normal or unstressed, which means that drought impacts may (and do) remain for weeks, months, or even years after precipitation has returned to average. Closely related to the question of "undeclaring" drought is the reality that if drought persists long enough, it can push a system over a threshold, sometimes resulting in radical state changes that may take decades or longer to recover, if recovery is even possible. For example, if persistent drought induces forest mortality, the initial death of the trees may be useful drought impact information. Five years into an ongoing drought, when that forest has not recovered, using the health of the forest as an indicator of drought becomes a moot point. If drought impacts are going to be useful in terms of monitoring and assessing drought, it will be important to consider these temporally complex issues.

Lessons Learned about Drought Impacts Reporting

We developed a preliminary list of lessons learned about drought impacts and drought impacts reporting. This section draws from findings from an evaluation of the Arizona DroughtWatch program (Meadow, Crimmins, and Ferguson 2013) and our experiences with respect to the motivations of individuals and agencies to participate in drought impacts reporting.

Several characteristics of existing drought impacts reporting systems limit the development of coordinated strategies to adapt to drought. First, the current system relies heavily on volunteers to report impacts. Volunteers often have differing motivations and interests, diverse technical capacities, and differing needs for regular communication and outreach, factors which challenge sustained impacts reporting efforts. Drought impacts reporting is most reliable and systematic in a few sectors where the value of the data collected is most clearly demonstrated, such as agriculture, water resources, and wildfire management. However, many other types of significant impacts are not well monitored or reported, such as second- and higher- order impacts and impacts on groups and sectors that are not well represented in drought monitoring and management plans (e.g., ecosystems, public health). Second, current drought impacts reporting systems lack a clear connection to decision-making processes. There appears to be a fundamental mismatch between where the responsibility to collect information resides and who acts during drought. In our experience, lack of understanding about how information will be used reduces motivation to report impacts. Consequently, reporters tend to provide "spot" reports about impacts rather than regular status reports about evolving conditions. At the same time, decision makers need a reliable stream of information about drought onset and recovery, including lingering and far-reaching social and environmental impacts and system changes and transitions, in order to develop mitigation plans.

Motivating Drought Impacts Reporting

It is generally recognized that collecting and having access to drought impacts information and measuring the full economic costs of drought is critical for understanding geographic or sectoral vulnerabilities to drought. Such understanding and information, in turn, can be used to develop mitigation and management options that are intended to reduce the vulnerability and thereby the impacts of drought. While the potential to reduce future impacts provides a type of incentive for impacts reporting, it is not clear that it is a sufficiently strong one. The experience of Arizona DroughtWatch and the Drought Impact Reporter (DIR) indicates that relatively few individuals submit observations to these programs. The evaluation of the strengths and weaknesses of the Arizona DroughtWatch program (Meadow, Crimmins, and Ferguson 2013) provides valuable information with respect to the factors that motivate stakeholders to engage with drought impacts reporting. Meadow et al. (2013) identified specific challenges, including over-use of volunteers, varying perceptions of drought impacts, lack of confidence in clearly identifying impacts, lack of funding, and challenges related to the complexities of drought monitoring such as identifying the beginning and end of drought.

A lack of awareness can be a barrier both for those who do not realize that they can submit drought impacts and for those who do not recognize the particular impacts a drought might have and the importance of reporting those impacts. Impacts can only be reported if they are observed. Different individuals and groups frequently have varying perceptions of drought impacts and lack a clear sense of what constitutes a drought impact and how to designate secondary impacts. It is also difficult to distinguish between drought impacts and results of multiple stresses that might or might not include drought. For example, are sinkholes in Florida or urban subsidence in Arizona a result of drought, overdraft of groundwater, or both? There is a similar lack of scientific information on how drought affects connections among ecosystems in a watershed, from the headwaters to the coast, and the species that depend on those ecosystems. Volunteers from the general public (e.g., citizen observers) are an important resource to tap into for impact monitoring efforts, but field personnel with direct

ties to and expertise in monitoring resources are critical partners that need to be engaged as well.

Although the monetary costs for reporting drought impacts through existing Web-based systems appear nominal, these efforts do have personnel and time costs. Some organizations might be reluctant to report drought impacts because they see it as an unfunded mandate or they perceive that drought impacts reporting would be another organization's responsibility, creating inefficient redundancies. Volunteers can and do report drought impacts, but there is a danger of over-reliance on volunteers who might become fatigued or over-committed.

In addition, some affected stakeholders lack incentives, or face disincentives, to report drought impacts. In some circumstances, there are either direct or indirect fiscal benefits to those who may be impacted by drought in the form of mitigation funding, insurance payouts, or changes to revenue streams. For example, the use of the USDM as a trigger for access to agriculture disaster assistance programs contributes to a perception that people are reluctant to report improving conditions because improvement might end federal aid. Other drought stakeholders might have political or economic disincentives for contributing critical information. For example, drought reporting might make a city or region less attractive to business development, therefore reducing competitive advantages. In the water resources sector, a water utility might be reluctant to implement water conservation measures that reduce income or report impacts that might foster a perception of poor water management. Reporting improved conditions may also be discouraged if higher revenues were realized during a period of decreased supply, which might be the case for agricultural crops receiving higher market prices.

Aside from the handful of sectors that have an obvious interest, concern about drought is much more diffuse, which complicates efforts to gather drought impacts information. For example, in South Carolina in 2007–08, drought caused soils to shrink and crack, damaging home foundations, brick walls, and wells. If such damage is not covered by homeowners' insurance, individuals lack a financial incentive to formally report the drought impact. In other parts of the US, the tourism industry is directly impacted by drought conditions but individual hotels, campgrounds, and marinas may have little interest in contributing drought impacts information, such as low reservoir levels and dry launch areas, because doing so might be counterproductive to their ultimate goal of promoting visitation to a region.

Low water in Lake Hartwell, South Carolina in 2008.
CREDIT: SC DEPARTMENT OF NATURAL RESOURCES STAFF

Moving Forward: Gaps & Recommendations

Linking Drought Impacts Information to Decision Making

While drought planning efforts routinely point to the importance of better impacts information, only a narrow subset of sectors has developed practical reporting mechanisms to link impacts information to decisions. Consequently, the system for reporting impacts to multiple constituencies and across levels is also underdeveloped. To better integrate drought impacts reporting into operational drought planning, response, and mitigation, we need to clearly and concisely communicate the purpose and benefits of collecting drought impacts data and devise processes and approaches that connect impact reporters with those who use impacts data and information for research or operational decisions.

The Existing System

The DIR is a national-level database of drought impacts. It represents a significant investment to catalogue and improve understanding of drought costs and impacts and is an operational component of the USDM process. Some USDM authors use it regularly in making decisions when developing the weekly drought map. FSA officials and other drought observers use the DIR to submit reports to document worsening conditions, typically in response to inquiries from regular USDM contributors (e.g., state climatologists). In other instances, reports go directly to the USDM listserv rather than via the DIR, and NDMC staff enters impacts from the listserv into the DIR as time and circumstances permit, adding them to the visible archive of impacts. Beyond the USDM process, the DIR is at times a source of information for policy makers, media, and scientific or academic researchers. Specific examples include:

- The DIR was a key source of information for the South Plains Drought Assessment conducted by the National Weather Service, with NDMC staff compiling impact information from the DIR for the assessment.
- Media coverage and contacts have demonstrated that the DIR is a source of information on drought impacts, typically when media are looking for examples of current impacts from a specific location (as opposed to any kind of big-picture summary of impacts).
- The NDMC also has provided information from and about the DIR to the Congressional Research Service and to staffers from congressional and state governors' offices.

In terms of informing decision making, there are two potential shortcomings in the way the existing DIR process integrates with the broader management systems. First, the DIR appears to be used primarily to compile single reports, rather than as a system for ongoing status monitoring, which limits the value of the DIR as a source of long-term data. Second, the extent to which groups at lower levels of decision making, such as state drought task forces and local planners, are aware of or use the database (or find it useful) is unclear. Although the drought impact information that is collected could be used to support specific decisions, limited capacity across management levels (local, regional, state, and national) has reduced the ability to regularly synthesize and communicate the available DIR information. However, producing such reports for entities across the nation is a tall order that exceeds the staffing levels of the DIR. Although USDA uses the USDM (and indirectly the DIR) to guide provision of disaster assistance to farmers, there is not a clear link between assistance and drought impacts in other sectors.

The ad hoc system of tools and processes for drought impacts reporting currently operating on the local and state levels has an inherent set of challenges related to the scale of the information collected

as well as the overall utility of that information for decision making. Arizona DroughtWatch and the University of Wisconsin-Extension Drought 2012 reporting project represent smaller scale, customized efforts to collect drought impact information for local purposes. An ideal national system would allow such local mechanisms to be easily integrated into a national structure like the DIR so that the information would simultaneously inform local decisions and national policy and resource allocation decisions. However, few resources exist to support the aggregation of local information to a national or regional scale. Furthermore, where state- or local-level initiatives to collect drought impacts information exist, the extent to which that information is systematically integrated into drought planning, monitoring, and mitigation activities appears extremely limited. For example, a recent study of drought preparedness programs in the western US found that "[p]aradoxically, while most states are active in drought monitoring and response, relatively few states have conducted post-drought assessments, impact and risk assessments, or mitigation. This suggests an imbalance between resource allocation for response-oriented actions and mitigation-oriented actions…limited resources were typically dedicated to response, rather than to mitigation and assessment" (Fontaine, Steinemann, and Hayes 2012, 18). Although some states have conducted or commissioned event-specific drought impact studies, our experience has been that these are often ad hoc or one-off activities.

Without a formal mechanism or institutional support for impact data collection and analysis, the value of drought reports is uncertain to both those who might provide and those who might use them. Disconnects may occur if components of drought response and planning (including impacts data collection) are conducted by different entities within a government and if no coordinating agency or process exists. For example, drought planning and response may be conducted by a range of departments, including those responsible for water resources, hazards mitigation, natural resources, agriculture, or forestry. Also, if a state, county, or city does not have an effective drought management plan, there may be no potential application for drought impacts reports. Without drought management plans, state and local governments are unlikely to provide incentives or mandates to collect drought impact data.

Components of a Comprehensive Drought Impacts Reporting System

As a first step in thinking about how to integrate information into decision making across multiple sectors and levels, we identified the key components of a comprehensive drought impacts reporting system (see also Figure 1). This new system would need to include:

- A range of data providers—individuals and organizations who observe, monitor, and report drought impacts at multiple scales (local to national). Data inputs are likely to be sector-specific.
- Mechanisms through which impacts data are collected and potentially aggregated from lower to higher scales. Some providers may have an internal agency or institutional mechanism through which to report impacts (for example, USDA's National Agricultural Statistics Service (NASS) and Farm Service Agency (FSA) collect information about agricultural and crop impacts), or may submit impact data through an existing drought reporting system (e.g. DIR, CoCoRaHS, AZDW).
- Mechanisms through which drought impacts data are communicated and made available and useful for users.
- A range of information users—decision makers and resource managers located at local to national scales. They may represent individual or multiple sectors.

While some pieces are currently in place, we identified many gaps in the existing system of drought impacts reporting. Particularly lacking is the capacity to aggregate and synthesize drought impacts data and translate that data into useable information for decision makers. In the following sections we discuss ways to address some of these gaps, drawing on our multiple layers of experience with drought impacts research and reporting. Given that there are many audiences and many applications for drought impacts information, such efforts likely will need to involve diverse groups of decision makers and researchers.

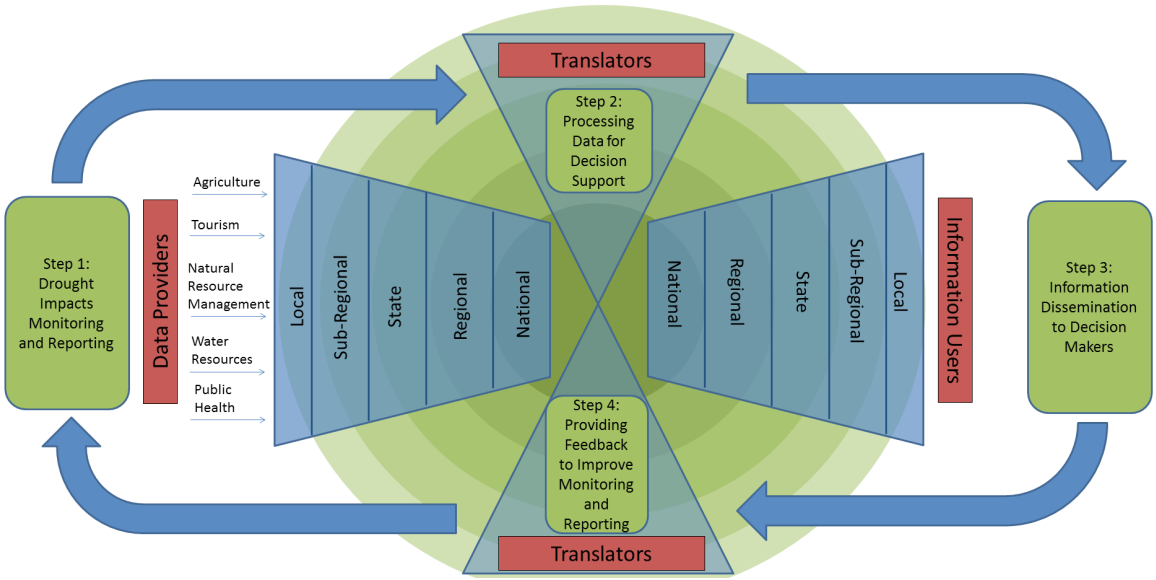


Figure 1. An idealized depiction of a comprehensive drought impacts reporting system

Step 1: Impacts are monitored and observations are entered into reporting mechanisms at various scales and by multiple sectors (data providers). Because many impacts are felt at the local level, this scale provides important opportunities for ground-truthing impacts data.

Step 2: Through reporting tools such as the Arizona DroughtWatch or DIR, impacts data are then converted into useable information for decision makers. These processes occur at multiple scales and for various sectors. Translators who are able to synthesize data and communicate effectively with data providers and information users are an important part of these processes.

Step 3: Impacts information is integrated into decision making and management through information dissemination mechanisms and tools to guide the use of impacts information (e.g., drought response plans).

Step 4: Through efforts to assess the practical use of impacts information in decision making, feedback can then be provided to translators and data providers to improve monitoring and reporting mechanisms. Such activities are expected to increase understanding of drought impacts and lead to the development of more effective drought mitigation and management options. Opportunities for mainstreaming monitoring and reporting into other efforts and activities may also be identified through this process.

Recommendations

1: Evaluate existing drought impacts reporting programs to identify successful approaches and opportunities.

A first step for determining the key elements that should be included in drought impacts reporting infrastructure at any scale (e.g., local to national) is evaluating existing tools and reporting systems. Systematic evaluations of current efforts, such as the one conducted for Arizona DroughtWatch, would yield insight into data collection, archival, visualization, and utilization best practices. Determining the strengths and weaknesses of various components of each program could be used to improve existing systems, develop new models, and coordinate efforts at different scales.

Since 2008, NIDIS pilot projects around the country have undertaken efforts to closely study drought impacts at regional (primarily watershed) scales. Projects have examined how well existing drought indicators match impacts, improved understanding of underlying drought vulnerabilities, and developed experimental methods for collecting drought impacts at a local scale. Because of this work, NIDIS is in a position to assess existing reporting tools and systems and engage stakeholders in future drought impacts reporting efforts.

2: Establish and foster effective connections between drought impacts reporting and decision making.

Developing a sustainable drought impacts reporting system will involve addressing diverse stakeholder needs and connecting impacts to policy and management decisions. Without a strong connection with decision makers, collected or reported data will not be used to its full potential. Given the many different audiences and potential applications for drought impact data and information, a better understanding of what data and information would be most useful for which decision makers is needed. Our initial thinking about such a program is that it would: 1)require a transdisciplinary approach (i.e., ongoing collaborations between researchers and practitioners) and iterative interactions with information providers and information users to identify the range of impacts that affect different sectors and management levels; 2) develop effective processes for integrating impacts information into planning, monitoring, and response activities; and 3) implement effective monitoring programs that incentivize both information providers and information users in a sustainable and systematic way.

To the extent possible, drought impacts reporting efforts should clearly articulate the incentives for participating in impacts monitoring and provide feedback to participants over time to sustain the engagement. The value of drought impact reports needs to be established and communicated to potential professional and volunteer reporters. In addition, specific guidance on local drought definitions and what constitutes a drought impact are necessary for successful observations, reports, and application to decision making. Developing processes that assure that drought data and information are shared with decision makers in a timely manner also will demonstrate the value of reported data. Ideally, impact monitoring efforts will be integrated into existing activities already carried out by field experts (e.g., resource managers, farmers, and ranchers) helping to support these efforts rather than adding new work.

The DIR could be leveraged to raise awareness of drought impacts and the value of monitoring them, particularly given the broad lack of understanding of drought impacts and limited use of drought impacts information outside the agricultural sector. The DIR

is built to be interactive and allows users to query it at different temporal and spatial scales. The extent to which various user communities want to be actively involved in data collection and synthesis merits further investigation, as does the extent to which they would want to be actively involved if they had greater awareness of drought impacts.

Meanwhile, decision makers and other potential users also need clearer incentives to employ drought impact reports. There are several potential strategies that might help improve understanding of the benefits for participating in a drought impacts reporting system and motivate the use of drought impact reports. The value might be economic, based on disaster-related assistance or improved business planning; environmental, such as improved protection of natural ecosystems; or social, such as improved public health coordination or more equitable allocation of a common resource. Financial incentives might include linking insurance and federal loan availability to participation in drought impacts reporting and drought preparedness activities.

Efforts that increase coordination among data collection systems, communication with the media, and engagement with representatives from the many different drought-sensitive sectors may help to encourage greater use of drought impact reports. Other efforts could identify and provide successful examples, case studies, or best practices of where drought impacts information was incorporated into all-hazards planning, water pricing structures, or watershed management activities.

3: Evaluate and develop new tools and methods to motivate reporting, facilitate the collection of impacts data, and improve the communication of drought impacts information.

We need an expanded set of methods and tools to facilitate the provision and use of drought impacts information. Applied research and related activities could include investigating how to most effectively display and communicate drought impacts information; guide the interpretation of hydrometeorological indicators compared to local conditions; select the appropriate triggers in drought plans at different scales; and characterize second- and higher- order impacts, including impacts with different time lags and spatial scales. Archived information on past drought impacts and mitigation or management actions taken to cope with those impacts is an essential part of identifying lessons learned and best practices for addressing the implications of drought. Long-term planning efforts can also be improved through this type of evaluation of past actions.

Offering various methods and tools for reporting may improve the capacity of audiences with varying technical expertise. Multiple data input tools might include an online portal, mobile phone applications, e-mail, and social media websites, in turn providing a wider range of contribution opportunities. In addition, as technology continues to evolve at an ever-increasing pace, allowing for multiple inputs ensures a more continuous stream of data and information, should an individual method become obsolete or encounter technical difficulties. The provision of decision-relevant information based on drought impacts reports may require different information delivery methods as well. Future efforts should examine how these multiple methods could be applied to the transfer of data and information output from the reporting tool.

Developing methods to coordinate and connect data collection efforts is critical in supporting national scale drought early warning systems and will help develop standardized datasets and protocols. Drought impact datasets with somewhat

standardized observations will be critical if they are to be used for research and planning purposes as datasets grow. The DIR is housed within an organization (the NDMC) that is able to consistently input and archive data. The ability to maintain the tool over the long-term is one of the strengths of the DIR, whereas other smaller efforts, such as Arizona DroughtWatch, may encounter staffing or resource issues that require cutbacks to operations or maintenance capacity. Opportunities for the DIR to "ingest" regionally or locally collected data from other reporting tools may help ensure an archive location for the data, should local efforts be hindered for unforeseen reasons. In addition, by including local level data, those responsible for translating impacts data into useful information for decision makers would have access to a finer scale of data inputs.

4: Investigate and pursue opportunities for mainstreaming.

To realize the potential utility of drought impacts information, a more systematic assessment of who is concerned about drought, the nature of their concern, and the type of data and information various stakeholders can both provide and consume is necessary. What is clear is that concern about drought is nearly as complex as its impacts. Sectors that are most vulnerable to drought, and which might benefit from improved drought impacts reporting, include energy, public health, tourism, natural ecosystems, and small businesses and communities dependent on natural resources. People motivated by interests other than drought likely will have knowledge that is useful for drought mitigation and management efforts. For example, some insights from research on adaptation to climate changes may be useful. Systematic efforts to more fully understand the interests of different sectors and regions will clarify the most fruitful opportunities for gathering and using drought impacts information.

Currently, a fairly fragmented universe of data and information exists. These resources might be useful in understanding drought impacts but are not integrated into drought monitoring and management activities. Many groups across the US conduct routine environmental monitoring, but this data typically is not used for assessing drought conditions or examining drought impacts on ecosystems. In addition, approaches for integrating diverse sources of information in a timely and useful way have not been fully defined. Identifying other sources of data and information relevant to different sectors may illuminate impacts that are underreported. Given the small likelihood of significant new funding for drought monitoring, it is important to identify existing federal and other data sources and evaluate their potential application for drought impacts reporting. Although a more thorough inventory of possible data sources would be required, Table 2 provides a preliminary list of sectors and organizations to consider when engaging in drought impacts reporting efforts.

As the NDMC works to improve both the collection and availability of impacts information, leveraging existing data collection efforts could provide additional context to better understand impacts, vulnerabilities, and attribution in multi-stress situations. This opportunity to mainstream drought impacts data collection with other current environmental and socioeconomic data collection efforts would help integrate data and information useful for a more robust understanding of drought onset, impacts, and recovery. As with other drought reporting activities, mainstreaming efforts may require additional support, resources, training, and incentives as well as clear linkages to decisions and users of information.

Table 2. Examples of agencies and organizations to engage in mainstreaming efforts.

Agriculture US Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA)	**Forestry and land management** US Forest Service (USFS), Bureau of Land Management (BLM), National Park Service (NPS)
Health Center for Disease Control (CDC), Environmental Protection Agency (EPA)	**Environmental resources, fish and wildlife** US Fish and Wildlife Service (US FWS), National Estuarine Research Reserve System (NERRS), National Phenology Network
Water US Army Corps of Engineers, EPA	**Weather and climate** National Weather Service (NWS) Weather Forecasting Offices (WFO), State Climate Offices, Regional Climate Centers

5: Investigate and pursue opportunities to "professionalize" or "institutionalize" drought impacts reporting.

One overarching conclusion of the Meadow, Crimmins, and Ferguson (2013) study was that volunteer observers alone could not sustain the reporting effort in Arizona. The authors suggest that the limited success of drought impacts reporting systems will persist if they continue to rely on volunteers for impact reports and that such a system is not a viable process for informing policy and management decisions. Drawing from that study, workshop participants discussed the need for a trained and professional group of impacts reporters to form the core of the observing effort. Many agencies and organizations have field personnel who may be collecting data relevant to drought impacts reporting (e.g, see Table 2).

In addition to identifying agencies, organizations, and networks that are currently collecting—or are willing to begin collecting—relevant data and information, coordinating various organizational levels will be a necessary component of an improved drought impacts reporting system. Coordinating local efforts will help bolster data aggregation and translation to decision-relevant information. Furthermore, if professionals were to submit regular drought status observations as part of their jobs, volunteers may be more likely to engage in the overall effort and submit additional reports. This strategy of partnering with and coordinating existing agency field personnel or existing monitoring efforts will require both strong incentives to

participate and strong leadership at the highest levels of management within each agency.

"Translators" are also needed to ensure that useful and relevant drought impacts data are provided to decision makers. Translators would use their local or regional expertise to evaluate, analyze, and interpret drought impacts reports; assist with the display and communication of impacts for decision makers; and serve as a liaison between impact reporters and the users of impact information. Impacts translators will be important in developing interconnections across scales and sectors and ensuring that impact information is stored, reported, and aggregated so that it can be utilized in meaningful ways.

"Professionalizing" drought impacts reporting will require funding, human resources, and administrative and institutional support, but it may be mainstreamed into other activities in drought-sensitive sectors. All groups involved in the drought reporting process—observers, translators, researchers, and decision makers—will benefit from training. Providing opportunities for ongoing interactions, communications, and coordination across groups will be invaluable in building a collective understanding of drought impacts.

Next Steps

One of the primary goals of the Tucson workshop was to scope out what a community of practice (CoP) focused on drought impacts reporting might involve. The absence of a coordinated community in the US focused on integrating drought impacts reporting into operational drought assessment and planning is, we believe, a key barrier to progress. Our vision of this community of practice would embrace the research, operations, and policy perspectives on drought and drought impacts so that interested parties could co-develop ideas and processes that would ultimately integrate this information into practice.

Regardless of how a CoP eventually comes together, a few features are likely to be critical. First, such a community could help tie together drought vulnerability and impacts, a dimension only nominally present in current drought management. Second, this community could systematically address the issues related to diffuse interests in drought by providing a venue for developing best practices related to assessing and cataloging the disparate information and concerns that are largely unconsolidated. Finally, this group could support the leveraging of existing drought impacts reporting efforts in promoting the greater integration of impacts information into drought assessment and planning.

Initial steps and actions might include conducting collaborative and comparative studies and inventories across regions, sectors, research projects, or drought impacts reporting systems and using existing venues and opportunities to interact with and engage others. Two additional opportunities for developing long-term, continuous drought impacts data collection and analysis include 1) the memorandum of understanding between NOAA and the US Department of Agriculture intended to promote data exchange between those two agencies, which could possibly facilitate Farm Services Administration and Cooperative Extension input into the Drought Impact Reporter and 2) the sustained assessment process for the National Climate Assessment.

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