Presentation of Drought Information in Agrometeorological Bulletins

M.V.K. Sivakumar[1]

Abstract

Drought is an insidious natural hazard with serious implications for the economic well being of the farming community. The overall goal of providing drought information in agrometeorological bulletins is to enable and persuade people and organisations to take action to maximise the probability of successful production in agriculture, forestry and fisheries and/or minimise the potential damage to established crops, forests and other assets. A number of components 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 and analysis of the risk of the phenomenon and its likely effect on agricultural production. Information on drought intensity can be presented in a number of different ways including the use of drought indices such as the Deciles, the Palmer Drought Severity Index, the Crop Moisture Index and the Standardized Precipitation Index. A brief description of each of these indices is presented. 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.

Introduction

Of all the extreme meteorological events affecting agriculture and forestry, drought is perhaps the most important hazard with serious implications for the economic well being of the farming community. Drought disrupts cropping programs, reduces breeding stock, and threatens

[1] Chief, Agricultural Meteorology Division, World Climate Programme Department, World Meteorological Organization, 7bis Avenue de la Paix, Case postale 2300, Ch-1211 GENEVA 2, Switzerland
Tel.: +41 22 730 8380, Fax: +41 22 730 8420, Email: msivakumar@wmo.int

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.

Since there are a large number of direct and indirect economic, environmental and social impacts of droughts, there is a clear necessity to convey information on droughts in a timely and useful manner in the agrometeorological bulletins that are routinely issued by the National Meteorological and Hydrological Services (NMHSs). Some of the key issues in the presentation of drought information and the different methods and tools available to prepare such information are presented here.

Drought - the concept

In any discussion on the preparation and presentation of information concerning a natural hazard, 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.

Goals and objectives for presentation of drought information

The overall goal of providing drought information in agrometeorological bulletins is to enable and persuade people and organisations to take action to maximise the probability of successful production in agriculture, forestry and fisheries and/or minimise the potential damage to established crops, forests and other assets.

Accomplishment of this goal requires not only precipitation data on a temporal and spatial scale suitable for effective interpretation of the nature and extent of droughts, but also information on the stage of crop/forest growth and the degree of sensitivity of crops/forests to droughts that are currently occurring and to droughts that may prolong into the future. Hence it is important that NMHSs establish a strong liaison with the agricultural research and extension agencies in the country to provide comprehensive information that could be useful to the user community in their applications.

The ultimate objective of presenting drought information in the agrometeorological bulletins is to enable governments and organizations to develop a pro-active response to droughts. 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. It is precisely these actions which are targetted by comprehensive drought information presented in agrometeorological bulletins.

Components of drought information

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.

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.

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 is now gaining increasing popularity and is being used in several 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.

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.

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.,

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. The Drought Monitor is a synthesis of several different climate indices and parameters.

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:

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

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

Analysis of the risk of the phenomenon and its likely effect on agricultural production.

As the drought information presented in the bulletins is primarily to assist the farming community in making operational decisions regarding the management of their farming systems, it is very important to provide a short analysis of the risk of the ongoing drought phenomenon and how it is likely to affect the agricultural activities. Any suggestions made for changes in operational activities must take into account the availability of inputs (where needed) and give sufficient lead time for farmers to take corrective action. In this regard, it would be useful to interact closely with the extension agencies active in the region. It is equally important to bring to the attention of planning agencies any important aspects of ongoing droughts and their likely impacts to assist them in making appropriate adjustments in their regional/national plans.

Conclusions

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. 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.

Willeke, G., J. R. M. Hosking, J. R. Wallis, and N. B. Guttman, 1994. The National Drought Atlas. Institute for Water Resources Report 94-NDS-4, U.S. Army Corps of Engineers