DROUGHT PREPAREDNESS AND DROUGHT MANAGEMENT

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Abstract

Drought is a normal, recurring feature of climate; it occurs in virtually all climatic regimes. It is the consequence of a natural reduction in the amount of precipitation received over an extended period, usually a season or more in length. The effects of drought accumulate slowly and its impacts are spread over a larger geographical area than are damages that result from other natural hazards. Most of the policy responses to drought tend to address the immediate needs, to provide what are often more costly remedies, and to attempt to balance competing interests in a charged atmosphere. There is an urgent need to replace this approach of crisis management with a more pro-active approach of risk management, which emphasizes preparedness, mitigation, prediction and early warning. The different steps in drought preparedness are illustrated with examples from the United States. Effective drought management emphasizes three components: monitoring and early warning, risk and impact assessment and mitigation and response. Steps in establishing the viability of a drought monitoring system are described. Seasonal forecasts are also useful in identifying current and future trends in these conditions. The recent improvement in seasonal forecast skills provide an important tool in support of effective drought management. An equally important element of drought early warning systems is the timely and effective delivery of this information to decision makers. There are several essential components of a drought information system which include information on the timing, intensity and duration of droughts. Different ways of providing information on drought intensity are described including the use of various drought indices. Common types of drought impacts are the result of exposure to drought hazards and are a combination of economic, social and environmental factors. To reduce vulnerability to drought, it is essential to identify relevant impacts and assess their underlying causes. It is important that governments develop and adopt National Drought Policies that move them towards a strategy to mitigate the impacts of drought, improve public awareness, and achieve the needed partnerships for better coordination and response to drought.

1. Introduction

Of the many climatic events that influence the earth's environmental fabric, drought is perhaps the one that is most linked with desertification. Drought is a natural hazard originating from a deficiency of precipitation that results in a water shortage for some activities or some groups and is often associated with other climatic factors (such as high temperatures, high winds and low relative humidity) that can aggravate the severity of the event. Drought differs from aridity in that the latter is restricted to low rainfall regions and is a permanent feature of the climate. Drought occurrences are common in virtually all climatic regimes.

Widespread and severe drought conditions in Asia, Latin America and the Caribbean in 2000 have raised serious concerns about the continuing vulnerability of the world community to extended periods of droughts and water shortages. In 2000, major droughts affected much of south-eastern Europe, the Middle East, and the area through central Asia to northern China. Especially hard hit were Afghanistan, Bulgaria, Iraq and the Islamic Republic of Iran and parts of China. In North America, months of above-average temperature coincided with below-normal precipitation through northern Mexico and much of the southern and western regions of the USA, leading to one of the worst wildfires in the past 50 years.

By August 2001, much of Western Asia, Central Asia, and the Middle East was suffering the third year of a continuing drought that severely reduced many countries' crop yields. The countries most affected were Afghanistan, India, Islamic Republic of Iran, Pakistan, and Tajikistan.

Drought disrupts cropping programs, reduces breeding stock, and threatens permanent erosion of the capital and resource base of farming enterprises. Continuous droughts stretching over several years in different parts of the world in the past significantly affected productivity and national economies. In addition, the risk of serious environmental damage, particularly through vegetation loss and soil erosion, as has happened in the Sahel during the 70s, has long term implications for the sustainability of agriculture. Bushfires and dust storms often increase during the dry period.

2. Drought - the concept

In any discussion on the preparedness and management strategies for natural hazards, it is necessary to understand first the basic concepts underlying the hazard under discussion. Hence, a brief discussion of the concept of droughts is presented here.

Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman, 1984). However, there remains much confusion within the scientific and policy communities about its characteristics. It is precisely this confusion that explains, to some extent, the lack of progress in drought preparedness in most parts of the world.

Drought is an insidious hazard of nature. Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. 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".

Drought is a slow-onset, creeping natural hazard that is a normal part of climate for virtually all regions of the world; it results in serious economic, social, and environmental impacts (Wilhite, 2000). Drought onset and end are often difficult to determine, as is its severity. Drought severity is dependent not only on the duration, intensity and spatial extent of a specific drought episode, but also on the demands made by human activities and vegetation on a specific region's water supply.

The impacts of drought are largely nonstructural and spread over a larger geographical area than are damages from other natural hazards. The nonstructural characteristic of drought impacts has certainly hindered the development of accurate, reliable, and timely estimates of severity and, ultimately, the formulation of drought preparedness plans by most governments.

Drought risk is a product of a region's exposure to the natural hazard and its vulnerability to extended periods of water shortage (Wilhite, 2000). If nations and regions are to make progress in reducing the serious consequences of drought, they must improve their understanding of the hazard and the factors that influence vulnerability.

3. Risk Management versus Crisis Management

The traditional approach to drought management has been reactive, relying largely on crisis management. This approach has been ineffective because response is untimely, poorly coordinated, and poorly targeted to drought stricken groups or areas. In addition, drought response is post-impact and relief tends to reinforce existing resource management methods. It is precisely these existing resource management practices that have often increased societal vulnerability to drought. The provision of drought relief only serves to reinforce the status quo in terms of resource management. Many governments and others now understand the fallacy of crisis management and are striving to learn how to employ proper risk management techniques to reduce societal vulnerability to drought and, therefore, lessen the impacts associated with future drought events.

As vulnerability to drought has increased globally, greater attention has been directed to reducing risks associated with its occurrence through the introduction of planning to improve operational capabilities (*i.e.*, climate and water supply monitoring, building institutional capacity) and mitigation measures that are aimed at reducing drought impacts. In the past, when a natural hazard event and resultant disaster has occurred, governments have followed with impact assessment, response, recovery, and reconstruction activities to return the region or locality to a pre-disaster state. Little attention has been given to preparedness, mitigation, and prediction/early warning actions (*i.e.*, risk management) that could reduce future impacts and lessen the need for government intervention in the future.

4. Drought Preparedness

A key point of dealing with droughts is drought preparedness. However the hydro-illogical cycle leads to shortsighted decision making. People tend to assume that plentiful water supplies are the norm, when occasional droughts are inevitable.

The methodology for drought preparedness planning has been developed in the United States. This methodology, a 10-step drought planning process, has been used by many states in the United States and also by several foreign governments. The purpose of the planning process is to derive a plan that is dynamic, reflecting the changing government policies, technologies, and natural resource management practices. The 10-steps in this process are:

- *Appoint* a drought task force
- *State* the purpose and objectives of the preparedness plan
- *Seek* stakeholder participation and resolve conflicts
- *Inventory* resources and *identify* groups at risk
- *Develop* organizational structure and *prepare* the drought plan
- *Identify* research needs and fill institutional gaps
- *Integrate* science and policy
- *Publicize* the drought plan, *build* public awareness
- *Teach* people about drought
- *Evaluate and revise* drought preparedness plan

The above process is intended to serve as a checklist to identify issues that should be addressed in plan development, with appropriate modifications.

5. Drought Management

Drought plans commonly have three major components:

- Monitoring and early warning
- Risk and impact assessment
- Mitigation and response

5.1 Monitoring and early warning

The overall goal of drought monitoring is to provide information that enables and persuades people and organisations to take action to maximise the probability of successful crop production and/or minimise the potential damage to established crops and other assets. In this regard, a reliable assessment of water availability and its outlook for near and long term is valuable information. In establishing the viability of a drought monitoring system, it is important to consider the following:

- An analysis of the risk of the phenomenon and its likely effect on agricultural production.

- Ensuring that the agricultural community has the ability to make use of the early warning system.

- Scientific assessment of the warning situation - are there useful techniques for forecasting the phenomena and adequate real time data to enable these techniques to be used ?

- A review of the communication systems to ensure timely dissemination of the message to the users.

In drought monitoring, data and information on each of the relevant indicators (eg., precipitation, temperature, evapotranspiration, seasonal weather forecasts, soil moisture, streamflow, ground water, reservoir and lake levels, and snowpack) should be considered in the evaluation of water situation and outlook for the country. There should be a monitoring committee comprising of representatives from agencies with responsibility for monitoring climate and water supply, traditionally meteorological, hydrological and agricultural services.

Primary objectives of a drought monitoring committee are to:

- Adopt a workable definition of drought that could be used to phase in and phase out levels of govt action in response to drought. In many instances, it may be necessary to apply several definitions that are impact or sector specific.
- Establish drought management areas.
- Develop a drought monitoring system. Coordinate and integrate the analysis so decision makers and public receive early warnings of emerging drought conditions.
- Inventory data quantity and quality from current observation networks.
- Determine data needs of primary users.
- Develop and/or modify current data and information delivery systems.

5.1.1 Components of drought information

The collection, analysis and dissemination of data and information on droughts will vary according to each country's infrastructure. There are a number of components that can be considered essential in the presentation of a comprehensive picture of droughts in a given region. These include information on:

- Timing of droughts
- Drought intensity
- Drought duration
- Spatial extent of a specific drought episode
- Analysis of the risk of the phenomenon and its likely effect on agricultural production.

A short description of each of these components is presented below.

5.1.1.1 Timing of droughts

As mentioned earlier, it is difficult to define the onset of droughts as it is a creeping phenomenon. However, some attempts have been made to define the onset of droughts. According to the British Meteorological Office (Crowe 1971), an absolute drought begins when at least 15 consecutive days have gone by with less than 0.25 mm of rainfall on all days and a "dry spell" is a period of at least 15 consecutive days none of which has received 1 mm or more. Other definitions of the onset of droughts have been developed using drought indices, which are described in the next section.

In addition to precipitation data, it is important to take into account the soil type, soil water holding capacity, and the specific cropping situation to which the information is to be applied.

5.1.1.2 Drought intensity

There are a number of ways to provide information on the drought intensity:

a) Presentation of current rainfall data along with long-term average rainfall

This is the most simple means of presenting information on drought intensity and is used frequently in many agrometeorological bulletins around the world. Information is presented in either a tabular form or a graphic format. Presentation of monthly totals of rainfall along with long-term average rainfall at representative locations is quite common to describe the drought intensity. While the information presented provides a bird's eye view of drought intensity, it is difficult to understand the spatial nature of droughts from the information provided. Also, when monthly rainfall totals are used, it is difficult to clearly discern the exact nature of the dry spell within the month.

b) Presentation of current rainfall as a percentage of long-term average rainfall

The percent of normal precipitation is one of the simplest measurements of rainfall for a location and is calculated by dividing actual precipitation by normal precipitation -- typically considered to be a 30-year mean -- and multiplying by 100%. Depending upon the need, it can be computed for either a single month or number of months or a whole year. Ideally, one should be able to compute this for the cropping season (taking into account the dates of sowing and harvesting of crops), but the computation of long-term normal in this case could be a bit cumbersome, especially if there are missing data of daily rainfall.

As Hayes (1999) explained, one of the disadvantages of using the percent of normal precipitation is that the mean, or average, precipitation is often not the same as the median precipitation, which is the value exceeded by 50% of the precipitation occurrences in a long-term climate record. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution. Use of the percent of normal comparison implies a normal distribution where the mean and median are considered to be the same.

c) Using different thresholds of current rainfall as a percentage of long-term average rainfall

Based on experience with previous droughts and the impacts caused by rainfall deficiency exceeding certain thresholds, some countries such as India use different thresholds of current rainfall as a percentage of long-term average rainfall to delineate the intensity of drought in different parts of the country. If the current rainfall in a given meteorological subdivision exceeds the Long-Period Average (LPA) by 20%, the subdivision is deemed to have received excess rainfall. Threshold values of +19 to -19% of LPA are considered as normal while current rainfall falling within -20 to -59% of LPA would categorize a subdivision as "deficient". When the threshold value falls below - 60% of LPA, rainfall in a subdivision is considered "scanty".

For example, in 1999, rainfall for India as a whole was 95.5% of the Long Period Average (LPA) rainfall, but seven out of the 35 meteorological subdivisions in the country received deficient rainfall ie., 20% to 59% below the normal rainfall. In other words, some 8.1% of the country was affected by droughts in 1999. Rainfall in 2000 was 92% of the LPA and again seven meteorological subdivisions received deficient rainfall.

d) *Computing drought indices and using the indices in a comparative mode to depict drought intensities*

Drought indices have been developed from known values of selected parameters to present a quantitative description of droughts. Following are some of the most commonly used drought indices around the world.

- The decile approach (Coughlan, 1987) used in Australia

- Palmer Drought Severity Index (Palmer, 1965) used in the United States

- Crop Moisture Index (Palmer, 1968) used in the United States

- The Standardized Precipitation Index (McKee et al. 1993) which has gained popularity and is being used in many countries

<u>The decile approach:</u> The decile approach (Gibbs and Maher, 1967) is a non parametric method to describe the distribution of rainfall totals. Annual rainfall totals for a long series of years are arranged in an ascending order (from lowest to highest) and are then split into 10 equal groups. The first group would be in decile range one, the second group in decile range two etc., In other words, deciles are used to give an element a ranking. It is possible in a decile rainfall map to show whether the rainfall is above average, average or below average for the time period and for the area chosen.

The drought maps highlight areas considered to be suffering from a serious or severe rainfall deficiency. In Australia, these classes are assigned by first examining rainfall periods of three months or more for selected places to see whether they lie below the 10th percentile (lowest 10% of records). The terms serious and severe are defined by:

- Serious rainfall deficiency:- rainfall lies above the lowest five per cent of recorded rainfall but below the lowest ten per cent (decile 1 value) for the period in question,

- Severe rainfall deficiency:- rainfall is among the lowest five per cent for the period in question.

Once an area has been classified, it remains in the severe/serious deficiency category of the review until the deficiency is removed. Rainfall deficiency is considered removed if it exceeds the third decile and is less than the seventh decile.

Palmer Drought Severity Index: The Palmer Drought Severity Index (PDSI), based on the concept of a hydrological accounting system, relates drought severity to the accumulated weighted differences between actual precipitation and the precipitation requirement of evapotranspiration (Palmer 1965). The PDSI is calculated based on precipitation and temperature data, as well as the available soil water content. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. The objective of this index was to provide measurements of moisture conditions that were standardized so that comparisons using the index could be made between locations and between months (Palmer 1965). Drought conditions indicated by different PDSI values are as follows:

PDSI	Indicated drought condition
4.0 or more	extremely wet
3.0 to 3.99	very wet
2.0 to 2.99	moderately wet
1.0 to 1.99	slightly wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

The Palmer Index is most effective in determining long term drought—a matter of several months—and is not as good with short-term forecasts (a matter of weeks). The Palmer Index is popular and has been widely used for a variety of applications across the United States. It is most effective measuring impacts sensitive to soil moisture conditions, such as agriculture (Willeke et al. 1994). It has also been useful as a drought monitoring tool and has been used to trigger actions associated with drought contingency plans (Willeke et al. 1994). Alley (1984) identified three positive characteristics of the Palmer Index that contribute to its popularity:

- it provides decision makers with a measurement of the abnormality of recent weather for a region
- it provides an opportunity to place current conditions in historical perspective; and
- it provides spatial and temporal representations of historical droughts.

There are also several significant limitations of the Palmer Index for monitoring drought. These include no inherent time scale (i.e., shorter length droughts may not be detected or may be underestimated in severity), the tendency to treat all precipitation as rainfall so that snowfall, snow cover, and frozen ground are not accounted for, making real-time winter index values of questionable reliability, and the wide variance in the occurrence of extreme and severe classifications of index values, depending on location. It is important for extreme and severe classifications to occur with the same relative frequency in various parts of a country if these values are going to be used in making policy decisions on eligibility for mitigation and response programs.

Crop Moisture Index: The Crop Moisture Index (CMI), developed by Palmer (1968) subsequent to his development of the PDSI, uses a meteorological approach to monitor week-to-week crop conditions. CMI defined drought in terms of the magnitude of computed abnormal ET deficit which 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 responds more rapidly than the Palmer Index and can change considerably from week to week, so it is more effective in calculating short-term abnormal dryness or wetness affecting agriculture. It differs from the Palmer Index in that the formula places less weight on the data from previous weeks and more weight on the recent week. CMI is weighted by location and time so that maps, which commonly display the weekly CMI across the United States, can be used to compare moisture conditions at different locations.

Because it is designed to monitor short-term moisture conditions affecting a developing crop, the CMI is not a good long-term drought monitoring tool (Hayes, 1999). The CMI's rapid response to changing short-term conditions may provide misleading information about long-term conditions. For example, a beneficial rainfall during a drought may allow the CMI value to indicate adequate moisture conditions, while the long-term drought at that location persists. Another characteristic of the CMI that limits its use as a long-term drought monitoring tool is that the CMI typically begins and ends each growing season near zero. This limitation prevents the CMI from being used to monitor moisture conditions outside the general growing season, especially in droughts that extend over several years. The CMI also may not be applicable during seed germination at the beginning of a specific crop's growing season.

Standardized precipitation index: McKee et al. (1993) developed the Standardized Precipitation Index (SPI) to quantify the precipitation deficit for multiple time scales. In SPI calculations, the long-term precipitation record for a desired period is fitted to a probability distribution. If a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. The cumulative probability gamma function is transformed into a standard normal random variable Z with mean of zero and standard deviation of one so that the mean SPI for the location and desired period is zero (Edwards and McKee 1997). Transformation of all probability functions fitted for different rainfall station data results in transformed variate in the same units. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. Positive SPI values indicate greater than median precipitation, while negative values indicate less than median precipitation.

SPI represents the amount of rainfall over a given time scale, with the advantage that it also gives an indication of what this amount is in relation to the normal, thus leading to the definition of whether a station is experiencing drought or not. Plotting a time series of year against SPI gives a good indication of the drought history of a particular station. Rainfall of two areas with different rainfall characteristics can be compared in terms of how badly they are experiencing drought conditions since the comparison is in terms of their normal rainfall.

McKee et al. (1993) used the classification system shown below to define drought intensities resulting from the SPI.

SPI Values	Drought intensity
2.0 +	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
.99 to -.99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

McKee et al. (1993) also defined the criteria for a "drought event" for any of the time scales. A drought event occurs any time the SPI is continuously negative and reaches an intensity where the SPI is -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The accumulated magnitude of drought can also be drought magnitude, and it is the positive sum of the SPI for all the months within a drought event.

One of the advantages of the SPI is that it can be computed for multiple time scales (i.e., 1-, 2- ,3- . . .72 months), thus allowing for comparisons between time periods. This can be an excellent communication tool to the public and to policy makers. In addition, these various time scales can be useful in assessing effects on different components of the hydrologic system (e.g., stream flow, reservoir levels, ground water levels). The SPI is used widely in the United States and in more than 30 countries on a research and operational basis.

5.1.1.3 Drought duration

Information on drought duration depends not only on the onset of drought, but equally on when exactly the droughts end. In some years, it might appear that drought had been relieved through a light shower, but in effect the drought could persist because of a subsequently long dry period. Hence it is important to evaluate carefully conditions that could clearly signal the end of droughts e.g., rainfall above a given threshold, soil moisture recharge that would enable crops to recover etc.,

It is important to document the exact duration of droughts as part of the drought records along with other details such as timing of droughts, intensity of droughts, drought impacts etc., because the length of the time the drought persisted is a good indicator of the nature of the problem and relates quite well to the damage suffered by crops, livestock etc.,

5.1.1.4 Spatial Extent of a Specific Drought Episode

The Spatial extent of specific drought episodes is best described using mapping tools. One of the good examples is the Drought Monitor which was developed for the United States and represents a weekly snapshot of current drought conditions (Fig. 1). The Drought Monitor is a synthesis of several different climate indices and parameters. It incorporates both objective measures and subjective interpretation in the mapping process. Droughts are also classified according to their severity, from 1 (moderate) to 4 (exceptional) (Wilhite and Svoboda, 2000).

One of the useful ways to represent the spatial extent of droughts is to map the average frequencies of dry spells which can be computed from the dry spell lengths:

$$F = \frac{N(Di)}{m} \cdot 100$$

where N(Di) is the number of occurrences of dry spells D for a prescribed period i

m is the number of years of data

As mentioned previously, there are three critical components of drought preparedness planning: monitoring and early warning; risk and impact assessment; and mitigation and response. Each of these components are addressed under step 5 of the 10-step planning process presented under item 4 in this paper. Drought monitoring and early warning has been discussed under 5.1; the remaining drought plan components are presented below.

5.2 Risk and Impact Assessment

Drought produces a complex web of impacts that not only ripple through many sectors of the economy but may be experienced well outside the affected region. To more clearly understand the impacts of drought, the phenomenon should not be viewed as merely a natural event. It is the result of an interplay between a natural event and the demand placed on water and other natural resources by human-use systems. For example, societies can exacerbate the impacts of drought by placing demands on water and other natural resources that exceed the supply of those resources.

Risk is a product of a region's exposure to the drought hazard (i.e., probability of occurrence as described by a region's drought climatology) and societal vulnerability, represented by a combination of economic, environmental, and social factors. Therefore, in order to reduce vulnerability to drought, it is essential to identify the most significant impacts and assess their underlying causes. Drought impacts cut across many sectors and across normal divisions of responsibility of government agencies at local, state, and national levels. These impacts have been classified by Wilhite and Vanyarkho (2000).

Information on drought's impacts and their causes is crucial for reducing risk before drought occurs and for appropriate responses during drought. As part of the drought planning process, it is recommended that a Risk Assessment Committee be established that represents those most at risk from drought. The task of this committee is to determine who and what is most at risk and why. This task is best accomplished through a series of working groups under the aegis of the Risk Assessment Committee. The responsibility of the committee and working groups is to assess sectors, population groups, and ecosystems most at risk and identify appropriate and reasonable mitigation measures to address these risks. Working groups would be composed of technical specialists representing those areas referred to above.

A methodology for assessing and reducing the risks associated with drought has been developed by the U.S. National Drought Mitigation Center and is available on the NDMC web site at http://drought.unl.edu/ndmc/handbook/risk.pdf. The guide focuses on identifying and prioritizing drought impacts, determining their underlying causes, and choosing actions to address the underlying causes. This methodology can be employed by each of the working groups. This effort requires an interdisciplinary analysis of impacts and management options and is divided into six tasks:

*Assemble the team***.** Select stakeholders, government planners, and others with a working knowledge of drought's effects on primary sectors, regions, and people.

*Evaluate the effects of past droughts***.** Identify how drought has affected the region, group, or ecosystem. Consult climatological records to determine the "drought of record," the worst in recorded history, and project what would happen if a similar drought occurred this year or in the near future, considering changes in land use, population growth, and development that have taken place since that drought.

*Rank impacts***.** Determine which of drought's effects are most urgently in need of attention. Various considerations in prioritizing these effects include cost, areal extent, trends over time, public opinion, social equity, and the ability of the affected area to recover.

*Identify underlying causes***.** Determine those factors that are causing the highest levels of risk for various sectors, regions, and populations. For example, an unreliable source of water for municipalities in a particular region may explain the impacts that have resulted from recent droughts in that area. To reduce the potential for drought impacts in the future, it is necessary to understand the underlying environmental, economic, and social causes of these impacts. To do this, drought impacts must be identified and the reason for their occurrence determined.

*Identify ways to reduce risk***.** Identify actions that can be taken before drought that will reduce risk. In the example above, taking steps to identify new or alternative sources of water (e.g., ground water) could increase resiliency to subsequent episodes of drought.

*Write a "to do" list***.** Choose actions that are likely to be the most feasible, cost-effective, and socially equitable. Implement steps to address these actions through existing government programs or the legislative process.

The choice of specific actions to deal with the underlying causes of the drought impacts will depend on the economic resources available and related social values. Typical concerns are associated with cost and technical feasibility, effectiveness, equity, and cultural perspectives. This process has the potential to lead to the identification of effective and appropriate drought risk reduction activities that will reduce long-term drought impacts, rather than ad hoc responses or untested mitigation actions that may not effectively reduce the impact of future droughts.

5.3. Mitigation and response

Mitigation is defined as short- and long-term actions, programs, or policies implemented during and in advance of drought that reduce the degree of risk to human life, property, and productive capacity. The types and forms of mitigation activities vary from one natural hazard to another. Drought-related mitigation actions are, for the most part, different from those used for other natural hazards because of the insidious nature of the hazard and the non-structural characteristics of many of the impacts. In contrast to mitigation, response actions are those taken once an area is experiencing severe drought and are intended to address impacts and expedite recovery of the affected area. One of the tasks of the Risk Assessment Committee is to identify mitigation actions that could be taken to lessen the risk associated with future drought events for each of the principal impact sectors. The goal is to emphasize mitigation over emergency response actions because the latter does little to reduce risk and may actually increase vulnerability to drought through increased dependence on government or donor intervention.

Wilhite (1997) completed an assessment of drought mitigation technologies implemented by U.S. states in response to drought conditions. These actions were clustered into nine primary areas: (1) monitoring and assessment; (2) legislation and public policy; (3) water supply augmentation; (4) public education programs; (5) technical assistance; (6) demand reduction; (7) emergency response; (8) water use conflict resolution; and (9) drought planning. The transferability of these actions to specific situations in other countries needs to be evaluated further because they may not be directly transferable in some cases. These actions are available on the NDMC web site (http://drought.unl.edu/mitigate/policy/mitig.htm#analysis).

6. Conclusions

Drought preparedness and management are effective strategies to reduce risks and therefore the impacts associated with droughts. Preparedness for drought necessitates greater institutional capacity at all levels of government and more efficient coordination between different levels of government. Preparedness also implies increasing the coping capacity of individuals and communities to deal with drought events.

Most commonly, there are three components in a drought plan: monitoring and early warning; risk assessment; and mitigation and response. Given the improved tools and technologies available today, it is possible to provide drought information that enables action to maximise the probability of successful crop production and/or minimise the potential damage to established crops and other assets. To this end, information should be provided on the timing, intensity and duration and the spatial extent of droughts. An equally important element of drought early warning systems is the timely and effective delivery of this information to decision makers. To provide effective drought information, there should be improved collaboration among scientists and managers to enhance the effectiveness of observation networks, drought monitoring, prediction, information delivery, and applied research. Such a collaboration could help foster public understanding of and preparedness for drought.

References

Alley, W. M., 1984. The Palmer Drought Severity Index: limitations and assumptions. Journal of Climate and Applied Meteorology, 23:1100-1109.

Coughlan, M.J. 1987. Monitoring drought in Australia. Pages 131-144 In: (D.A. Wilhite and W.E. Easterling with D.A. Wood. Eds.) Planning for Drought: Toward a Reduction of Societal Vulnerability. Boulder and London: West View Press.

Crowe, P.R. 1971. Concepts in climatology. London, UK: Longman. 135 pp.

Edwards, D. C. and T. B. McKee, 1997. Characteristics of 20th Century drought in the United States at multiple time scales. Climatology Report Number 97-2, Colorado State University, Fort Collins, Colorado.

Gibbs, W. J. and J. V. Maher, 1967. Rainfall deciles as drought indicators. Bureau of Meteorology Bulletin, No. 48, Commonwealth of Australia, Melbourne.

Hagman, G. (1984). Prevention Better than Cure: Report on Human and Natural Disasters in the Third World, Swedish Red Cross, Stockholm.

Hayes, M.J. 1999. Drought indices. National Drought Mitigation Center. http://enso.unl.edu/ndmc.

McKee, T. B., N. J. Doesken, and J. Kleist, 1993. The relationship of drought frequency and duration to time scales. Preprints, 8th Conference on Applied Climatology, 17-22 January, Anaheim, CA, pp. 179-184.

Palmer, W. C., 1968. Keeping track of crop moisture conditions, nationwide: the new Crop Moisture Index, Weatherwis*e*, 21:156-161.

Palmer, W. C., 1965. Meteorological Drought. Research Paper No. 45, U.S. Department of Commerce Weather Bureau, Washington, D.C.

Wilhite, D. A. 1997. State Actions to Mitigate Drought: Lessons Learned. Journal of the American Water Resources Association: 33(5): 961-968.

Wilhite, D.A. 2000. Drought as a Natural Hazard: Concepts and Definitions (Chapter 1, pp. 3-18). *In:* Wilhite, D.A. (ed.) Drought: A Global Assessment (Volume 1), Routledge Publishers, London, U.K.

Wilhite, D.A. and M.D. Svoboda. 2000. Drought Early Warning Systems in the Context of Drought Preparedness and Mitigation. In: D.A. Wilhite, M.V.K. Sivakumar, and D.A. Wood (eds.). *Early Warning Systems for Drought Preparedness and Management*. World Meteorological Organization, Geneva, Switzerland.

Wilhite, D.A. and O. Vanyarkho. 2000. Drought: Pervasive Impacts of a Creeping Phenomenon (Chapter 18). In: D.A. Wilhite (ed.), Drought: A Global Assessment, Natural Hazards and Disasters Series, Routledge Publishers, UK.

U.S. Drought Monitor

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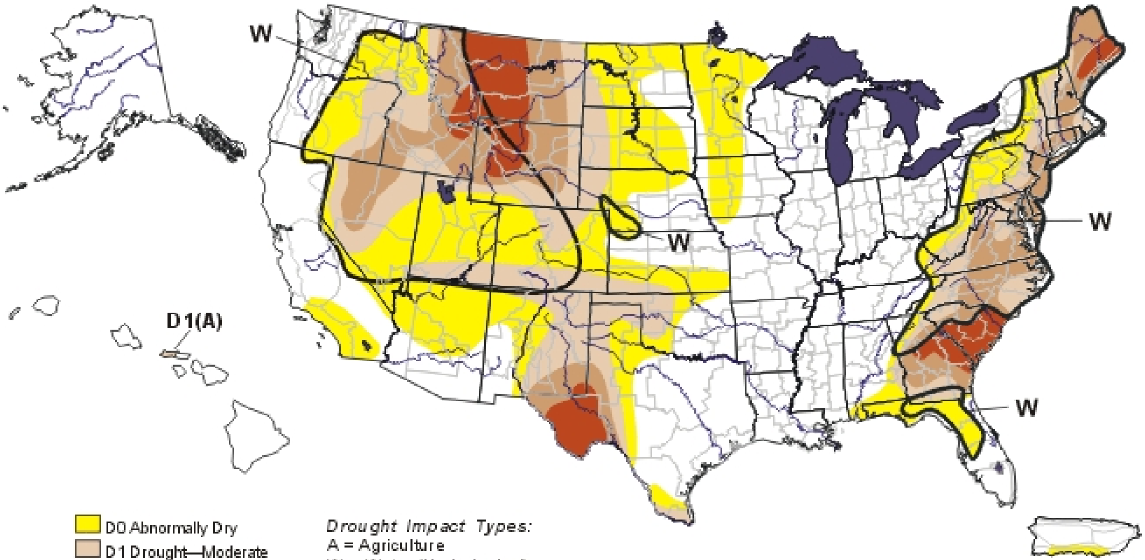

D0 Abnormally Dry
D1 Drought—Moderate
D2 Drought—Severe
D3 Drought—Extreme
D4 Drought—Exceptional

Drought Impact Types:
A = Agriculture
W = Water (Hydrological)
F = Fire danger (Wildfires)
Delineates dominant impacts
(No type = All 3 impacts)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/monitor/monitor.html

USDA National Drought Mitigation Center

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