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Drought

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Scores of definitions of drought exist, reflecting different applications and regions of concern. Common to all types of drought is the fact that they originate from a deficiency of precipitation that results in water shortage for some activity (e.g., plant growth, transportation) or some group (e.g., farmer, water suppliers). Drought can be defined as a deficiency of precipitation from expected or "normal" that, when extended over a season or longer period of time, is insufficient to meet the demands of human activities. Drought must be considered a relative, rather than absolute, condition. The ultimate results of these precipitation deficiencies are, at times, enormous economic and environmental impacts as well as personal hardship. Scientists speculate that the frequency and severity of droughts may increase if projected changes in climate occur because of increasing concentrations of CO_2 and other atmospheric trace gases.

I. Introduction

Throughout human history, drought has been a threat to our existence, often altering the course of history itself. Drought should not be viewed as merely a physical phenomenon. It is the result of an interplay between a natural event (precipitation deficiencies due to natural climatic variability on varying time scales) and the demand placed on water supply by human-use systems. Literature is replete with references showing how extended periods of drought have resulted in food supply disruptions, famine, massive migrations of people, and wars. In the United States, for example, the droughts of the 1890s and 1930s significantly altered the settlement of the western frontier.

The impact of drought is often exacerbated by human beings. The earth's rapidly expanding population is placing an ever-increasing demand on local and regional water resources and, in many areas, accelerating environmental degradation. In the past several decades we have been continuously besieged by reports of drought and its impacts on natural and anthropogenic ecosystems. 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.

II. Drought: An Overview

Drought differs from other natural hazards (e.g., floods, hurricanes, earthquakes) in several ways. First, it is a "creeping phenomenon," making its onset and end difficult to determine. The effects of drought accumulate slowly over a considerable period of time and may linger for years after the termination of the event. 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. 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 is a far more difficult task for drought than it is 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 (such as the 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).

A. Definitions and Types of Drought

Because drought affects so many economic and social sectors, scores of definitions have been developed by a variety of disciplines. In addition, because drought occurs with varying frequency in nearly all regions of the globe, in all types of economic systems, and in developed and developing countries alike, the approaches taken to define it also reflect regional differences as well as differences in ideological perspectives. Impacts also differ spatially and temporally, depending on the societal context of drought. A universal definition of drought is an unrealistic expectation.

Definitions of drought can be categorized broadly as either conceptual or operational. Conceptual definitions are of the "dictionary" type, generally defining the boundaries of the concept of drought and thus are very generic in their description of the phenomenon. Operational definitions attempt to identify the onset, severity, and termination of drought episodes. Definitions of this type are often used in an "operational" mode to detect the onset, continuation, severity, and termination of drought. These definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. An operational definition of agricultural drought might be one that compares daily precipitation to evapotranspiration (ET) rates to determine the rate of soil-water depletion and then expresses these relationships in terms of drought effects on plant behavior at various stages of development. The effects of these meteorological conditions on plant growth would be reevaluated continuously by agricultural specialists as the growing season progresses.

Many disciplinary perspectives of drought exist. 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. It must be accepted that the importance of drought lies in its impacts. Thus definitions should be impact and region specific to be used in an operational mode by decision makers.

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. For example, some definitions of meteorological drought differentiate periods on the basis of the number of days with precipitation less than some specified threshold. Extended periods without rainfall are common for many regions; such a definition is unrealistic in this case. Other definitions may relate actual precipitation departures to average amounts on monthly, seasonal, or annual time scales. Definitions derived for application to one region but applied to another often create problems, since meteorological characteristics differ. Human perceptions of these conditions are equally variable. Both of these points must be taken into account to identify the characteristics of drought and make comparisons between regions.

Hydrological droughts are concerned more with the effects of periods of precipitation shortfalls on surface or subsurface water supply (such as 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. Meteorological droughts result from precipitation deficiencies while agricultural droughts are largely the result of soil moisture deficiencies. More time elapses before precipitation deficiencies show up in components of the hydrological system. As a result, impacts are out of phase with those in other economic sectors. Also, water in hydrological storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes, further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought, and conflicts between water users increase significantly.

The frequency and severity of hydrological drought is often defined on the basis of its influence on river basins. Since low-flow frequencies have been determined for most streams, hydrological drought periods can be of any specified length. If the actual flow for a selected time period falls below a certain threshold, then hydrological drought is considered to be in progress. However, the number of days and the level of probability that must be exceeded to define a hydrological drought period is somewhat arbitrary. These criteria will vary between streams and 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. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. An operational definition of agricultural drought should account for the variable susceptibility of crops at different stages of crop development. For example, deficient subsoil moisture in an early growth stage will have little impact on final crop yield if topsoil moisture is sufficient to meet early growth requirements. However, if the deficiency of subsoil moisture continues, a substantial yield loss may result.

Finally, socioeconomic drought associates the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. Some scientists suggest that the time and space processes of supply and demand are the two basic processes that should be included in an objective definition of drought. For example, the supply of some economic good (such as water, hay, electric power) is weather dependent. In most instances, the demand for that good is increasing as a result of increasing population or per capita consumption. Therefore, drought could be defined as occurring when the demand exceeds supply as a result of a weather-related supply shortfall. 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 decrease animal carrying capacity and increase soil erosion, which exacerbates the impacts of and vulnerability to future droughts.

B. Drought Characteristics 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 12 or more months. One of the principal difficulties with this approach is the choice of the threshold of precipitation deficiency (e.g., 75% of normal) to define the onset of drought. Thresholds are usually chosen arbitrarily, but they should be linked to impact. Actual precipitation departures are normally compared to expected or average amounts on a monthly, seasonal, annual, or water year (October–September) time period.

The most widely used method for determining drought severity in the United States is the Palmer Drought Severity Index (PDSI). Developed in the mid-1960s, the PDSI is a meteorological index that evaluates prolonged periods of abnormally wet or abnormally dry weather. The index can be thought of as a hydrological accounting system. The input to the system is precipitation. Outputs include evapotranspiration, runoff, soil infiltration, and deep percolation through the soil layer to the ground water. The PDSI relates accumulated differences of actual precipitation to evapotranspiration, runoff, and soil infiltration to average precipitation for individual climatic regions. PDSI values generally range from +4 (extreme wetness) to –4 (extreme drought), although values above or below these thresholds are not unusual. For example, during the severe drought of 1976–1977 in the United States, PDSI values exceeded –4 for extended periods of time for portions of the Pacific Northwest and the upper Midwest. The PDSI has been used to classify and compare historical drought periods from 1895 to the present.

Another distinguishing feature of drought is its duration. Droughts usually require a minimum of two to three months to become established but then can continue for several consecutive years. The magnitude of drought impacts is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event. An analysis of the sequence of monthly PDSI values for southeast Nebraska from 1931 to 1978 indicates seven drought periods exceeding 10 months in length. These occurred in the 1930s, 1950s, and 1970s. The duration of the longest drought in that period of record began in May 1936 and extended through August 1941, sixty-four consecutive months of PDSI values below –1.0. During that drought period, 61 months were calculated to have had PDSI values less than –2.0 (moderate drought). Of these 61 months, 21 and 24 months, respectively, were in the extreme (–4.0) and severe (–3.0) category.

Droughts of equal and longer duration are common in the Great Plains. Unfortunately, weather records for this region seldom exceed 100 years. To ascertain a clearer picture of the occurrence of drought over the last several hundred years, scientists must rely on other sources of data to extend the weather record. The most notable source of data is tree rings. Trees respond to wet or dry periods by producing wider or narrower growth rings. These growth rings are calibrated with weather records and then extended back in time. Early studies of tree rings taken from samples in western Nebraska back to nearly A.D. 1200 reveal numerous drought episodes ranging in length from five to 38 years. More recent studies conducted by scientists at the University of Arizona's Laboratory of Tree-Ring Research confirm drought as a normal part of the western United States' climate back to A.D. 1700.

Each drought has unique spatial characteristics. The percentage of the total area of the contiguous United States affected by severe to extreme drought has been highly variable over the past century (fig. 1). The largest area affected by drought occurred during the 1930s—particularly 1934, when more than 65% of the country was experiencing severe or extreme drought. Using the percent of total area to define major drought episodes, significant areas were also affected in the 1890s, 1910, 1925–1926, 1953–1957, 1964–1965, 1976–1977, 1983, and 1988–1990.

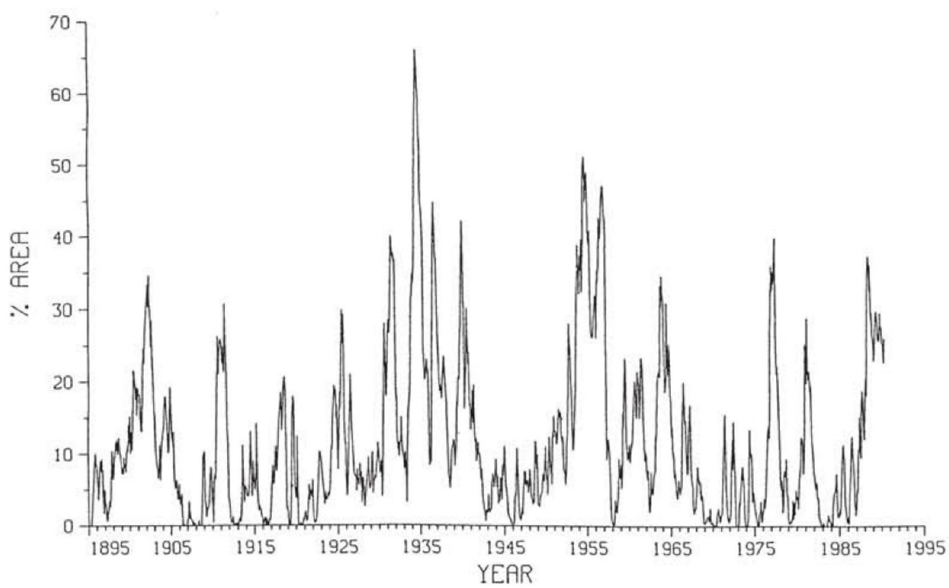

Figure 1. Percentage of the area of the contiguous United States affected by severe to extreme drought, 1895–1990.

The spatial dimensions of several major drought episodes of this century in the United States illustrate the uniqueness of each drought. The drought years of the 1930s, commonly referred to as the Dust Bowl or dirty thirties, affected nearly all parts of the United States to some degree during the decade. The most widespread drought conditions occurred in 1934 and 1936. The 1934 drought was concentrated primarily in the northern part of the country, extending from New York to the West Coast. A significant area of prolonged drought also occurred in the southern Great Plains states. During 1936 the principal drought area was concentrated mainly in the northern and central Great Plains. By contrast, the pattern of extreme drought in July 1956 was centered mainly in the Southwest and in the southern and central Great Plains states.

In 1976–1977 the far western, northern Great Plains, and upper midwestern states were most seriously affected. Although this drought equaled previous droughts in intensity for some parts of the United States, neither duration nor spatial extent was comparable. The very recent severe drought of 1988 (fig. 2) was somewhat similar in spatial extent to the drought of 1976–1977, concentrating in the far western and upper midwestern states. In addition, it also affected significant portions of the northern plains and Corn Belt states. This drought continued into 1989, with the principal area affected extending from the western Corn Belt through the Central Rocky Mountain states to California. The western half of the United States continued to be affected through the summer of 1990, with California being the hardest hit. The southeastern portion of the country was also affected in 1990.

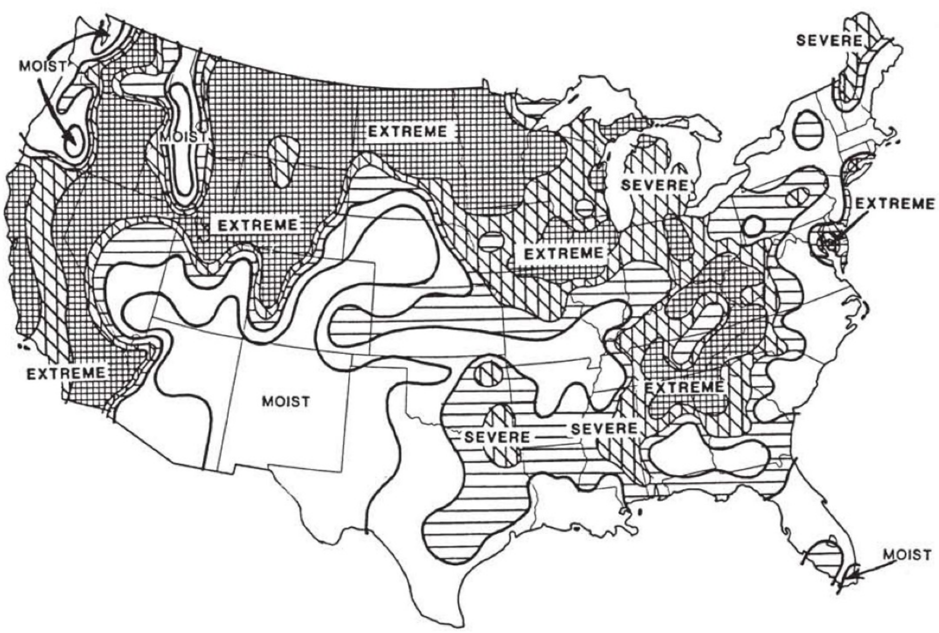

Figure 2. The pattern of drought severity in the United States (July 23, 1988) according to the Palmer Drought Severity Index.

III. Causes and Predictability

Empirical studies conducted over the past century have shown that drought is never the result of a single cause. Rather, it 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. A great deal of research has been conducted in recent years on the role of interacting systems or *teleconnections* in explaining 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. For regions under the influence of semi-permanent high pressure during all or a major portion of the year, desert (arid) conditions result (e.g., Sahara and Kalahari of Africa, Gobi desert of Asia). Most climatic regions, however, 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 extreme drought that affected the United States and Canada during 1988 is a good example of a large-scale atmospheric circulation anomaly.

The drought of 1988 was one of the most extensive droughts to occur in North America in many years. During the peak of the drought in July, nearly 40% of the contiguous states and a substantial portion of the Prairie Provinces of Canada were experiencing severe to extreme drought. In addition, another 30% of the United States was experiencing moderate drought conditions. Figure 2 illustrates the extent of the drought in the United States during late July 1988. Because of the complexity of the temporal and spatial pattern represented in this illustration, the origins of drought cannot be traced to a single cause. A common explanation for the drought that 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. The southeastern United States, for example, had experienced a severe to extreme drought during 1986, the beginning of which can be traced to the fall of 1985. In the spring of 1987, drought conditions continued in the southeast and had also developed along the West Coast and in the Pacific Northwest. These conditions 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, connecting the substantial drought areas of the west and southeast that had existed before the spring.

The West Coast drought of 1987 was associated with the occurrence of El Nino conditions in the tropical Pacific Ocean. Associated with an El Nino event are major alterations in atmospheric circulation, which in tum 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 jet stream. The southerly branch was not very active and did not result in much precipitation in southern California; the northerly 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. In the tropics, for example, meteorologists have made significant advances in their understanding of the climate system. Specifically, it is now known 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. Major global meteorological experiments are underway to investigate these questions further. An improvement in the predictability of ENSO episodes, for example, would have a profound influence on seasonal predictions in the tropics. To date, empirical relationships have been developed for some tropical and near-tropical regions such as the Indian Peninsula and Australia. Significant advancements beyond what has been achieved will require major breakthroughs in the use of dynamical models that couple the ocean-atmosphere systems.

In the extratropical regions, current long-range forecasts are of very limited skill. The National Weather Service of the United States periodically issues 30-day and 90-day forecasts of temperature and precipitation for regions north of 30°N latitude. The skill that does exist is primarily the result of empirical and statistical relationships. In the tropics, empirical relationships have been demonstrated to exist between precipitation and ENSO events, but few such relationships have been confirmed above 30°N. Therefore, meteorologists do not believe that highly skilled forecasts are attainable for all regions a season or more in advance.

IV. Impacts of Drought

The impacts of drought are diverse and often ripple through the economy. Thus, 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. However, the consequences of that impact (e.g., loss of income, farm foreclosures, outmigration, government relief programs) are secondary or tertiary impacts. First-order impacts are usually of a biophysical nature, whereas higher-order impacts are usually associated with socioeconomic valuation, adjustment responses, and long-term "change."

Because of the number of affected groups and sectors associated with drought, the geographic size of the area affected, and the difficulties connected with quantifying environmental damages and personal hardships, the precise determination of the financial costs of drought is an arduous task. Scientists have estimated the direct losses of drought in the United States to be on the order of $1.2 billion annually. Although drought occurs somewhere in the country each year, such figures are misleading since 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. Government estimates of recent losses associated with the droughts of 1976–1977 and 1988 were $36 billion and $40 billion, respectively. These estimates include direct losses broadly grouped into foodstuffs, transportation, energy, production, and sales.

The impacts of drought can be classified into three principal areas: economic, environmental, and social. Table I presents a simplified illustration of the impacts associated with each of these areas. 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 would 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 fires; degradation of landscape quality; and soil erosion. Although these losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention on these effects. Social impacts mainly involve public safety, health, conflicts between water users, and inequities in the distribution of impacts and disaster relief programs.

Table I. Classification of Drought-Related Impacts

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 cropland (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 (fertilizer manufacturers, food processors, etc.)
	Unemployment from declines in drought-related production
	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
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 (diminished sewage flows, increased pollutant concentrations, etc.)
	Inequity in the distribution of drought impacts/relief

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.

V. 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. Actions of this type have long been criticized by scientists and government officials, as well as by recipients of relief, 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. Most of this relief is 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. Few, if any, of these assistance measures in recent years have been aimed at reducing future vulnerability. The drought program passed by the U.S. Congress in April 1977 is a good example (Table II). The intent of this program was to reduce the immediate, short-term effects of drought. The president's proposed program totaled $943.8 million; however, Congress appropriated only $843.8 million of that requested. In the 1974–1977 drought period, the federal government provided in excess of $7 billion in relief, principally to the agricultural sector. An additional $6 billion was provided in 1988. 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.

Table II. President Carter's Proposed Drought Program, 23 March 1977

Title	Purpose/description	Amount ($)
Emergency Loans Program (FmHA)	5% loans to cover prospective losses to farmers and ranchers	100,000,000
Community Program Loans (FmHA)	$150 million in 5% loans and $75 million in grants to communities of less than 10,000 for emergency water supplies	225,000,000
Emergency Conservation Measures Program (ASCS)	Soil conservation cost-sharing grants	100,000,000
FCIC Insurance	Increase in FCIC Capital Stock	100,000,000
Drought Emergency Program (BuRec)	Creation of water bank, protection of fish and wildlife, grants to states, 5% for water supply and conservation measures	100,000,000
Emergency Fund (BuRec)	Emergency irrigation loans	30,000,000
Emergency Power (SWPA)	Purchase of emergency power supply	13,800,000
Community Emergency Drought Relief Program (EDA)	$150 million in 5% loans and $75 million in grants to communities of more than 10,000 for emergency water supply	225,000,000[a]
Physical Loss and Economic Injury Loans (SBA)	Low-interest loans for small businesses (including farmers)	50,000,000[b]
	Total requested	943,800,000
	Total appropriated	843,800,000

a. Only $175 million of this amount was finally appropriated.

b. Action on this proposal resulted in the lowering of interest rates for physical loss and economic injury loans (both ongoing, funded programs) but none of the additional appropriation originally requested was granted.

Because of the unique character of drought, governments have been less inclined to invest resources to develop well-conceived mitigation programs and contingency plans. 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. 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.

A. Drought Planning

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. 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. Operational assessment programs to reliably determine the likely impact of the drought event in a timely manner.
3. An institutional structure for coordinating governmental actions, including information flow within and between levels of government, and drought declaration and revocation criteria and procedures.
4. Appropriate drought assistance programs (both technical and relief) with predetermined eligibility and implementation criteria.
5. Financial resources to maintain operational programs and to initiate research required to support drought assessment and response activities.
6. 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.

B. Drought Policy and Planning Objectives

Before the development of a contingency plan for more effectively assessing and responding to drought, government officials should first define what they hope to achieve by that plan. Thus, a drought policy statement should be prepared in advance of a plan. The objectives of a drought *policy* differ from those of a drought *plan.* A clear distinction of these differences must be made at the outset of the planning process. 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. Typically, the objectives of drought policy have *not* been stated explicitly by government. What generally exists is a *de facto policy*, one defined by the most pressing needs of the moment. Ironically, under these circumstances, it is the specific instruments of that policy (i.e., assistance measures), particularly at the federal level, that define the objectives of the policy.

The objectives of drought policy will differ between levels of government. Generally speaking, these objectives 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. An 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.

To develop drought policy objectives government officials should consider many questions. A basic question that must be addressed 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. The principal environmental concerns must also be identified. Government officials must also determine what human and financial resources are available to invest in the planning process. Answers to these and other questions should help to determine the objectives of drought policy and therefore focus the drought planning process.

C. Impediments to Drought Planning

Identifying the principal obstacles or impediments to drought planning may be the first step in any attempt to initiate the development of a drought plan. 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. Drought is often viewed by government officials as an extreme event that is, implicitly, rare and of random occurrence. Officials must understand that droughts, like floods, are a normal feature of climate. Their recurrence is inevitable. Drought manifests itself in ways that span the jurisdiction of numerous bureaucratic organizations (agricultural, water resources, health, and so forth) and levels of government (e.g., federal, state, and local). Competing interests for scarce government resources and institutional rivalry impede the development of concise drought assessment and response initiatives. To solve these problems, policy makers and bureaucrats, as well as the general public, must be educated about the consequences of drought and the advantages of preparedness. Drought planning requires input by several disciplines, and decision makers must play an integral role in this process.

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. This, in turn, could improve the constituents' perception of government. Planning should also be a dynamic process that reflects socioeconomic, agricultural, and political trends.

It is sometimes difficult to determine the benefits of drought planning versus the costs of drought. There is little doubt that drought preparedness requires financial and human resources that are, at times, scarce. This cost has been and will continue to be an impediment to the development of drought plans. Preparedness costs are fixed and occur now, while drought costs are uncertain and will occur later. Further complicating this issue is the fact that the costs of drought are not solely economic. They must also be stated in terms of human suffering and the degradation of the physical environment, items whose values are inherently difficult to estimate.

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. The federal government has expended similar amounts during subsequent drought periods. Between 1970 and 1984, state and federal government in Australia expended nearly $1 billion on drought relief. The Republic of South Africa has spent approximately $1.5 billion for drought relief in the past decade. When compared to these expenditures, a small investment in mitigation programs in advance of drought would seem to be a sound economic decision.

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.

D. Status of Drought Planning

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 1982–1983 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. Droughts are a climatic certainty and recent events worldwide have highlighted the importance of preparing now for future episodes. From an institutional point of view, learning today to deal more effectively with climatic events such as drought may serve us well in preparing proper response strategies to long-term climate-related issues.

Governmental interest in and progress toward the development of drought plans worldwide has increased significantly in the past decade. The greatest progress has been made at the state level in the United States. In 1982, three states had developed drought plans: South Dakota, Colorado, and New York. At present, 23 states have drought plans. 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. Considerable progress is also being made in Canada, Brazil, Australia, and many drought-prone African countries.

The challenge of changing the perception of policy makers and scientists worldwide about drought is a formidable one. The typical mode of operation for government in dealing with natural hazards is crisis management. It is indeed a difficult task for government to engage in long-range planning. However, the progress made toward planning in recent years demonstrates a new awareness and improved understanding of drought and its impacts on individual citizens, economic development, and the environment.

VI. 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 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 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 has 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 (1988–1991) 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 that 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 hardship 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.

Bibliography

Glantz, M. H., ed. (1987). "Drought and Hunger in Africa: Denying Famine a Future." Cambridge Univ. Press, New York.

Karl, T. R., Quinlan, F. T., and Ezell, D. S. (1987). Drought termination and amelioration: Its climatological probability. *J. Clim. Appl. Meteorol.* 26, 1198–1209.

Klemeš, V. (1987). Drought prediction—A hydrological perspective. *In* "Planning for Drought: Toward a Reduction of Societal Vulnerability" (D. A. Wilhite and W. E. Easterling, eds.), pp. 81–94. Westview Press, Boulder, Colorado.

Riebsame, W. E., Changnon, S. A., and Karl, T. R. (1990). "Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987–90 Drought." Westview Press, Boulder, Colorado.

Wilhite, D. A., and Easterling, W. E., eds. (1987). "Planning for Drought: Toward a Reduction of Societal Vulnerability." Westview Press, Boulder, Colorado.

Wilhite, D. A., and Glantz, M. H. (1985). Understanding the drought phenomenon: The role of definitions. *Water International* 10, 111–120.

Wilhite, D. A., Rosenberg, N. J., and Glantz, M. H. (1986). Improving federal response to drought. *J. Clim. Appl. Meteorol.* 25(3), 332–342.

Glossary

El Niño. Invasion of warm surface water from the western equatorial part of the Pacific Basin to the eastern equatorial region and along the west coast of South America. El Niño events occur about twice every ten years, although the interval between two events is irregular.

ENSO. Combination of El Niño and Southern Oscillation events.

Evapotranspiration (ET). Total process of water transfer into the atmosphere by transpiration from vegetation and evaporation from the soil surface.

Jet stream. Strong zonal current of air, usually near the 500-mbar constant pressure surface in each hemisphere, that encircles the earth. Referred to as the jet stream because of its high concentration and great speed, often up to 500 km h^{-1}

Southern Oscillation. Out-of-phase relationship between atmospheric pressure over the southeast Pacific and the Indian Ocean. When pressure is high in the Indian Ocean, it is lower than usual in the south Pacific Ocean. Rainfall varies in the opposite direction. The Southern Oscillation is closely linked to El Niño events and was first observed during the latter part of the nineteenth century.

Teleconnections. Regional or global patterns of atmospheric variability that reappear with considerable frequency in roughly the same form and often persist or recur throughout a month or season. ENSO is a good example of a teleconnection.