

## Understanding the complex impacts of drought: A key to enhancing drought mitigation and preparedness\*

Donald A. Wilhite · Mark D. Svoboda ·  
Michael J. Hayes

Received: 25 January 2006 / Accepted: 15 June 2006 / Published online: 11 January 2007  
© Springer Science + Business Media B.V. 2007

**Abstract** Recent droughts in the United States have highlighted the nation's current and increasing vulnerability to this natural hazard. Drought-related impacts are also becoming more complex, as illustrated by the rapidly rising impacts in sectors such as recreation and tourism, energy, and transportation. Environmental and social consequences are also of increasing importance. Conflicts between water users and disputes between political entities on transboundary water issues are a reflection of the need for improved documentation of the consequences of extended periods of water shortage. Unfortunately, no national drought impact database exists and drought impact statistics are not routinely compiled at the state, regional, or national level. Without this information, it is an arduous task to convince policy and other decision makers of the need for additional investments in drought monitoring and prediction, mitigation, and preparedness. The National Drought Mitigation Center at the University of Nebraska-Lincoln is addressing this problem by creating a web-based Drought Impact Reporter (DIR) that has the following primary functions: (1) to create a database archive of drought impacts information; (2) to provide an interactive map delivery system that is efficient and user-oriented; (3) to build links with governmental agencies, non-governmental organizations, university research groups and extension programs, and others, including the public, in order to provide timely impact reports to ensure a comprehensive collection of drought impacts across all potential sectors and scales; and (4) to foster a continual process of user feedback, evaluation, assessment, and dissemination of drought impacts. The Drought Impact Reporter was launched in July 2005 and is available on the NDMC's web site (<http://drought.unl.edu>).

**Keywords** Drought impacts · Drought preparedness · Drought mitigation · Drought monitoring and early warning

---

\*A contribution of the University of Nebraska Agricultural Research Division, Lincoln, NE 68583. Journal Series No. 15122.

---

D. A. Wilhite (✉) · M. D. Svoboda · M. J. Hayes  
National Drought Mitigation Center, University of Nebraska, Lincoln, Nebraska 68583-0988, U.S.A.  
e-mail: [dwilhite2@unl.edu](mailto:dwilhite2@unl.edu)

## Introduction

Drought is an insidious, slow-onset natural hazard that produces a complex web of impacts that ripple through many sectors of the economy. These impacts may be experienced well outside the affected region, extending even to the global scale. The complexity of impacts is largely caused by the dependence of so many sectors on water for producing goods and providing services. As vulnerability to drought increases because of mounting pressure on water and other natural resources, it is clear that the scientific community faces a significant challenge to produce more timely and more comprehensive assessments of impacts. It is often said that drought is the most complex of all natural hazards, and more people are affected by it than any other hazard. Still, few studies have endeavored to identify the complexity of these impacts at the local, regional, or national scale, and databases to document impacts and track trends by region or sector are virtually nonexistent. As nations strive to improve their level of drought preparedness through the creation of improved early warning systems and the adoption of drought policies and response and mitigation plans, it is imperative for scientists and policy makers to document to what degree these investments are diminishing economic, social, and environmental losses in order to justify future investments in drought mitigation and planning.

The purpose of this paper is to highlight the complexity of impacts associated with drought, with the primary focus on the United States, and to illustrate recent initiatives by the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, U.S.A., to track these impacts through a web-based drought impact reporting tool that was launched in July 2005 and will result in the creation of a nationwide drought impacts database.

## Drought impacts: A key to understanding societal vulnerability

One important characteristic of drought that distinguishes it from other natural hazards is its lack of a universal definition. Literally, hundreds of definitions exist, largely because drought must be defined according to the characteristics of each climatic regime and the specific impact sector or application to which the definition is being applied. Another complicating factor in characterizing drought impacts is that they vary on both a spatial and temporal scale. Each region or watershed is unique, and the societal characteristics for that area or basin are dynamic in response to numerous factors. A drought event today may be of similar intensity and duration as a historical drought event, but the impacts will likely differ markedly because of changes in societal characteristics. Thus, the impacts that occur from drought are the result of interplay between a natural event (precipitation deficiencies because of natural climatic variability) and the demand placed on water and other natural resources by human-use systems. For example, societies can exacerbate the impacts of drought by placing demands on water and other natural resources that exceed the supply of those resources (i.e., overdevelopment or overappropriation) or through a degradation of the natural resource base. The literature is replete with examples of this situation in many countries. Societies often plan for normal or above-normal water supplies, ignoring the natural variability of climate and the challenges of adapting to a significant reduction in supply, especially when this reduction extends over multiple seasons or years and drought effects are aggravated by a rapidly increasing population, urbanization, land degradation, or other factors.

Expressed another way, societal risk from a natural hazard is determined not only by the degree of exposure or frequency of the natural hazard but also by the vulnerability

of society at that moment in time—vulnerability is dynamic in response to changes in the economic, social, and environmental characteristics of the locale or region. According to Randolph Kent (1987), a disaster occurs when a disaster agent, such as drought, exposes the vulnerability of a group or groups in such a way that their lives are directly threatened or sufficient harm has been done to economic and social structures, inevitably undermining their ability to cope and survive. The goal of disaster management is to impose changes between hazard events such that the risk associated with the next event has been reduced through the implementation of well-formulated policies, plans, and mitigation actions that have been embraced by stakeholders.

Recent droughts in developing and developed countries and the concomitant impacts and personal hardships that resulted have underscored the vulnerability of all societies to this 'natural' hazard. Statistics compiled by the International Decade for Natural Disaster Reduction (IDNDR, 1995) indicate that drought accounts for 22 percent of the damage from disasters, 33 percent of the number of persons affected by disasters, and 3 percent of the number of deaths attributed to natural disasters.

Impacts from drought are commonly classified as direct or indirect. Reduced crop, range land, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. For example, a reduction in crop, range land, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced government tax revenues because of decreased expenditures, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs. The indirect losses associated with drought often exceed direct losses.

Because of the number of affected groups and sectors associated with drought, the geographic size of the area affected, and the difficulties in quantifying environmental damages and personal hardships, the precise determination of the financial costs of drought is a formidable challenge. These costs and losses are also quite variable from one drought year to another in the same place, depending on timing, intensity, and spatial extent of the droughts.

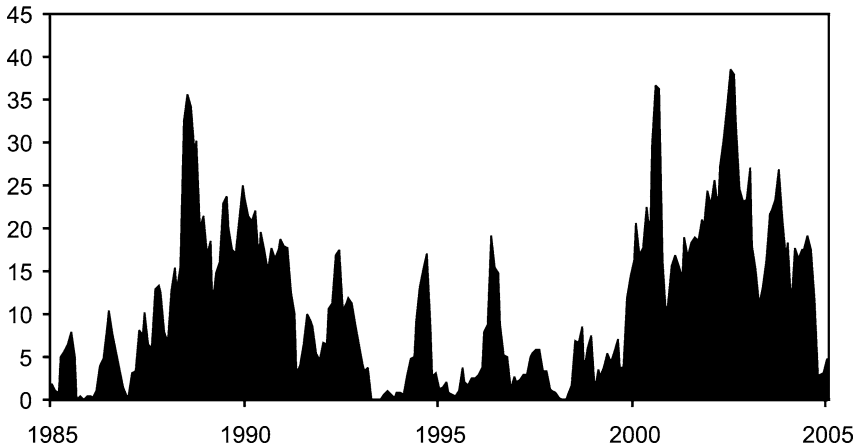
The impacts of drought are commonly classified as economic, environmental, and social. A comprehensive list of the impacts associated with drought has been described by Wilhite (1992) and is available on the NDMC's web site (<http://drought.unl.edu>). As with all natural hazards, the economic impacts of drought are highly variable within and between economic sectors and geographic regions, producing a complex assortment of winners and losers with the occurrence of each disaster. For example, decreases in agricultural production result in enormous negative financial impacts on farmers in drought-affected areas, at times leading to foreclosure. This decreased production also leads to higher grain, vegetable, and fruit prices. These price increases have a negative impact on all consumers as food prices increase. However, farmers outside the drought-affected area with normal or above-normal production or those with significant grain in storage reap the benefits of these higher prices. Similar examples of winners and losers could be given for other economic sectors as well.

### **Monitoring and documenting drought impacts: The U.S. drought impact reporter**

Over the past two decades, the United States has endured two significant drought periods—1986 to 1992 and 1996 to present (Figure 1). According to the Palmer Drought Severity Index (PDSI), severe to extreme drought covered more than 25% of the United States in

## Percent Area of the United States in Severe and Extreme Drought

January 1985–November 2005



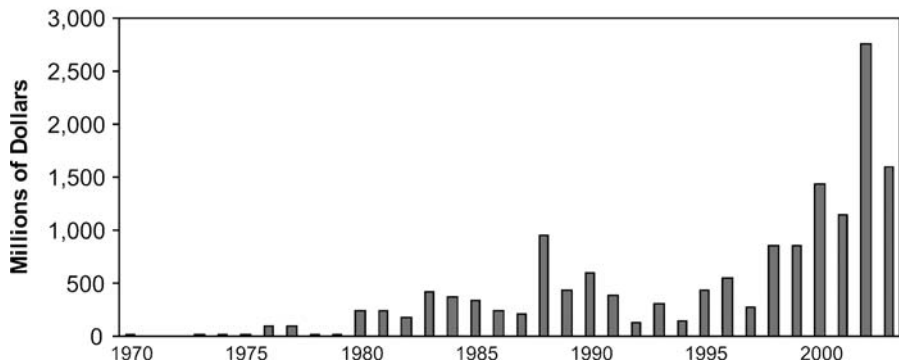
Based on data from the National Climatic Data Center/NOAA

**Fig. 1** Percent area of the United States in severe to extreme drought, 1985–2005, according to the Palmer Drought Severity Index. (Source: Based on data from the National Climatic Data Center, National Oceanic and Atmospheric Administration)

2000, 2002, 2003, and 2004. For example, at the end of July 2002, drought or dryness was affecting all 50 states at the same time, and parts of 26 states were classified under “severe”, “extreme”, or “exceptional” designations, according to the U.S. Drought Monitor (<http://drought.unl.edu/dm>). In spite of the widespread severity of recent drought years, there has been no comprehensive assessment of economic, environmental, or social impacts. The only national statistics are for the indemnities paid through crop insurance for the crops covered for all types of losses, including droughts (RMA, 2004). Indemnities paid for drought losses exceeded \$1.4 billion in 2000, \$1.1 billion in 2001, \$2.7 billion in 2002, and \$1.5 billion in 2003. Figure 2 illustrates the trend in crop indemnities because of drought between 1970 and 2003.

Although drought impacts have not been well documented during these recent droughts, it would appear that the impacts of drought are increasing in magnitude and complexity (Wilhite and Pulwarty, 2005). This paucity of quantitative assessments of drought impacts limits the ability of officials to respond adequately to drought events or to allocate resources in advance of an event. The lack of comprehensive (i.e., multiple sectors and for all drought-affected regions) and more quantitative impact assessments attracted the attention of public officials and policy makers following the 1995–96 drought in the southern Plains and southwestern states (FEMA, 1996; Western Governors’ Association, 1996). As drought continued in subsequent years, greater attention was drawn to the inadequacy of loss estimates associated with drought. Several recent national initiatives highlighted this problem and recommended greater attention be devoted to improving the understanding of impacts and the development of improved and more consistent impact assessment techniques for the United States. The report of the National Drought Policy Commission (2000) discussed the importance

### Crop Indemnity Amounts Due to Drought 1970-2003



**Fig. 2** Crop insurance indemnities because of drought, 1970–2003. (Source: Risk Management Agency, U.S. Department of Agriculture)

of preparedness in reducing drought impacts and the enormity of indirect impacts that are inflicted on agriculture, recreation, tourism, and water-based businesses. In 2004, the Western Governors' Association released a report on the vision of a National Integrated Drought Information System (NIDIS) (Western Governors' Association, 2004). One of the recommendations in the NIDIS report calls for a "methodology to accurately and comprehensively quantify the reporting of drought impacts across all relevant sectors and scales." Understanding the wide-ranging severity of drought impacts is also a major component of the National Drought Preparedness Act (U.S. Senate bill, S802; House of Representatives bill, HR 1386, 2005), introduced to the U.S. Congress in 2005. NIDIS is also an element of the National Drought Preparedness Act.

As with other natural hazards, mitigation and preparedness are the keys to reducing future drought impacts. Without more timely and precise estimates of impacts across the multitude of sectors affected by drought, policy and other decision makers are reluctant to allocate money and resources to mitigation and preparedness, according to the Council of Governors' Policy Advisors (Brenner, 1997). These state officials had a general understanding that "mitigation makes sense," but their desire was for quantitative proof. In fact, this report identified the "lack of information" as the major obstacle to adopting mitigation strategies. Wilhite and Buchanan-Smith (2005) also identified the lack of a comprehensive impact assessment methodology as an obstacle to activating effective drought mitigation and response programs. To overcome this obstacle, timely and quantitative assessments of the impacts and economic losses associated with drought must be compiled.

#### The drought impact reporter: A web-based impact assessment tool and database

In July 2005, the National Drought Mitigation Center (NDMC) launched a prototype web-based Drought Impact Reporter (DIR) to present real-time information on current drought impacts and serve as a national drought impacts database. The DIR has two main components: (1) a comprehensive database or archive of drought impacts and (2) an interactive map delivery system that provides quick access to the archive. The drought impacts archive is the

backbone of the DIR. NDMC staff began entering impact information during summer 2005 that documents current drought impacts. When the DIR was launched in July, the web-based tool was still in its earliest development phase. The NDMC has now received additional funding to broaden and enhance the scope of the DIR and the interactive map delivery system so it is more efficient and user-oriented. The NDMC is also developing additional linkages with governmental agencies, non-governmental organizations, university research groups and extension programs, and others in order to provide impact reports to ensure a comprehensive collection of drought impacts across all potential sectors and scales. User evaluations and feedbacks are also important components of the DIR system. The NDMC will continue to foster linkages with a broad range of users as it enhances the DIR. The DIR has been constructed so its primary elements are consistent with an increased emphasis on drought impact assessment and mitigation and the need for an interactive web-based system to deliver information for all users, as called for in the NIDIS report (Western Governors' Association, 2004).

The sources of the drought impact data for the DIR are:

- An online clipping service that provides daily drought impact-related news articles and scientific publications. The NDMC began subscribing to this service in March 2005.
- Drought-related articles have been collected routinely since 1997 and the NDMC now has an internal archive of more than 11,000 articles. These articles will also be reviewed for drought impact information and entered into the database.
- Drought impact information from reports and other materials from historical drought periods such as the 1930s, 1950s, 1970s, and late 1980s to early 1990s and other shorter-duration drought events will be reviewed and entered.
- Government officials and the public can enter drought impact information directly through the web site. This information is reviewed and verified by NDMC staff and will be characterized as “submitted” reports.

The DIR has been developed and is supported by an ArcGIS/IMS architecture. As this tool evolves, enhancements to the delivery system will be needed. In addition, since the Drought Impact Reporter is one tool in the larger National Drought Impacts Reporting Strategy, it is envisioned that there will be a suite of web-based products and interactive features that will also be supported as part of the same delivery system.

### **Drought impact reporter: Illustrating the tool**

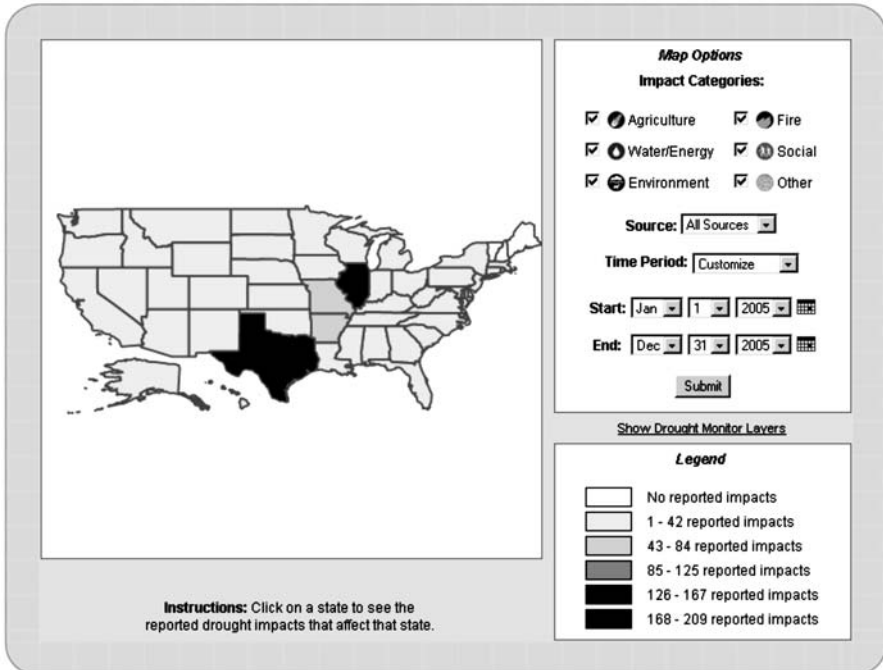
The DIR can be accessed through the NDMC's web site (<http://drought.unl.edu>) or directly at <http://droughtreporter.unl.edu>. When the tool is accessed, the first default screen displays a map of the United States illustrating the number of drought impacts reported during the past month (Figure 3). The legend appears in the lower right corner of the page. In the upper right corner is a list of impact categories. All categories will be displayed initially, but the user can select only those categories of interest. The user can also select the sources of information (e.g., media, public), but all sources are shown initially. The user can also select the time period for the impacts [Note: NDMC staff have, at this writing, entered impacts reported through news articles back to 1999]. The default for the map is the past month. After making the selections for sources and time period, the user can click the select button to generate a new map.

By positioning the cursor over a state, a box appears with a listing of the total number of impacts for the period and how these break down by sectors. Clicking on the state will

# Drought Impact Reporter

National Drought Mitigation Center 

[View Drought Impacts](#) | [Add A Drought Impact](#) | [Time-Lapse Animation](#) |



created by  
 GIS Workshop

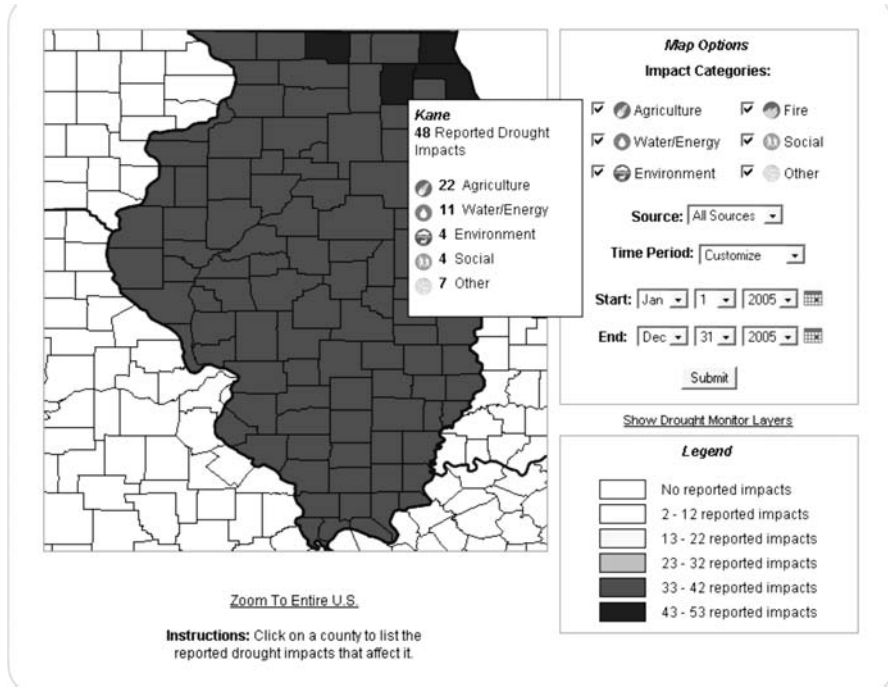
UNIVERSITY OF  
**Nebraska**  
Lincoln

**Fig. 3** Drought Impact Reporter, national map illustrating drought impacts for 2005. (Source: National Drought Mitigation Center, University of Nebraska-Lincoln)

produce a map of that state depicting counties (Figure 4). By placing the cursor over a county, a box appears again depicting the number of impacts for that county with a breakdown by sector. Clicking on the county will reveal the sources for this information (queried from the database), allowing the user to learn more about the impacts reported. This ‘drill down’ technique is a critically important feature of the DIR, allowing users to interrogate to the local or county scale to identify specific impacts.

The user also has the option to overlay the various categories of drought severity from the U.S. Drought Monitor map (<http://drought.unl.edu/dm>), a weekly product produced by the NDMC in partnership with the National Oceanic and Atmospheric Administration and the U.S. Department of Agriculture (Svoboda *et al.*, 2002). This map, see Figure 5, illustrates four categories of drought severity, D1 through D4, representing an increasing severity level from moderate to exceptional for the week of August 2, 2005. An exceptional drought, as defined by the Drought Monitor, represents a 1 in 50 year event. The D0 category reflects a period of abnormally dry conditions that could either illustrate a region trending toward drought or one recovering from it. Overlaying the drought categories on the Drought Impact Reporter map gives users the option of visually correlating impacts with drought severity





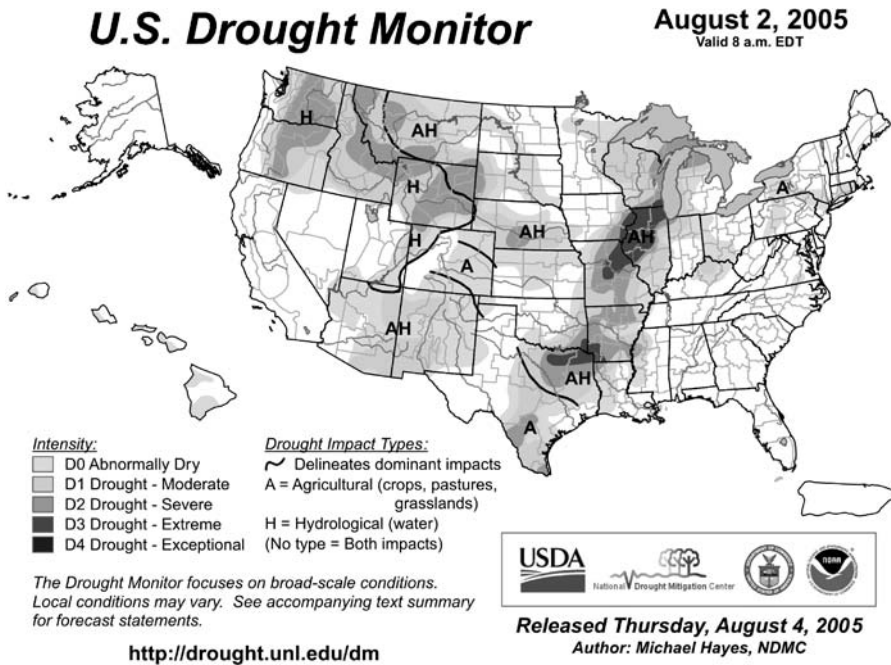
**Fig. 4** Illinois drought impact map, by county, illustrating drought impacts for 2005. The cursor is positioned over Kane County with 48 reported impacts, itemized by impact type. (Source: National Drought Mitigation Center, University of Nebraska-Lincoln)

levels. Currently, this option is only available for the most recent U.S. Drought Monitor, but we plan to expand this capability in the future. Overlaying the drought categories over the Drought Monitor will also help users understand and appreciate the lag characteristics of drought impacts since dry conditions may persist for long periods. For example, the northern Great Plains and northern Rocky Mountain states have been in various drought severity levels for the past seven years.

Other features of the DIR include an option to animate the impacts over a time period and also for users to add drought impacts. To add an impact, the user clicks on this feature and then enters the requested information, including selecting the impact categories and describing the impact (Figure 6). Information entered is quality-checked by NDMC staff before it is added to the database. To date, about 10% of the impacts entered have been from the public, but this number is expected to increase significantly as user groups become more aware of the DIR and the archive becomes more comprehensive.

Numerous sectoral impacts have been added to the database since it was first launched. The total number of impacts added for the period 1995 to present is nearly 3,000. Although this represents only a small fraction of the impacts that have occurred during this period, it does illustrate both the diversity of impacts and the relative importance of these impacts by sector. As one would expect, the largest number of impacts reported is in the agricultural sector, but significant impacts have also been reported in the water, energy, and fire sectors. Social impacts, which are usually underappreciated for drought, are significant over the period of 1995 to present.





**Fig. 5** U.S. Drought Monitor map for August 2, 2005, illustrating the pattern of drought severity and spatial extent. (Source: National Drought Mitigation Center, University of Nebraska-Lincoln)

**Expected benefits of the drought impact reporter**

Many benefits are expected for policy and other decision makers, the scientific community, and the general public as a result of improved drought impact assessments and the creation of an impact archive. First, this project is the first step toward development of national and regional assessments of drought conditions across the United States. For example, Canada was able to make a rough national assessment of the 2001–02 drought, estimating losses at approximately Canadian \$5.7 billion (Saskatchewan Research Council, 2003). Although not perfect, the Canadian drought assessment placed the losses in context for officials and provided a basis for making adjustments and improving on this assessment in future drought events. Second, the archived collection of drought impacts within the large database will be freely and easily accessible to researchers, as well as to decision makers requiring information for policy and management options. Initial reaction to the DIR has been extremely positive and ongoing efforts to enhance this product will further heighten its use and popularity. For example, since the DIR was launched on July 27, 2005, it has received more than 25,000 users accounting for more than 142,000 page views and more than 1.25 million hits (as of December 31, 2005). The NDMC is actively publicizing this product and engaging a wide range of user groups in building the archive and obtaining user feedback. Important bridges will be built between research and user communities that will ultimately increase the capacity for better drought mitigation and response activities across the country. Third, the project builds a foundation for development of standardized methodologies of identifying, collecting, and quantifying drought impacts on national, regional, state, and local levels, as well as the methods for estimating economic losses at these levels. The NDMC will

**Drought Impact Reporter**  
National Drought Mitigation Center

[View Drought Impacts](#) | [Add A Drought Impact](#) | [Time-Lapse Animation](#) | [About](#) | [Help](#) | [User Login](#)

**Add A Drought Impact:**

Items marked with a star (\*) are required.

**States\***  You may select more than one state/county by holding down the Ctr, Shift or Command (Mac) keys.

**Counties\*** Please select a state from the dropdown list above to begin choosing counties.

**Impact Categories\***

Agriculture  Fire  
 Water/Energy  Social  
 Environment  Other

**Description\*** 500 characters max, no HTML, please.

**Source\***

**External URL**

**Monetary Loss**

Please enter the time period when the impact occurred:

**Impact Start\***

**Impact End\***

**Your Contact Info**


**Full Name\***


**Organization**

**Address**

**E-Mail Address\***

**Note:** Thanks for your submission. Before this drought impact event will appear on the web site, a member of the Drought Impact Reporter team will verify the information you've provided. Be sure to provide a valid e-mail address so we can contact you if we have any questions about your submission.

created by  **GIS** Workshop

University of  **Nebraska** Lincoln

**Fig. 6** Representation of the computer screen providing the option for users to add a drought impact for their county and state. Users can choose the impact sector and describe the details of the impact and submit to the database. (Source: National Drought Mitigation Center, University of Nebraska-Lincoln)

continue to pursue development of these methodologies in collaboration with other research entities. Future enhancements to the DIR will include linking this tool to databases such as agricultural statistics at the state and local levels to compare reported impact information with specific production losses as well as to information on drought disaster declarations by federal agencies. Fourth, the DIR will provide a platform for identifying and reporting drought impacts in under-reported sectors, such as livestock, timber, recreation, tourism, and energy. It is likely that the recent drought years from 1996 to 2005 across the United States resulted in impacts in these sectors greater than or equal to crop production losses, which are the most frequently quantified economic impact of drought. Fifth, discussions

have been held between the NDMC and NOAA/National Weather Service (NWS) and U.S. Department of Agriculture personnel about using the Drought Impact Reporter and its data entry format as the tool for entering and documenting “drought incident reports” similar to storm reports that are filed on severe weather events. This would provide NWS offices with a uniform format for reporting drought conditions and impacts, and would provide an additional dissemination method for these reports, and the drought impacts taking place, through the Drought Impact Reporter’s map-based delivery system. Finally, this project supports both the National Integrated Drought Information System (NIDIS) and the National Drought Preparedness Act. The interactive map delivery system will easily connect with other drought-related decision-support tools now being developed by the NDMC, government agencies, and other organizations.

### Summary and conclusions

Drought is a pervasive natural hazard that is a normal part of the climate of virtually all countries. It should not be viewed as merely a physical phenomenon. Rather, drought is the result of interplay between a natural event and the demand placed on water and other natural resources by human-use systems. These systems can significantly exacerbate the impacts of drought through the unsustainable use of natural resources.

The impacts of drought are diverse; they ripple through the economy and may linger for years after the termination of the period of deficient precipitation. Impacts are often referred to as direct or indirect. Because of the number of groups and economic sectors affected by drought, its geographic extent, and the difficulties in quantifying environmental damages and personal hardships, the precise calculation of the financial costs of drought is difficult. Drought years frequently occur in clusters, and thus the costs of drought are not evenly distributed between years. Drought impacts are classified as economic, environmental, and social.

In the United States, the impacts of drought appear to be increasing in magnitude and complexity. Yet, no systematic effort has been made to document the economic, social, and environmental losses associated with this ‘natural’ hazard. Increased attention toward improving drought management at the state and national level in recent years has noted the absence of comprehensive and reliable information on drought impacts and the importance of compiling this information into a national database. This information is considered essential to a better understanding of our vulnerability to this hazard and to justify increased investment in drought monitoring, prediction, mitigation, and preparedness.

In 2005, the National Drought Mitigation Center at the University of Nebraska-Lincoln initiated development of a web-based drought impact reporting tool that is directed at creating the nation’s first drought impact database. The Drought Impact Reporter, although still in its early stages of development, has been well received by scientists, policy makers, natural resource managers, and the public. This tool will continue to be improved through the addition of new features and options. The NDMC will also continue the development of this database by adding impacts from recent and historical drought episodes while continuing to add impact information from current events. The NDMC is striving to engage federal agencies, other organizations, and the public in using this database as a routine reporting mechanism for drought impacts across the country.

Drought is a global issue that is garnering increased attention from many nations and international organizations. The Drought Impact Reporter represents a model others can use in documenting impacts and justifying greater investment in a more proactive, risk-based

management approach to drought. It is critical for all drought-prone nations to share their lessons learned in drought risk management if we are to make progress in reducing societal vulnerability to drought.

**Acknowledgment** The authors would like to acknowledge the significant contributions of Deborah Wood and Melissa Higgins in the development of the Drought Impact Reporter tool and in the preparation of the figures for this paper.

## References

- Brenner E (1997) Reducing the impact of natural disasters: Governors' advisors talk about mitigation. Council of Governors' Policy Advisors, Washington, DC
- Federal Emergency Management Agency (FEMA) (1996) Drought of '96: multi-state drought task force findings. Washington, DC
- International Decade for Natural Disaster Reduction (IDNDR) (1995) Major disasters around the world. Secretariat, International Decade for Natural Disaster Reduction, Geneva, Switzerland
- Kent RC (1987) Anatomy of disaster relief: the international network in action. Pinter Publishers, New York and London
- National Drought Policy Commission (2000) Preparing for drought in the 21st century, Washington, DC, [<http://www.fsa.usda.gov/drought/finalreport/accesstoreports.htm>]
- Risk Management Agency (RMA) (2004) Crop Insurance indemnities paid for drought. Personal Communication with James Callan, August 5, 2004, Risk Management Agency, U.S. Department of Agriculture, Washington, DC
- Saskatchewan Research Council (2003) Canadian droughts of 2001 and 2002: climatology, impacts and adaptations, SRC publication No. 11602-1E03. Saskatoon, SK. (unpublished)
- Svoboda M, LeComte D, Hayes M, Heim R, Gleason K, Angel J, Rippey B, Tinker R, Palecki M, Stooksbury D, Miskus D, Stephens S (2002) The drought monitor. *Bull Am Meteorol Soc* 83:1181–1192
- Western Governors' Association (WGA) (1996) Drought response action plan. Denver, CO
- Western Governors' Association (WGA) (2004) Creating a drought early warning system for the 21st Century: the national integrated drought information system. Denver, CO, [<http://www.westgov.org/wga/publicat/nidis.pdf>]
- Wilhite DA (1992) Drought. In: Nierenberg WA (ed) *Encyclopedia of earth system science*, vol 2. Academic Press, San Diego, CA, pp 81–92
- Wilhite DA, Buchanan-Smith M (2005) Drought as a natural hazard: understanding the natural and social context. In: Wilhite DA (ed) *Drought and water crises: science, technology, and management issues*. CRC Press, Boca Raton, FL, pp 3–29
- Wilhite DA, Pulwarty RS (2005) Drought and water crises: lessons learned and the road ahead. In: Wilhite DA (ed) *Drought and water crises: science, technology, and management issues*. CRC Press, Boca Raton, FL, pp 389–398