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Donald A. Wilhite
University of Nebraska - Lincoln, dwilhite2@unl.edu

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Chapter Eighteen

DROUGHT: ITS PHYSICAL AND SOCIAL DIMENSIONS

DONALD A. WILHITE
Associate Professor
Department of Agricultural Meteorology and
Director, International Drought Information Center
University of Nebraska
Lincoln, NE 68583-0728

INTRODUCTION

Drought has been a threat to human existence throughout history. Today, as in the past, drought alters the course of civilizations. It is not merely a physical phenomenon, but the result of an interplay between a natural event (precipitation deficiencies due to natural climatic variability on varying timescales) and the demand placed on water supply by human-use systems. Extended periods of drought have resulted in significant economic, environmental, and social impacts, including food supply disruptions, famine, massive soil erosion, migrations of people, and wars.

Human activities often exacerbate the impacts of drought (e.g., the Dust Bowl in the Great Plains, the Sahelian drought of the early 1970s). This trend appears to be accelerating because of the increasing demand being placed on local and regional water resources as a result of the earth's rapidly expanding population. 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. It is difficult to determine whether it is the frequency of drought that is increasing, or simply societal vulnerability to it.

DROUGHT AS NATURAL HAZARD

Drought differs from other natural hazards (such as floods, hurricanes, and earthquakes) in several ways. First, since the effects of drought accumulate slowly over a considerable period of time, and may linger for years after the termination of the event, its onset and end are difficult to determine. Because of this, drought has been described as a "creeping phenomenon". [1] Second, the absence of a precise and universally accepted definition of drought adds to the confusion about whether or not a drought exists and, if it does, its severity.[2] Third, drought impacts are less obvious and are spread over a larger geographical area than are damages that result from other natural hazards. Drought seldom results in structural damage. For these reasons the quantification of impacts and the provision of disaster relief are far more difficult tasks for drought than they are for other natural hazards.

Drought is a normal part of climate for virtually all climatic regimes. It is a temporary aberration that occurs in high as well as low rainfall areas. Drought therefore differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate. The character of drought is distinctly regional, reflecting unique meteorological, hydrological, and socioeconomic characteristics. Many people associate the occurrence of drought with the Great Plains of North America, Africa's Sahelian region, India, or Australia; they may have difficulty visualizing drought in Southeast Asia, Brazil, Western Europe, or the eastern United States, regions normally considered to have a surplus of water.

Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration in a particular area, a condition often perceived as "normal". It is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length, although other climatic factors (such as high temperatures, high winds, and low relative humidity) are often associated with it in many regions of the world and can significantly aggravate the severity of the event. Drought is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness of the rains (i.e., rainfall intensity, number of rainfall events).

Drought Types and Definitions

Because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines. Each discipline incorporates different physical, biological, and/or socioeconomic factors in its definition of drought. Because of these numerous and diverse disciplinary views, considerable confusion often exists over exactly what constitutes a drought. Research has shown that the lack of a precise and objective definition in specific situations has been an obstacle to understanding drought, which has led to indecision and/or inaction on the part of managers, policy makers, and others.[2] It must be accepted that the importance of drought lies in its impacts. Thus definitions should be impact and region specific in order to be used in an operational mode by decision makers. A universal definition of drought is an unrealistic expectation.

Drought can be grouped by type as follows: meteorological, hydrological, agricultural, and socioeconomic. *Meteorological* drought is expressed solely on the basis of the degree of dryness (often in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. *Hydrological* droughts are concerned more with the effects of periods of precipitation shortfalls on surface or subsurface water supply (stream flow, reservoir and lake levels, ground water) rather than with precipitation shortfalls. Hydrological droughts are usually out-of-phase or lag the occurrence of meteorological and agricultural droughts. The frequency and severity of hydrological drought is often defined on the basis of its influence on river basins. *Agricultural* drought links various characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and so forth. An operational definition of agricultural drought should account for the variable susceptibility of crops at different stages of crop development. *Socioeconomic* drought associates the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. This concept of drought supports the strong symbiosis that exists between drought and human activities. For example, poor land use practices such as overgrazing can reduce vegetative quality and increase soil erosion. Ultimately, this practice will lead to a reduction in animal carrying capacity, exacerbating the impacts of and vulnerability to future droughts.

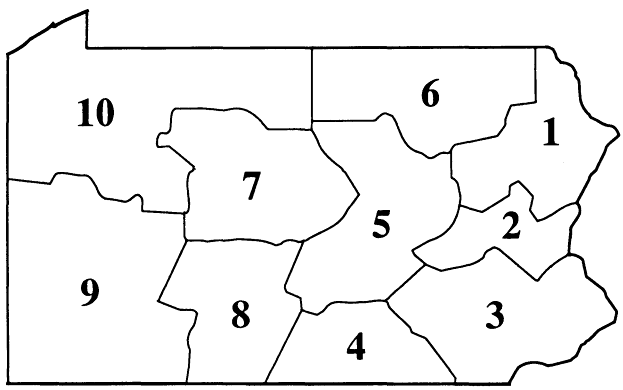
Drought Charcteristics and Severity

Droughts differ in three essential characteristics—intensity, duration, and spatial coverage. *Intensity* refers to the degree of the precipitation shortfall and/or the severity of impacts associated with the shortfall. It is generally measured by the departure of some climatic index from normal and is closely linked to duration in the determination of impact. The simplest index in widespread use is the percent of normal precipitation. With this index, actual precipitation is compared to "normal" or average precipitation (defined as the most recent 30-year mean) for time periods ranging from one to twelve or more months. Numerous other precipitation-based indices exist, such as the decile-based system used operationally in Australia for monitoring meteorological/climatological drought.[3]

The most widely used method for determining drought severity in the United States is the Palmer Drought Severity Index (PDSI).[4] The PDSI evaluates prolonged periods of abnormally wet or abnormally dry weather. It relates accumulated differences of actual precipitation to average precipitation for individual climatic regions, taking into account evapotranspiration, runoff, and soil infiltration. PDSI values generally range from +4 (extreme wetness) to −4 (extreme drought), although values above or below these thresholds are not unusual. The PDSI, which was developed in the mid-1960s, is used operationally to track moisture conditions and anomalies in the United States. It has also been used to classify and compare historical drought periods from 1895 to the present.[5]

Another distinguishing feature of drought is its *duration*. Droughts usually require a minimum of two or three months to become established but then can continue for several consecutive years. The magnitude of drought impact is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event.

Each drought has unique spatial characteristics. The percent of the total area of the contiguous United States affected by severe to extreme drought has been highly variable over the past century (Figure 1). The largest area affected by drought occurred during the 1930s—particularly 1934, when more than 65 percent of the



PDSI Value	District										
	1	2	3	4	5	6	7	8	9	10	Avg.
< -2.00	17.3	18.9	15.7	16.9	19.4	19.1	17.1	16.1	18.1	18.7	17.7
-2.00 to -2.99	1.5	1.3	0.8	1.8	4.3	3.6	3.9	2.9	2.8	3.2	2.6
-3.00 to -3.99	10.9	11.1	10.1	10.4	9.0	11.0	9.3	8.0	11.4	9.6	10.1
≤ -4.00	4.9	6.5	5.0	5.0	6.1	4.7	3.9	5.3	3.9	6.0	5.1

FIGURE 1. PDSI values for Pennsylvania, 1895-1989, for the state's ten climatic divisions.

country was experiencing severe or extreme drought. Significant areas of the United States experienced severe to extreme drought in the 1890s, 1910, 1925-26, 1953-57, 1964-65, 1976-77, 1983, and 1988-91.

From a historical perspective, the frequency of drought occurrence varies by region according to climatic regime. Wilhite and Wood[6] have shown that the greatest frequency of extreme drought (4 to 10%), according to the PDSI, occurs in the interior portion of the country, particularly states in the Great Plains, Rocky Mountains, Great Basin, and Upper Midwest.

An analysis of PDSI values for Pennsylvania for the period 1895-1989 reveals only a minor degree of east-west variation in drought frequency for the ten climatic divisions (Figure 1). For moderate to extreme drought (PDSI ≤ -2.00), PDSI values range from 19.4% in division 5 to 15.7% in division 3. The average for the state is 17.7%. Moderate (-2.00 to -2.99), severe (-3.00 to -3.99), and extreme (≤ -4.00) droughts average 2.6%, 10.1%, and 5.1%, respectively, across the State.

Figure 2 depicts a historical time series of PDSI values for the Pocono Climatic Division in northeastern Pennsylvania for the period of 1895-1989. The length of the bar above or below the zero (normal) line indicates the magnitude of dry or wet periods during this period. This time series has several noteworthy characteristics. First, wet and dry years are often clustered, such as in the years from about 1962 to current. Second, the duration of wet and dry periods in this climatic division was less from 1895 until the early 1960s. Since the early 1960s there has

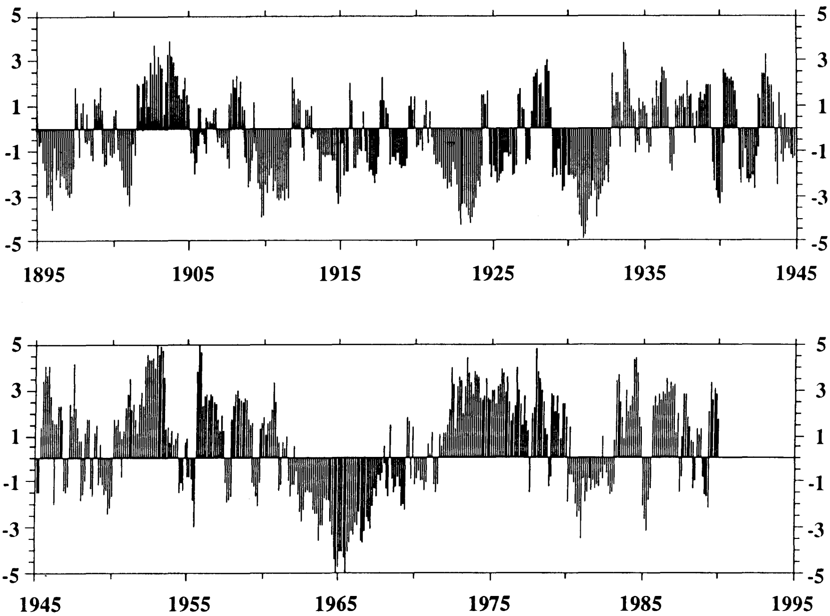


FIGURE 2. Historical time series of PDSI values for the Pocono Climatic Division, 1895-1989.

occurred one extended drought and one extended wet period. Since 1980, drought and wet periods have been of short duration and moderate intensity. Third, the drought of record for this climatic division is the period of years in the mid-1960s. Drought conditions persisted between 1962 until about 1968 with PDSI values less than -4.00 (extreme drought) during 1964-1965. The drought of record is an important concept for engineering design purposes. For most of the country, the 1930s represents the drought of record, although this will vary from one region to another.

CAUSES AND PREDICTABILITY

Empirical studies conducted over the past century have shown that drought is the result of many causes, and these are often synergistic in nature. Some of the causes may be the result of influences that originate far from the drought-affected area. In recent years, research on the role of interacting systems, or *teleconnections*, has helped explain regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics. One such teleconnection is the El Niño/Southern Oscillation (ENSO).

The immediate cause of drought is the predominant sinking motion of air (subsidence) that results in compressional warming or high pressure, thus inhibiting cloud formation and resulting in a lowered relative humidity and less precipitation. Most climatic regions experience varying degrees of dominance by high pressure, often depending on the season. Prolonged droughts occur when large-scale anomalies in atmospheric circulation patterns become established and persist for periods of months, seasons, or longer.

The underlying causes for these disruptions in large-scale atmospheric circulation patterns are not well understood. The principal causal mechanisms that have been identified are the El Niño/Southern Oscillation (ENSO), abnormal sea-surface temperature patterns, soil moisture desiccation, and nonlinear behavior of the climate system.[7] Although the occurrence of an ENSO event is principally associated with disruptions in atmospheric circulation patterns in the tropical and southern hemispheric areas of the Pacific Ocean and changes in sea-surface temperatures in the eastern and central equatorial Pacific, weather patterns are disrupted for regions well outside of the Pacific region. The recent severe ENSO event of 1982-83, for example, resulted in floods and drought worldwide. ENSO events have been related to droughts in Australia, Indonesia, India, and the United States, to name just a few locations.

The extreme drought that affected the United States and Canada during 1988 is a good example of a large-scale atmospheric circulation anomaly. This drought was one of the most extensive droughts to occur in North America in many years. A common explanation for the drought, which set up quickly in the spring and continued through most of the summer months, was the displacement of the jet stream to the north of its normal position so that storm tracks were similarly displaced.

However, to fully understand the origins of the drought, one must investigate the reasons for the displacement of the jet stream.

Several years of drought for portions of the United States preceded the extremely dry conditions of 1988. Drought conditions in the southeastern United States, along the West Coast, and in the Pacific Northwest persisted into the spring of 1988, spreading across the Prairie Provinces and the northern and midwestern portions of the United States during the spring and summer months. The West Coast drought of 1987 had been associated with the occurrence of El Niño conditions in the tropical Pacific Ocean. Associated with an El Niño event are major alterations in atmospheric circulation, which in turn result in conditions favorable to the development of an unusually strong high pressure ridge near the West Coast of the United States and lower pressure over the north Pacific Ocean. In 1987, this resulted in a split of the jet stream into two branches. The southern branch was not very active and did not result in much precipitation in southern California; the northern branch was displaced far to the north. The end product of this pattern was that the high pressure ridge blocked the passage of precipitation-producing low-pressure systems and cold fronts into the western states and the northern Great Plains states. The establishment and persistent recurrence of an atmospheric system such as a ridge of high pressure can dominate a region for a month, season, year, or period of years and thus set the stage for the persistent subsidence of air and drought.

Very little skill currently exists to predict drought for a month or more in advance. What are the prospects that these predictions can be improved significantly in the near future? The potential predictability differs by region, season, and climatic regime. Recent technological advancements make prospects somewhat better today than a decade ago for some regions, such as the tropics. Meteorologists in this area now know that a major portion of the atmospheric variability that occurs on time scales of months to several years is associated with variations in tropical sea surface temperatures. But significant advancements beyond what has been achieved will require major breakthroughs in the use of dynamical models that couple the ocean-atmosphere systems. Meteorologists do not believe that highly skilled forecasts are attainable for all regions a season or more in advance.

THE IMPACTS OF DROUGHT

Drought impacts are often referred to as direct or indirect, or they are assigned an order of propagation (i.e., first-, second-, or third-order). Conceptually speaking, the more removed the impact from the cause, the more complex the link to the cause. In other words, a loss of yield resulting from drought is a direct or first-order impact of drought, but the consequences of that impact, such as loss of income, farm foreclosures, outmigration, and government relief programs, are secondary or tertiary impacts. First-order impacts are usually of a biophysical nature; higher-order impacts are usually associated with socioeconomic valuation, adjustment responses, and long-term "change".

The impacts of drought can be classified into three principal types: economic, environmental, and social (Table 1). Economic impacts range from direct losses in the broad agricultural and agriculturally related sectors, including forestry and fishing, to losses in recreation, transportation, banking, and energy sectors. Other economic impacts include added unemployment and loss of revenue to local, state, and federal government. Environmental losses are the result of damages to plant and animal species, wildlife habitat, and air and water quality; forest and range

TABLE 1.

Economic, environmental, and social impacts of drought.

Problem Sectors	Impacts
Economic	• loss from dairy and livestock production reduced productivity of range land forced reduction of foundation stock closure/limitation of public lands to grazing high cost/unavailability of water for livestock high cost/unavailability of feed for livestock increased predation range fires
	• loss from crop production damage to perennial crops; crop loss reduced productivity of crop land (wind erosion, etc.) insect infestation plant disease wildlife damage to crops
	• loss from timber production forest fires tree disease insect infestation impaired productivity of forest land
	• loss from fishery production damage to fish habitat loss of young fish due to decreased flows
	• loss from recreational businesses
	• loss to manufacturers and sellers of recreational equipment
	• loss to energy industries affected by drought-related power curtailments
	• loss to industries directly dependent on agricultural production (e.g., fertilizer manufacturers, food processors, etc.)
	• unemployment from drought-related production declines
	• strain on financial institutions (foreclosures, greater credit risks, capital shortfalls, etc.)
	• revenue losses to State and local governments (from reduced tax base)
	• revenues to water supply firms revenue shortfalls windfall profits
	• loss from impaired navigability of streams, rivers and canals
	• cost of water transport or transfer
	• cost of new or supplemental water source development

TABLE 1 *(continued)*

Problem Sectors	Impacts
Environmental	• damage to animal species wildlife habitat lack of feed and drinking water disease vulnerability to predation (e.g., from species concentration near water) • damage to fish species • damage to plant species • water quality effects (e.g., salt concentration) • air quality effects (dust, pollutants) • visual and landscape quality (dust, vegetative cover, etc.)
Social	• public safety from forest and range fires • health-related low flow problems (e.g., diminished sewage flows, increased pollutant concentrations, etc.) • inequity in the distribution of drought impacts/relief

fires; degradation of landscape quality; and soil erosion. These losses are difficult to quantify, but growing public awareness and concern for environmental quality has forced public officials to focus greater attention on these effects. Social impacts involve public safety, health, conflicts between water users, and inequities in the distribution of impacts and disaster relief programs.

Because of the number of affected groups and sectors associated with drought, the geographic size of the area affected, and the problems associated with quantifying environmental damages and personal hardships, the precise determination of the financial costs of drought is difficult. Although drought occurs somewhere in the country each year, *significant* or *major* episodes often occur in clusters. Therefore, direct and indirect losses may be extremely large for one or two consecutive years and then negligible for several years. The impacts of the 1988 drought in the United States have been estimated at nearly $40 billion.[8]

DROUGHT RESPONSE AND PREPAREDNESS

With the occurrence of any natural disaster come appeals for disaster assistance from the affected area. During the twentieth century, governments have typically responded to drought by providing emergency, short-term, and long-term assistance to distressed areas. Emergency and short-term assistance programs are often reactive, a kind of "Band-Aid" approach to more serious land and water management problems. Scientists, government officials, and recipients of relief have long criticized this approach as inefficient and ineffective. Long-term assistance programs are far fewer in number, but they are proactive. They attempt to lessen a region's vulnerability to drought through improved management and planning.

Governmental response to drought includes a wide range of potential actions to deal with the impacts of water shortages on people and various economic sectors. In the United States, agencies of the federal government and Congress typically respond by making massive amounts of relief available to the affected areas, mostly in the form of short-term emergency measures to agricultural producers, such as feed assistance for livestock, drilling of new wells, and low-interest farm operating loans. This reactive approach to natural disasters is commonly referred to as crisis management. In crisis management the time to act is perceived by decision makers to be short. Emergency relief programs do little if anything to reduce vulnerability to drought and may in fact increase vulnerability in the long term.

Research has demonstrated that reaction to crisis often results in the implementation of hastily prepared assessment and response procedures that lead to ineffective, poorly coordinated, and untimely response. An alternative approach is to initiate planning between periods of drought, thus developing a more coordinated response that might more effectively address longer-term issues and specific problem areas. Also, the limited resources available to government to mitigate the effects of drought could be allocated in a more beneficial manner. But because drought is not as well-defined as other natural disasters, governments have been less inclined to invest resources to develop well-conceived mitigation programs and contingency plans. Until recently, States have traditionally played a passive role in drought assessment and response efforts, relying largely on the federal government to come to their rescue during periods of severe water shortages.

Drought Planning

To improve society's level of preparedness to future droughts, contingency plans can be developed by governments to improve the efficiency of assessment and response efforts. Drought planning is defined as actions taken by individual citizens, industry, government, and others in advance of drought for the purpose of mitigating some of the impacts and conflicts associated with its occurrence. From an institutional or governmental perspective, drought planning should include, but is not limited to, the following activities:

1. Creation of a monitoring/early warning system to provide decision makers at all levels with information about the onset, continuation, and termination of drought conditions and their severity.
2. Establishing operational assessment programs to reliably determine the likely impact of the drought event in a timely manner.
3. Formulate an institutional structure for coordinating governmental actions, including information flow within and between levels of government, and criteria and procedures for drought declaration and revocation.
4. Establish appropriate drought assistance programs (both technical and relief) with predetermined eligibility and implementation criteria.
5. Allocate financial resources to maintain operational programs and to initiate research required to support drought assessment and response activities.

6. Initiate educational and public awareness programs designed to promote an understanding and adoption of appropriate drought mitigation and water conservation strategies among the various economic sectors most affected by drought.

To be successful, drought planning must be integrated between levels of government, involving regional organizations and the private sector as appropriate.

Drought Policy and Planning Objectives

Before a drought contingency plan is prepared, government officals should formulate a drought policy to define what they hope to achieve with that plan.[9] The objectives of a drought *policy* differ from those of a drought *plan.* A drought *policy* will be broadly stated and should express the purpose of government involvement in drought assessment, mitigation, and assistance programs. Drought *plan* objectives are more specific and action-oriented.

The objectives of drought policy should encourage or provide incentives for agricultural producers, municipalities, and other water-dependent sectors or groups to adopt appropriate and efficient management practices that help to alleviate the effects of drought. Past relief measures have, at times, discouraged the adoption of appropriate management techniques. Assistance should also be provided in an equitable, consistent, and predictable manner to all without regard to economic circumstances, industry, or geographic region. Assistance can be provided in the form of technical aid or relief measures. Whatever the form, those at risk would know what to expect from government during drought and thus would be better prepared to manage risks. At least one objective should also seek to protect the natural and agricultural resource base. Degradation of these resources can result in spiraling economic, environmental, and social costs.

One question that government officials must address is the purpose and role of government involvement in drought mitigation efforts. Other questions should address the scope of the plan and identify geographic areas, economic sectors, and population groups that are most at risk; principal environmental concerns; and potential human and financial resources to invest in the planning process. Answers to these and other questions should help to determine the objectives of drought policy and therefore provide a focus for the drought planning process.

IMPEDIMENTS TO DROUGHT PLANNING

As a first step, government officials may have to identify the principal obstacles or impediments to drought planning. Some common impediments include an inadequate understanding of drought, uncertainty about the economics of preparedness, lack of skill in drought prediction, variability in societal vulnerability to drought, information gaps and insufficient human resources, inadequate scientific base for water management, and difficulties in identifying drought impact sensitivities and adaptations.

In the United States, the most significant impediments to drought planning are an inadequate understanding of drought and uncertainty about the economics of preparedness.[9,10] Drought is often viewed by government officials as an extreme event that is, implicitly, rare and of random occurrence, and they may not be convinced that the expense of planning is justified. But officials must understand that droughts, like floods, are a normal feature of climate, and their recurrence is inevitable. Planning, if undertaken properly and implemented during nondrought periods, can improve governmental ability to respond in a timely and effective manner during periods of water shortage. Thus, planning can mitigate and, in some cases, prevent some impacts while reducing physical and emotional hardship. Planning should also be a dynamic process that reflects socioeconomic, agricultural, and political trends. Conversely, post-drought evaluations have shown assessment and response efforts of state and federal governments with a low level of preparedness to be largely ineffective, poorly coordinated, untimely, and economically inefficient. Unanticipated expenditures for drought relief programs can also be devastating to State and national budgets. For example, during the droughts of the mid-1970s in the United States, specifically 1974, 1976, and 1977, the federal government spent more than $7 billion on drought relief programs.[11] The federal government has expended similar amounts during subsequent drought periods.

Drought plans should be incorporated into general natural disaster and/or water management plans wherever possible. This would reduce the cost of drought preparedness substantially. Politicians and many other decision makers simply must be better informed about drought, its impacts, and alternative management approaches and how existing information and technology can be used more effectively to reduce the impact of drought at a relatively modest cost.

STATUS OF DROUGHT PLANNING IN THE UNITED STATES

Governments worldwide have shown increased interest in drought planning since the early 1980s. Several factors have contributed to this interest. First, the widespread occurrence of severe drought over the past several decades and, specifically, the years during and following the extreme ENSO event of 1982-83 focused attention on the vulnerability of all nations to drought. Second, the costs associated with drought are now better understood by government. These costs include not only the direct impacts of drought, but also the indirect costs (i.e., personal hardship, the costs of response programs, and accelerated environmental degradation). Nations can no longer afford to allocate scarce financial resources to short-sighted response programs that do nothing to mitigate the effects of future droughts. Finally, the intensity and frequency of extreme meteorological events such as drought are likely to increase, given projected changes in climate associated with increasing concentrations of CO_2 and other atmospheric trace gases.

Governmental interest in and progress toward the development of drought plans has increased significantly in the United States in the past decade. The greatest progress has been made at the State level, although contingency plans are also being prepared at the local level by municipalities and at the regional level for river basins by the U.S. Army Corps of Engineers and other organizations such as the Delaware River Basin Commission.[12] In 1982, three States had developed drought plans: South Dakota, Colorado, and New York. At present, twenty-three States have drought plans (Figure 3). These plans differ considerably in their structure and comprehensiveness, but at least these States have taken a first step to address the unique and complicated assessment and response problems associated with drought. The goal of these plans is to reduce the direct and indirect impacts of drought, lessen the need for government relief programs, and ultimately minimize societal vulnerability.

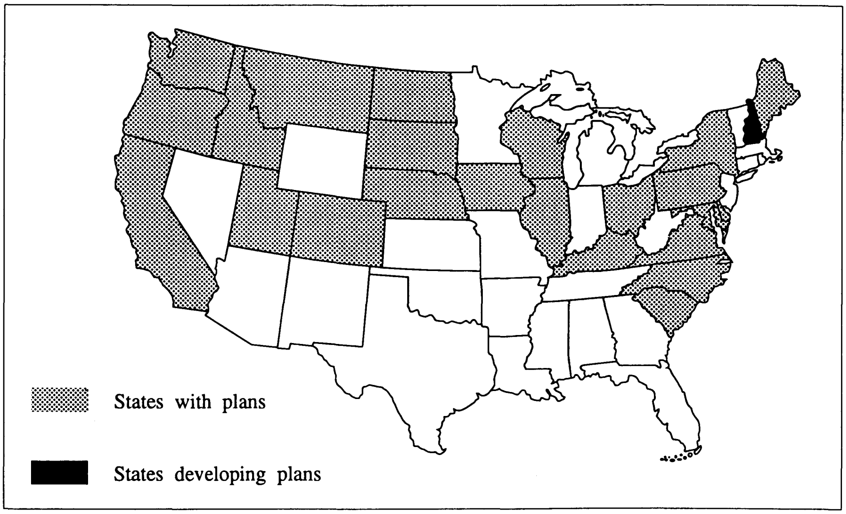


FIGURE 3. Status of drought planning. 1991.

CONCLUSIONS

Drought is a pervasive natural hazard that is a normal part of the climate of virtually all regions. It should not be viewed as merely a physical phenomenon. Rather, drought is the result of an interplay between a natural event and the demand placed on water supply by human-use systems. Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration.

Many definitions of drought exist; it is unrealistic to expect a universal definition to be derived. Drought can be grouped by type or disciplinary perspective as follows: meteorological, hydrological, agricultural, and socioeconomic. Each discipline incorporates different physical, biological, and/or socioeconomic factors in its definition. It must be accepted that the importance of drought lies in its impacts. Thus, definitions should be impact- and region-specific in order to be used in an operational mode by decision makers.

The three characteristics that differentiate one drought from another are intensity, duration, and spatial extent. Intensity refers to the degree of precipitation shortfall and/or the severity of impacts associated with the departure. Intensity is closely linked with the duration of the event. Droughts normally take two to three months to become established but may then persist for months or years, although the intensity and spatial character of the event will change from month to month or season to season.

Drought is the result of many causes, which may be synergistic in nature. Some of the causes may be the result of influences that originate far from the drought-affected area. Prolonged droughts occur when large-scale anomalies in atmospheric circulation patterns become established and persist for periods of months, seasons, or longer. Recent droughts in the United States (1988-90) are a good example.

The skill to predict meteorological drought for a month or season in advance is very limited. The potential for improved forecasts differs by region, season, and climatic regime. Significant advances have been made in understanding the climate system in the tropics. Much of this improvement is the result of a better understanding of the fact that a major portion of atmospheric variability which occurs on time scales of months to several years is associated with variations in tropical sea surface temperatures. In the extratropical regions, current long-range meteorological forecasts are of very limited skill and are not likely to improve significantly in the next decade.

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.

Government response to drought includes a wide range of potential actions to deal with the impacts of water shortages on people and various economic sectors. The types of actions taken will vary considerably between developed and developing countries and from one region to another. Few, if any, actions of government attempt to reduce long-term vulnerability to the hazard. Rather, assistance or relief programs are reactive and address only short-term, emergency needs; they are intended to reduce the impacts and hardships of the present drought.

Developing a drought policy and contingency plan is one way that governments can improve the effectiveness of future response efforts. A drought policy will be broadly stated and should express the purpose of government involvement in drought assessment, mitigation, and response programs. Drought plan objectives are more specific and action oriented and will differ between levels of government. The development of a drought contingency plan results in a higher level of preparedness that can mitigate and, in some cases, prevent some impacts while reducing physical and emotional hardship. An increasing number of governments in the United States and elsewhere are now developing policies and plans to reduce the impacts of future periods of water shortage associated with drought.

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