

1987

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Wilhite, Donald A. and Glantz, Michael H., "CHAPfER2 UNDERSTANDING THE DROUGHT PHENOMENON: THE ROLE OF DEFINITIONS" (1987). *Drought Mitigation Center Faculty Publications*. 86.
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CHAPTER 2

UNDERSTANDING THE DROUGHT PHENOMENON: THE ROLE OF DEFINITIONS

Donald A. Wilhite and Michael H. Glantz

INTRODUCTION

The occurrence of widespread, severe drought in Africa, India, North America, China, the USSR, Australia, and western Europe has once again underscored the vulnerability of developed and developing societies to drought. The occurrence of severe drought during 1982-83 is shown in Fig. 1. These recent droughts have emphasized the need for more research on the causes as well as the impacts of drought and the need for additional planning to help mitigate the possible worst effects of future droughts. Drought has been the subject of a great deal of systematic study, particularly reconstructions of drought history, computations of drought frequency, and, to a lesser extent, investigations of first-, second-, and even third-order impacts of drought on society.

Considerable disagreement exists about the concept of drought. During a recent drought in the Brazilian Northeast, for example, some Brazilian scientists and policy makers suggested that the region had been affected by a five-year drought. However, Brazilian meteorologists noted that the rainfall record indicated that only two of the last five years could have been classified as experiencing drought. Similar conflicts occurred in Australia as recently as 1984 between the Bureau of Meteorology and state Department of Agriculture officials as to the existence of drought conditions at the beginning of the planting season for winter wheat.

This paper reviews numerous definitions of drought to determine those characteristics scientists consider most essential for a description and understanding of the phenomenon. It also discusses the far-reaching impacts of drought on society. The final section suggests that definitions of drought are typically simplistic and, in that way, often lead to a rather poor understanding of the dimensions of the concept. It is suggested that definitions of drought should not be formulated in a narrow sense, but rather should incorporate both physical and social measures that have a local or regional significance.

DROUGHT: AN OVERVIEW

Drought occurs in high as well as low rainfall areas. It is a condition relative to some long-term average condition of balance between rainfall and evapotranspiration in a particular area, a condition often perceived as "normal." Yet average rainfall does not

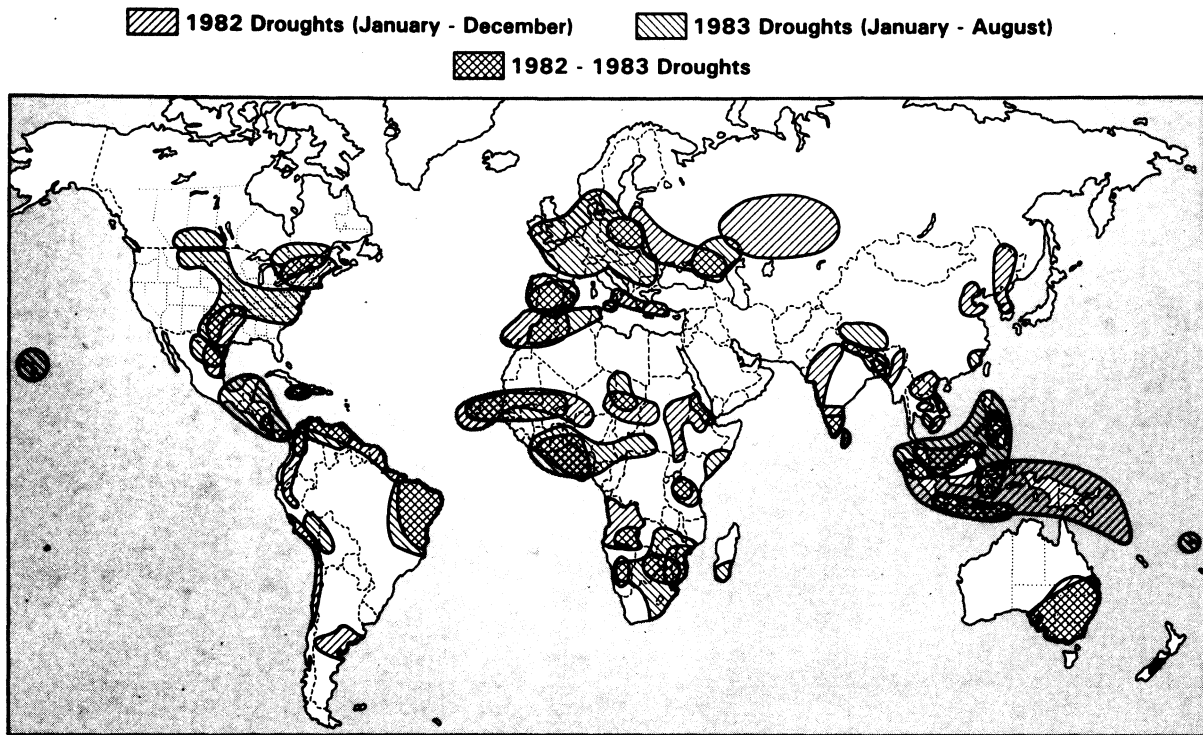


Fig. 1 The occurrence of drought, January 1982 to August 1983.

provide an adequate statistical measure of rainfall characteristics in a given region, especially in the drier areas.

Drought is a "creeping phenomenon" (Gillette, 1950), making an accurate prediction of either its onset or end a difficult task. To most observers, it seems to start with a delay in the timing (or a failure) of the rains. Others suggest that it can be identified only in retrospect. Tannehill (1947), for example, noted:

We have no good definition of drought. We may say truthfully that we scarcely know a drought when we see one. We welcome the first clear day after a rainy spell. Rainless days continue for a time and we are pleased to have a long spell of such fine weather. It keeps on and we are a little worried. A few days more and we are really in trouble. The first rainless day in a spell of fine weather contributes as much to the drought as the last, but no one knows how serious it will be until the last dry day is gone and the rains have come again.... we are not sure about it until the crops have withered and died.

Drought severity, too, is difficult to determine. It is dependent not only on the duration, intensity, and geographical extent of a specific drought episode, but also on the demands made by human activities and by the vegetation on a region's water supplies. Drought's characteristics along with its far-reaching impacts make its effects on society, economy, and environment difficult, though not impossible, to identify and quantify. The significance of drought should not be divorced from its societal context. While a drought may take place in a season or in a run of years, its impacts on society may linger for many years. Also, the impact of a drought depends largely on society's vulnerability to drought at that particular moment. Subsequent droughts in the same region will probably have different effects, even if the droughts are identical in intensity, duration, and spatial characteristics.

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) or for some group (e.g., farmer). Clearly there are many natural and human factors that ultimately affect the availability of water to society. Sometimes this shortage coincides with periods of high temperature, low humidity, and/or high wind speed. Water shortages related to drought, however, must be considered a relative, rather than absolute, condition.

The lack of general acceptance of a precise and objective definition of drought, according to Yevjevich (1967), has been one of the principal obstacles to the investigation of drought. Indeed, Yevjevich's view may represent the dominant view about drought definitions. Many contend that conflicting drought definitions often lead to confusion among decision makers about what constitutes a drought (Glantz and Katz, 1977). Confusion can lead to inaction, indecision, and, in many cases, ad hoc responses with little understanding of the societal and environmental implications of those responses (Wilhite, et al., 1984). Some observers suggest that a precise and objective drought definition could, at least in theory, form the basis for the development of more appropriate drought management strategies by individual citizens and government.

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 all regions of the globe, in all types of economic systems

(socialist and capitalist), and in developed and less developed countries alike, the approaches taken to define drought also reflect regional differences as well as differences in ideological perspectives. Impacts also differ from one location to the next, depending on the societal context in which drought is occurring. Therefore, the search for a universally acceptable definition of drought appears to be a fruitless endeavor.

THE DEFINITION OF DROUGHT

Drought definitions might be categorized as either conceptual or operational, with *conceptual* referring to those definitions formulated in general terms to identify the boundaries of the concept of drought. For example, the American Heritage Dictionary (1976) defined drought as "a long period with no rain, especially during a planting season." As another example, Random House Dictionary (1969) defined it as "an extended period of dry weather, especially one injurious to crops." Conceptual definitions provide little guidance to those who wish to apply them to current (i.e., real-time) drought assessments.

Operational definitions attempt to identify the onset, severity, and termination of drought episodes. Estimations of potential impacts are included in some operational definitions. An operational definition, for example, would be one that compares daily precipitation values to evapotranspiration (ET) rates to determine the rate of soil moisture depletion, and expresses these relationships in terms of drought effects on plant behavior at various stages of crop development. The effects of these meteorological conditions on plant growth would be reevaluated continuously by agricultural specialists as the growing season progresses.

Operational definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. Such definitions, however, require data on hourly, daily, monthly, or seasonal moisture deficiency, or yield departures from "normal" (i.e., expected) in order to identify when drought occurred. These definitions can be used to calculate the probabilities of droughts of varying intensity, duration, and spatial characteristics.

Disciplinary Views of Drought

Drought is frequently defined according to disciplinary perspective. Subrahmanyam (1967) has identified six types of drought: meteorological, climatological, atmospheric, agricultural, hydrologic, and water management. Many others have also included economic or socioeconomic factors as an essential factor in the determination of drought occurrence (Hoyt, 1942; Gibbs, 1975; Guerrero Salazar, 1975). Although it is useful to compartmentalize the various views of drought, the boundary separating these views is often vague.

The discussion of the disciplinary perspectives of drought which follows is the result of a review of more than 150 published definitions. For purposes of discussion these definitions of drought are clustered into four types—meteorological, agricultural, hydrologic, and socioeconomic.

Meteorological Drought. Meteorological definitions of drought are the most prevalent. They often define drought solely on the basis of the degree of dryness and the duration of the dry period. For example, meteorological drought has been defined as a "period of more than some particular number of days with precipitation less than some specified small amount" (Great Britain Meteorological Office, 1951). Linsley, et al. (1958), referred to it as a "sustained period of time without significant rainfall." Downer, et al. (1967), considered it to be a "deficit of water below a given reference value, with both deficit duration and deficit magnitude taken into account." Each of these definitions is vague. What is meant, for example, by *sustained* and *significant*?

Meteorological drought definitions are also often site specific, and the thresholds used to distinguish drought from nondrought periods are seldom spelled out. Some meteorological drought definitions developed for application in various countries of the world include:

1. United States: Less than 2.5 mm of rainfall in forty-eight hours (Blumenstock, 1942).
2. Britain: Fifteen days, none of which received as much as 0.25 mm of rainfall (British Rainfall Organization, 1936).
3. Libya: When annual rainfall is less than 180 mm (Hudson, 1964).
4. India: Actual seasonal rainfall is deficient by more than twice the mean deviation (Ramdas, 1960).
5. Bali: A period of six days without rain (Hudson, 1964).

Definitions constructed for application to one region but applied to another often create problems since the meteorological conditions that result in drought are highly variable around the world. Perceptions of these conditions are equally variable. Both of these points must be taken into account in order to identify the characteristics of drought and make comparisons between regions.

To answer the question, What is a viable meteorological definition of drought? we must know the reason behind the choice for each of the delimiting criteria used in each definition. What, for example, is the significance of forty-eight hours with less than 2.5 mm of rainfall? Were these values arbitrarily selected, or were they chosen to coincide with a critical threshold in plant behavior or streamflow reduction? Answers to these questions are important, because they allow us to test a definition's reliability and applicability.

Other drought definitions compare the degree of dryness to a long-term average, often referred to as "normal." McGuire and Palmer (1957), for example, have referred to drought as a "period of monthly or annual precipitation less than some particular percentage of normal." To some (e.g., Palmer, 1957), drought is a temporary departure from the average climate toward drier conditions.

The Palmer Drought Severity Index (PDSI), developed in 1965 by W. C. Palmer (1965), is probably the best-known meteorologic drought definition in the United States and is well known internationally. For example, its applicability in assessments of moisture conditions has recently been tested in South Africa, China, and Australia. The index is based on the concept of a hydrologic accounting system.

The PDSI relates drought severity to the accumulated weighted differences between actual precipitation and the precipitation requirement of evapotranspiration (ET). Although commonly referred to as a drought index, the PDSI is actually used to evaluate prolonged periods of abnormally wet or abnormally dry weather. It is widely used in the

United States to evaluate long-term moisture conditions. A national map of index values is published monthly in the U.S. Department of Agriculture's Weekly Weather and Crop Bulletin.

Gibbs and Maher (1967) have applied the concept of deciles of precipitation to the study and classification of droughts in Australia. Monthly and annual precipitation totals are ranked, highest to lowest, and decile ranges are determined from the cumulative frequency of the distribution. The first decile represents the precipitation values in the lowest 10% of the distribution. The second decile represents the precipitation values falling between 10% and 20% of the distribution, and so on. The tenth decile range would represent the highest 10% of the precipitation values in the distribution.

This system has formed the basis of the Australian Drought Watch System (Lee, 1979). Severe drought is equated with a dry period not exceeding the fifth decile range over a period of three or more months. Extreme drought occurs when precipitation values do not exceed the first decile range over a period of three or more months. Severe and extreme drought occurred over all of eastern Australia during the peak of the 1982-83 drought episode (Gibbs, 1984). Meteorological droughts do not necessarily coincide with periods of agricultural drought. At times, inconsistencies of this kind result in conflicts between the agriculturist and meteorologist, as noted above.

In the United States, Changnon (1980) has attempted to link drought thresholds and impacts in Illinois. Using departure of precipitation from normal over a twelve-month period as the basis for his study, Changnon found that 75% of normal precipitation over a twelve-month period resulted in only selected economic sectors being affected, such as some agricultural activities and the water supply of a few small towns. All agricultural activities and production were affected when precipitation was 60% of normal; 50% of normal precipitation produced an impact on all agricultural activities and most urban and industrial users.

Some scientists are critical of climatically defined drought because it is expressed in terms of a thirty-year precipitation period, which has been agreed to (by international convention) as the basis for the calculation of "normal." Thirty years, however, represents only a small part of the historical record for most locations and would not be representative of the long-term climatic record. Moreover, for climatic regimes characterized by a large interannual variation of precipitation, the "normal" is less meaningful than other statistical measures such as the range, median, or mode of the precipitation distribution (Glantz and Katz, 1977).

Some meteorological definitions of drought also encompass atmospheric parameters other than precipitation, but these definitions are less common. Popov (1948) used wet-bulb depression and Ivanov (1948) incorporated humidity and temperature as an indicator of the drying power of the atmosphere. Levitt (1958) expressed atmospheric drought as proportional to the vapor pressure deficit of the air. Condra (1944) referred to drought as a "period of strong wind, low precipitation, high temperature and, usually, low relative humidity," a definition formulated for the U.S. Great Plains and reflecting drought characteristics specific to this region. These definitions, however, may not be transferable to other regions of the world.

Agricultural Drought. Agricultural drought definitions link various characteristics of meteorological drought to agricultural impacts, focusing, for example, on precipitation shortages (Humphreys, 1931; Rosenberg, 1980), departures from normal

(World Book Encyclopedia, 1975), or numerous meteorological factors such as evapotranspiration (Laikhtman and Rusin, 1957).

A plant's demand for water is dependent on prevailing meteorological 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 would result. Barger and Thom (1949) have tried to link drought to its impact on a specific crop—corn.

Kulik (1958) represented drought intensity as the difference between plant water demand and available soil water. Kulik concluded that the upper 0.2 m of soil was critical to plant growth because of nutrient supplies and the root activity and activities of microorganisms that take place in that layer. Therefore, drying of this soil layer was an early indicator of yield loss (i.e., a measure of drought intensity). Kulik defined a dry period as one during which only 19 mm of available water remained in the upper 0.2 m of soil; when only 9 mm of available water remains, very dry conditions prevail.

In 1968 Palmer (1968) modified the PDSI to better reflect agricultural drought conditions. The Crop Moisture Index (CMI) defined drought in terms of the magnitude of computed abnormal ET deficit. This deficit is the difference between actual and expected weekly ET. The expected weekly ET is the normal value, adjusted up or down according to the departure of the week's temperature from normal. The CMI has been adopted by the U.S. Department of Agriculture and is published weekly in its Weekly Weather and Crop Bulletin as an indicator of the availability of moisture to meet short-term crop needs.

Hydrologic Drought. Definitions of hydrologic drought are concerned with the effects of dry spells on surface or subsurface hydrology, rather than with the meteorological explanation of the event. For example, Linsley, et al. (1975), considered hydrologic drought a "period during which streamflows are inadequate to supply established uses under a given water management system" (see also Dracup, 1980). The frequency and severity of hydrologic drought is often defined on the basis of its influence on river basins. Hydrologic droughts are often out of phase with both meteorological and agricultural drought.

Whipple (1966) defined a drought year as one in which the aggregate runoff is less than the long-term average runoff. Since low-flow frequencies have been determined for most streams, hydrologic drought periods can be of any specified length. If the actual flow for a selected period of time falls below a certain threshold, then hydrologic drought is considered to be in progress. However, the number of days and the level of probability that must be exceeded to define a hydrologic drought period is arbitrary (Matthai, 1979). These criteria are specific to individual streams or river basins.

Although the PDSI is sometimes used as an indicator of hydrologic drought, other definitions have been formulated which better serve the needs of hydrologists. For example, a definition of hydrologic drought was developed in Colorado during 1981 to provide information about drought conditions and water supply in high-elevation river basins that are dependent on snow melt as their main source of water supply (Dezman, et al., 1982). The Surface Water Supply Index (SWSI) was intended to be complementary

to the PDSI, with the latter applying mainly to nonirrigated areas independent of mountain water supplies.

The SWSI integrates historical data with current figures of reservoir storage, streamflow, and precipitation at high elevation into a single index number. The SWSI scale is synonymous with the scale used for PDSI values. Colorado's Drought Assessment and Response Plan (Colorado Division of Disaster Emergency Services, 1981) is implemented when SWSI and PDSI values exceed specified thresholds. For example, a SWSI of -1.0 activates Colorado's Water Availability Task Force, which makes assessments and projections on snowpack, soil moisture, reservoir and ground-water levels, precipitation, temperature, and streamflow.

Socioeconomic Drought. Definitions that express features of the socioeconomic effects of drought can also incorporate features of meteorological, agricultural, and hydrological drought (Kifer and Stewart, 1938). They are usually associated with the supply and demand of some economic good. Yevjevich (1967) has suggested that the time and space processes of supply and demand are the two basic processes that should be considered for an objective definition of drought. Heathcote (1974), for example, defined agricultural drought as a "shortage of water harmful to man's agricultural activities. It occurs as an interaction between agricultural activity (i.e., demand) and natural events (i.e., supply), which results in a water volume or quality inadequate for plant and/or animal needs." Gibbs (1975) expanded this definition, noting that demand was "dependent upon the distribution of plant, animal and human populations, their lifestyle and their use of the land."

In some instances, land use practices can either create a drought situation (e.g., agricultural or hydrologic drought) or make an existing one worse. The Dust Bowl years in the U.S. Great Plains in the 1930s, the Sahelian drought in West Africa in the early 1970s, and the recent Ethiopian drought are often cited as examples of the symbiosis between drought and human activities.

In 1936, J. C. Hoyt (1936) referred to drought as occurring "when precipitation is not sufficient to meet the needs of established human activities." He proposed this definition in the midst of the 1930s U.S. Great Plains drought. W. G. Hoyt (1942) later expanded this concept, stating that droughts may result if "in the economic development of a region man creates a demand for more water than is normally available."

Sandford (1979) argued that drought should be linked not only to precipitation (supply) but also to trends or fluctuations in demand as well as to factors other than weather which influence supply. Sandford presents two scenarios that represent time (x axis) and supply of some economic good (y axis). In the first scenario, demand by society for an economic good is assumed to be static throughout the time period. The level of supply (livestock feed in Sandford's example) varies considerably from one year to the next as a result of shortages of rainfall and other factors influencing supply. Therefore, drought occurs when supply falls below the level of requirement. In the second scenario, the demand trend is more realistically represented as increasing with time. The trend of supply, however, is decreasing as a result of ecological changes, such as declining soil fertility. Thus the frequency with which supply falls below demand increases. We feel that the interrelationship between man and drought requires more scientific attention.

The preceding discussion illustrates several significant features of drought. First, the various approaches taken by scientists and nonscientists to define drought

demonstrate its complex and interdisciplinary nature. Second, although most definitions emphasize the physical aspects of drought, the social aspects are closely related. Third, few (if any) definitions adequately address the impacts of drought. As a result, the primary, secondary, and tertiary impacts of drought are poorly understood.

THE IMPACT OF DROUGHT

Yevjevich, et al. (1978), suggested that the study of drought problems would be facilitated if drought was considered in a systems context. Figure 2 describes succinctly the interrelationships between the physical and social factors. As Yevjevich, et al., noted, the physical aspects of drought are derived from the atmosphere-ocean-continent system. Each drought is unique in its set of physical characteristics as well as in its geographic scope and location. It is interesting to note that Yevjevich considers the physical characteristics of drought to be dictated by the physical environment. Drought events are shown as inputs to a physical-environment system and a social system. The characteristics of drought events, physical-environment systems, and social systems combine and interact to produce impacts on the physical-environment and social system. The social system responds to mitigate or alleviate drought-related impacts. This view of drought reflects the focus of previous studies of drought on the physical aspects of the phenomenon. Yet the ultimate significance of drought to society lies in its impacts.

Figure 3, from a U.S. Department of Agriculture report on food problems and prospects in sub-Saharan Africa (USDA/ERS, 1981), presents a similar picture about weather (or climate), and drought as a part of it. Weather is viewed strictly as a physical phenomenon, whose origins and impacts are independent from social factors. After examining Fig. 3, it is evident that weather, or drought, affects far more than just crop yields and that social factors can be equally significant in determining society's vulnerability to drought and, thus, the type and magnitude of drought impacts. Thus, how drought is perceived, and defined, determines the likely response of societies to drought events.

The far-reaching impacts of drought in the United States (Table 1) were recently classified by the Institute for Policy Research of the Western Governors' Policy Office (WESTPO). WESTPO (1977) assembled this comprehensive listing of drought-related impacts in the economic, environmental, and social sectors in response to several consecutive years of drought. Many of these impacts are relevant to drought situations in other countries. In the United States' case, each impact cited is linked to one or more of the following five groups: municipalities, state governments, businesses and industries, agricultural enterprises, and households and individual citizens. This list suggests that droughts often have complex and long-lasting impacts. Also listed in Table 1 are constraints that inhibit responses to drought by each of these groups.

Although Table 1 appears to be a complete summary of drought impacts, at least one important group, the federal government, has been omitted. Since the 1930s drought in the United States, the federal government has become the primary, and usually only, source of assistance to the distressed area. During the mid-1970s drought, sixteen federal agencies administered forty separate assistance programs. During 1976-77, aid to water users alone, primarily in the form of loans and grants from four agencies, totaled \$5 billion (General Accounting Office, 1979). The total cost to the federal govern-

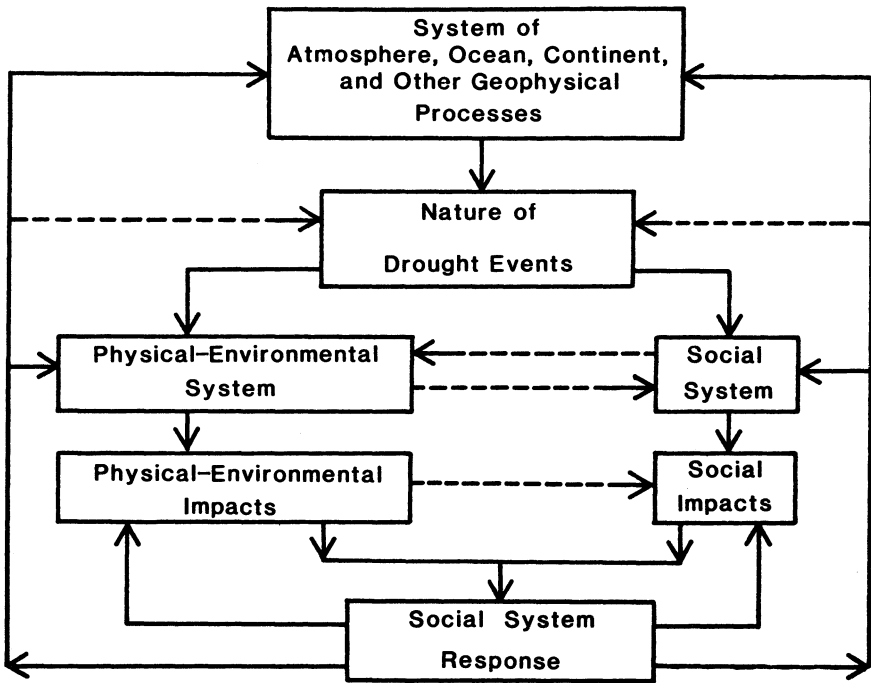


Fig. 2 Drought viewed in a systems context (Gibbs, 1975).

ment of the 1974-77 drought program probably exceeded \$7 billion (Wilhite, et al., 1984). Other governments, such as Australia, South Africa, the United Kingdom, India, and Kenya, to name just a few, have responded in a similar fashion (but on a lesser scale) to recent episodes of severe drought.

Table 1 shows clearly that the potential impacts of drought in the United States, at least, are concentrated largely in the economic sector, with agriculture the most often affected of the five groups identified. Because of the diversity of these impacts and their ripple effect on the economy, they are difficult to quantify. More explicit and objective definitions, incorporating both physical and socioeconomic aspects of drought, could assist in the quantification of impacts and allow for more precise comparisons of the effects of drought within and between geographical regions.

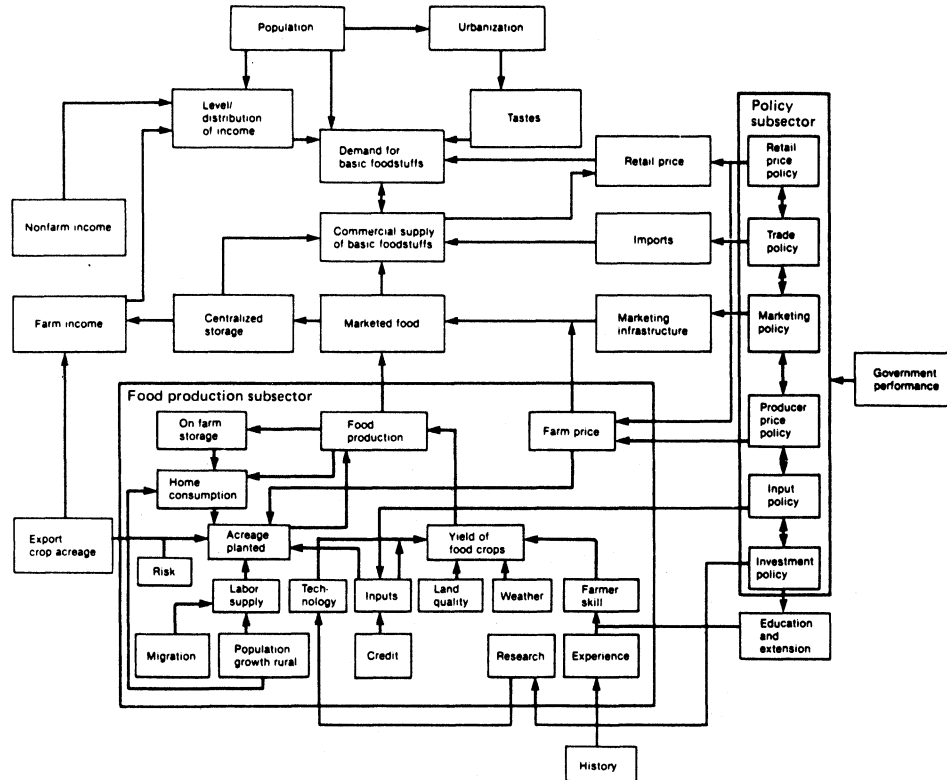


Fig. 3 Interaction among food balance factors, sub-Saharan Africa (USDA/ERS, 1981).

Table 1
Identification and Classification of Drought-Related Problems

AFFECTED GROUPS AND SECTORS ^a	PROBLEMS AND IMPACTS
<u>Economic Impacts</u>	
A	• economic loss from drought-impacted dairy and beef production
A	• impaired productivity of rangeland
A	• forced reduction of foundation stock
A	• closure/limitation of public lands to grazing
A	• high cost/unavailability of water for cattle
A	• high cost/unavailability of feed for cattle
A	• increased predation
AMS	• range fires
A	• economic loss from drought-impacted crop production
A	• damage to perennial crops; crop loss
A	• impaired productivity of cropland (wind erosion, etc.)
A	• insect infestation
AS	• plant disease
A	• wildlife damage to crops
B	• economic loss from drought-impacted timber production
B	• forest fires
BS	• tree disease
BS	• insect infestation
BS	• impaired productivity of forest land
AS	• economic loss from drought-impacted fishery production
HS	• damage to fish habitat
HS	• insufficient flows for anadromous and catadramous fish
HS	• loss of young fish due to decreased flows
BMS	• economic loss from drought-impacted recreational businesses
BMS	• economic loss to manufacturers and sellers of recreational equipment
BMS	• economic loss to industries impacted by drought-related power curtailments
BMS	• economic loss to industries directly dependent on agricultural production (e.g., fertilizer manufacturers, food processors, etc.)
HBS	• unemployment from drought-related production declines
SA	• strain on financial institutions
SM	• revenue losses to state and local governments
M	• revenues to water supply firms
M	• revenue shortfalls
M	• windfall profits
B	• economic loss from impaired navigability of streams, rivers, and canals
HABMS	• cost of water transport or transfer
HABMS	• cost of new or supplemental water source development

Environmental Impacts

- AS • damage to animal species
- SH • damage to wildlife habitat
- AH • lack of feed and drinking water
- AS • disease
- A • vulnerability to predation
- S • damage to fish species
- S • damage to plant species
- AM • water quality effects (e.g., salt concentration)
- HS • air quality effects (dust, pollutants)
- HS • visual and landscape quality (dust, vegetative cover, etc.)

Social Impacts

- MS • public safety from forest and range fires
- MS • health-related low flow problems (e.g., diminished sewage flows, increased pollutant concentrations, etc.)
- AHBMS • inequity in the distribution of drought impacts/relief
- lifestyle impacts
- HAS • unemployment
- A • loss of ownership
- HA • loss of savings
- H • retirement
- A • small family farming
- HABMS • uncertainty
- HBMS • recreation
- H • personal hygiene
- H • dirty cars and streets
- H • water reuse in home
- HB • entertaining

Constraints to Implementation of Drought

Mitigation Measures

- MS • legal/institutional constraints
- MSA • to water conservation/efficiency measures
- MSA • to water supply augmentation measures
- HABMS • financial constraints
- ABMS • to water conservation/efficiency measures
- ABM • to water supply augmentation measures
- inadequate drought management capability/authority
- M • local, state, federal
- MS • inadequate understanding of drought problems and mitigation measures; public apathy
- AM • shortages of needed parts, equipment, manpower

^aM - Municipalities

S - State governments

B - Businesses and industries

A - Agricultural enterprises

H - Households and individuals

Source: WESTPO, 1977.

CONCLUSION

To summarize:

1. The lack of a precise (and objective) definition of drought in a specific situation 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. There cannot (and should not) be a universal definition of drought.
3. Available definitions demonstrate a multidisciplinary interest in drought.
4. It is useful to subdivide definitions of drought into four types on the basis of disciplinary perspective (meteorologic, agricultural, hydrologic, and socioeconomic).
5. Drought is a complex phenomenon with pervasive societal ramifications.
6. Most scientific research related to drought has emphasized physical rather than societal aspects.
7. Drought severity is sometimes expressed by its societal impacts, although the precise nature of those impacts is difficult to quantify.
8. Secondary and tertiary effects often extend beyond the spatially defined borders of drought.
9. Drought impacts are long lasting, at times lingering for many years.
10. Human or social factors often aggravate the effects of drought.

Each of these points highlights our need to develop a better understanding of the concept of drought. The criteria selected to define drought must be stated explicitly so that the definition can be evaluated and its applicability to other locations examined.

Drought's impacts must be seen as dynamic, resulting from interactions between supply and demand. Supply can be expressed in terms of the physical subsystem and linked to concomitant impacts in the social subsystem. Demand must be viewed as interacting with supply and as continually changing. The relationships of supply and demand for the principal economic goods are highly variable from one country to another, from one region to the next, and from one period to another.

Definitions of drought should reflect a regional bias since water supply is largely a function of climatic regime. Of course, the size of the region over which any definition is applicable may vary considerably. Primary impacts will likewise be regional in character, but secondary and tertiary effects of a drought can have national and, at times, global implications. For example, droughts in Zimbabwe can adversely affect regional food supplies in southern Africa.

The inadequate understanding of the concept of drought and the lack of appreciation of its physical and social impacts by the scientific community and governments has serious worldwide implications for the future as the difference between food production and consumption narrows. Governments should prepare for droughts by developing and implementing strategies and plans that reduce associated impacts. More precise and objective definitions of drought can greatly improve the understanding of the concept and its impacts and facilitate strategy development. Otherwise, the mistakes and failures of the past will no doubt be repeated, although with the likelihood of more severe consequences.

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ACKNOWLEDGMENTS

The authors wish to thank Professors Norman J. Rosenberg, Albert Weiss, Gordon McKay, and Jonathan Taylor for their critical review of this paper. Deborah Wood and Steven Meyer assisted with the library research and the classification of the numerous definitions of drought, respectively. Deborah Wood, along with Maria Krenz, assisted in editing the manuscript. Sharon Kelly was responsible for the preparation of the manuscript. Their help is gratefully acknowledged.

The work was conducted under Nebraska Experiment Station Project 27-001. This material is based on work partially supported by the National Science Foundation under Grant ATM-8108447.

REFERENCES

- American Heritage Dictionary. 1976. Drought. Houghton Mifflin, Boston.
- Barger, G. L.; and H. C. S. Thom. 1949. Method for characterizing drought intensity in Iowa. *Agron. J.* 41:13-19.
- Blumenstock, G., Jr. 1942. Drought in the U.S. analyzed by means of the theory of probability. USDA Tech. Bull. 819. GPO, Washington, D.C.
- British Rainfall Organization. 1936. British Rainfall. Air Ministry, Meteorological Office, London. Cited in World Meteorological Organization. 1975. Drought and agriculture. Technical Note 138. WMO, Geneva.
- Changnon, S. A. 1980. Removing the confusion over droughts and floods: The interface between scientists and policy makers. *Water Int.* 5:10-18.
- Colorado Division of Disaster Emergency Services. 1981. The Colorado drought response plan. Colorado Division of Disaster Emergency Services, Denver.
- Condra, G. E. 1944. Drought, its effects and measure of control in Nebraska. *Conservation Bulletin* 25. Conservation and Survey Division, University of Nebraska-Lincoln.
- Dezman, L. E.; B. A. Shafer; H. D. Simpson; and J. A. Danielson. 1982. Development of a surface water supply index—A drought severity indicator for Colorado. In A. I. Johnson and R. A. Clark, eds. *Proc. International Symposium on Hydrometeorology*. American Water Resources Association, Bethesda, Maryland.
- Downer, R. N.; M. M. Siddiqui; and V. Yevjevich. 1967. Applications of runs to hydrologic droughts. pp. 496-505. In *Proc. International Hydrology Symposium*. Colorado State University, Fort Collins.
- Dracup, J. A.; K. S. Lee; and E. G. Paulson, Jr. 1980. On the definition of droughts. *Water Resour. Res.* 16(2):297-302.
- General Accounting Office. 1979. Federal response to the 1976-77 drought: What should be done next? Report to the Comptroller General. GPO, Washington, D.C.

- Gibbs, W. J. 1975. Drought—its definition, delineation, and effects. pp. 3-39. In Drought: Lectures presented at the 26th session of the WMO Executive Committee. Special Environmental Report No. 5. WMO, Geneva.
- Gibbs, W. J. 1984. The great Australian drought: 1982-83. Disasters, published by the International Disaster Institute, London, August 2.
- Gibbs, W. J.; and J. V. Maher. 1967. Rainfall deciles as drought indicators. Bureau of Meteorology Bulletin No. 48. Melbourne, Australia.
- Gillette, H. P. 1950. A creeping drought under way. Water and Sewage Works, March, pp. 104-105.
- Glantz, M. H.; and R. Katz. 1977. When is a drought a drought? Nature 267:192-193.
- Great Britain Meteorological Office. 1951. The Meteorological Glossary. Chemical Publishing Co., New York.
- Guerrero Salazar, P.; and V. Yevjevich. 1975. Analysis of drought characteristics by the theory of runs. Hydrology Paper No. 80, Department of Civil Engineering, Colorado State University, Fort Collins.
- Heathcote, R. L. 1974. Drought in South Australia. p. 129. In G. F. White, ed. Natural Hazards: Local, National, Global. Oxford, New York.
- Hoyt, J. C. 1936. Droughts of 1930-1934. USGS Water Supply Paper No. 680. USGS, Washington, D.C.
- Hoyt, W. G. 1942. Droughts. p. 579. In O. E. Meinzer, ed. Hydrology. Dover Publications, New York.
- Hudson, H. E.; and R. Hazen. 1964. Drought and low streamflow. Chap. 18. In V. T. Chow, ed. Handbook of Applied Hydrology. McGraw-Hill, New York.
- Humphreys, W. J. 1931. How droughts occur. Bull. Am. Meteorol. Soc. 12:18-22.
- Ivanov, N. N. 1948. Landscape-climatic zones of the earth surface. Proc. All Soviet Geographical Conference, New Series Vol. 1. Academy of Sciences of the U.S.S.R., Leningrad.
- Kifer, R. S.; and H. L. Stewart. 1938. Farming hazards in the drought area. Works Progress Administration, Monograph XVI, Washington, D.C.
- Kulik, M. S. 1958. Agroclimatic indices of drought. In F. F. Davidaya and M. S. Kulik, eds. Compendium of abridged reports to the second session of CAgM (WMO). Hydrometeorological Publishing, Moscow; trans. A. Nurlik, Meteorological Translations 7:75-81 (1962).
- Laikhtman, D. L.; and N. P. Rusin. 1957. On the meteorological criterion of drought [in Russian]. Glavnaia Geofizicheskaya Observatoriia, Trudy, 69:65-70.
- Lee, D. M. 1979. Australian drought watch system. In M. T. Hinchey, ed. Botswana Drought Symposium. Botswana Society, Gaborone, Botswana.
- Levitt, J. 1958. Frost, drought and heat resistance. Protoplasmatologia 8(6).
- Linsley, R. K.; M. A. Kohler; and J. L. H. Paulhus. 1958. Hydrology for Engineers. McGraw-Hill, New York.
- Linsley, R. K., Jr.; M. A. Kohler; and J. L. H. Paulhus. 1975. Hydrology for Engineers, 2nd ed. McGraw-Hill, Kogakusha, Tokyo.
- Matthai, H. F. 1979. Hydrologic and human aspects of the 1976-77 drought. USGS Survey Professional Paper 1130. GPO, Washington, D.C.
- McGuire, J. K.; and W. C. Palmer. 1957. The 1957 drought in the eastern U. S. Mon. Weather Rev. 85, No. 9 (September 1957):305-314.

- Palmer, W. C. 1957. Drought—A normal part of climate. In *Weekly Weather and Crop Bulletin* 44, No. 1a (January 10):6-8.
- Palmer, W. C. 1965. Meteorological drought. Research Paper No. 45. U. S. Weather Bureau, Washington, D.C.
- Palmer, W. C. 1968. Keeping track of crop moisture conditions, nationwide: The new crop moisture index. *Weatherwise* 21(4):156-161.
- Popov, V. P. 1948. Moisture balance in the soil and the dryness indices of climate in the Ukrainian S.S.R. *Sci. Rep. of the State Univ. of Kiev*, Vol. 7, No. 1.
- Ramdas, D. A. 1960. Crops and weather in India. ICAR, New Delhi, India.
- Random House Dictionary. 1969. Drought. Random House, New York.
- Rosenberg, N. J., ed. 1980. Drought in the Great Plains: Research on Impacts and Strategies. Water Resources Publications, Littleton, Colorado.
- Sandford, S. 1979. Towards a definition of drought. In M. T. Hinchey, ed. *Botswana Drought Symposium*. Botswana Society, Gaborone, Botswana.
- Subrahmanyam, V. P. 1967. Incidence and spread of continental drought. WMO/IHD Report No. 2. WMO, Geneva.
- Tannehill, I. R. 1947. Drought, Its Causes and Effects. Princeton University Press, Princeton, New Jersey.
- U. S. Department of Agriculture, Economic Research Service (USDA/ERS). 1981. Food problems and prospects in Sub-Saharan Africa—The decade of the 1980s. Foreign Agricultural Research Report No. 156, August. Washington, D.C.
- Western Governors' Policy Office (WESTPO). 1977. Directory of Federal Drought Assistance. Prepared by the Institute for Policy Research for the Western Region Drought Action Task Force. USDA, Washington, D.C.
- Whipple, W., Jr. 1966. Regional drought frequency analysis. *Proc. ASCE* 92, No. IR2 (June 1966):11-31.
- Wilhite, D. A.; N. J. Rosenberg; and M. H. Glantz. 1984. Government response to drought in the United States. Completion Report to the National Science Foundation. CAMaC Progress Reports 84-1 to 84-4. Center for Agricultural Meteorology and Climatology, University of Nebraska-Lincoln.
- World Book Encyclopedia. 1975. Drought. Field Enterprises Educational Corporation, Chicago.
- Yevjevich, V. 1967. An objective approach to definitions and investigations of continental hydrologic droughts. *Hydrology Papers*, No. 23. Colorado State University, Fort Collins.
- Yevjevich, V.; W. A. Hall; and J. D. Salas, eds. 1978. *Proc. Conference on Drought Research Needs*. Water Resources Publications, Fort Collins.