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Drought Network News

Winter 1999–Spring 2000

A Newsletter of the International Drought Information Center and the National Drought Mitigation Center

Volume 12 No. 1

Did you know . . .

. . . that *Drought Network News* is also available online at

http://enso.unl.edu/ndmc/center/publish.htm

as a .pdf file. It's presented in the same format that you see here. Mailing costs for distributing the newsletter are substantial, and they continue to increase as our mailing list grows, so we would like to encourage you to accept *Drought Network News* in its electronic format. If you're willing to forgo your paper copy of the newsletter, please let Kim Klemsz (kklemsz2@unl.edu) know, and she will send you e-mail notification when new issues are available. Thank you!!

From the Director

I hope that those of our readers with Internet access will consider receiving future issues of *Drought Network News* online. We realize that some of you do not have access to the Internet, so we will continue to publish hard copies of the newsletter. If you are willing to receive the newsletter electronically, please contact Kim Klemsz as soon as possible. Our plan is to notify readers via e-mail when each new issue of *Drought Network News* is available. Back issues of the newsletter are also available online.

This is a joint winter/spring issue of *Drought Network News*. It contains considerable discussion about drought indices and a description of a new product, the Drought Monitor, that is available on

Published in cooperation with the World Climate Program of the WMO

the World Wide Web. This new product is the result of a partnership formed in spring 1999 between the Joint Agricultural Weather Facility of the U.S. Department of Agriculture, the Climate Prediction Center of the National Oceanic and Atmospheric Administration, and the National Drought Mitigation Center at the University of Nebraska. The Drought Monitor integrates climate information and information from a variety of indices to determine drought severity across the United States. This product is updated weekly and has been well received by technical specialists, policy makers, the media, and commercial groups. I encourage readers to visit the Drought Monitor website (http://enso.unl.edu/monitor/) to learn more about this activity and to consider how this approach might be modeled for other countries or regions.

As some of you know, for the past two years I have been involved in the preparation of a book on drought. This book, *Droughts: A Global Assessment*, was published in two volumes in December 1999 by Routledge as part of a series on natural hazards and disasters. Routledge will eventually publish seven books as part of this series. Another volume, *Storms*, is also available, and a volume on floods should be available very soon. A more detailed description of *Droughts* is provided on page 21 of this issue.

Readers are encouraged to submit articles, announcements of workshops and conferences, and other information of interest to our network members to *Drought Network News*. **The deadline for submission for the next issue is May 25, 2000**.

Donald A. Wilhite

Contents

Characteristics of Drought in Kerala, India

Kerala state in India, which is the first area of the country to experience the southwest monsoon, has a moist and wet climate. Kerala is in the extreme southwestern part of the Indian subcontinent; it borders Karnataka state in the north, Tamil Nadu in the east, and the Arabian Sea in the west (Figure 1). The entire state is one of the 35 meteorological subdivisions in India.

Kerala's climate is tropical monsoon and tropical savanna, according to Koppen's climatic classification (Figure 1). The state normally experiences excessive seasonal rainfall, with hot summers (except in the extreme southern districts like Trivandrum, where dry season and hot summer climate prevails). The three main seasons of the state are the hot season (March–May), southwest monsoon season (May–September), and northeast monsoon season (October–February).

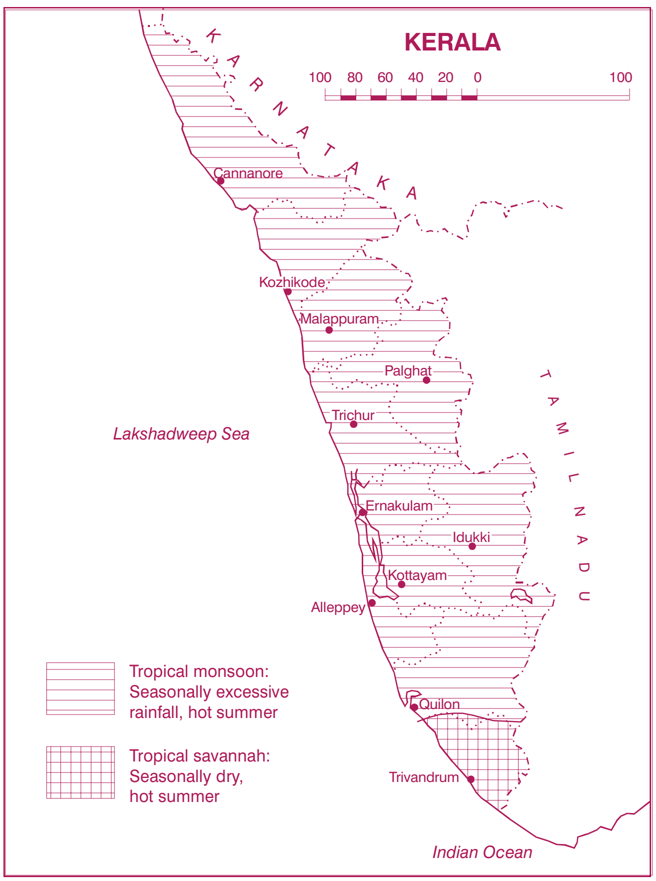

Figure 1. Climatic classification of Kerala.

The annual rainfall of the state varies from 3,800 mm over the north to 1,800 mm in the extreme south. The potential rainy season for Kerala is the southwest monsoon period, which contributes more than 80% of the annual rainfall. The monsoon rain decreases from the north to the south. In recent years, a trend of decreasing rainfall has been seen both in seasonal rainfall and 10-day extreme rainfall duration.

There is significant rainfall variation in north and south Kerala. North and south Kerala have two rainfall distribution subzones. In north Kerala, northeast monsoon rainfall shows a decreasing trend and contributes about 15% of the annual rainfall. This may adversely affect cultivation of the second rice crop in the area. Southwest monsoon rain, which contributes 82% of the area's total rainfall, does not show any increasing trend. Similarly, in south Kerala, southwest and northeast monsoon rains have decreased by 5% and 8.3%, respectively. Mean annual rainfall is also decreasing in south Kerala.

The decreasing rainfall over the region, late onset of the monsoon, failure of the monsoon, and break in the monsoon in the state lead to many drought situations. Kerala had severe dry spells and droughts in 1983, 1985, 1986, and 1987, even though the state has a wet climate. There were dry spells of 5 and 4 weeks in 1985 and 1986, respectively, during the southwest monsoon period.

Damage due to drought was particularly significant in Kerala in 1987. About 1,500 villages in 14 districts were affected, and 9.82 lakh[1] hectares of cropland and 6 lakh cattle were also affected. During January–May 1987, the entire Kerala region was affected by drought. About 30% of the rabi season

[1] 1 lakh = 100,000

paddy crop was lost, and cash crops like coconuts, arcanuts, cashews, and bananas were damaged, resulting in a loss of Rs. 1,000 crores.

Kerala also experienced a significant drought in 1983. About 323,000 hectares of paddy were lost, at an estimated cost of Rs. 106.86 crores. Other major cash crops affected were coconuts, rubber, coffee, and tea. In Ernakulam district of Kerala, 36,000 hectares of paddy were lost; in Tiruchur, 33,000 hectares were lost. Coconut losses of Rs. 14 crores and Rs. 11 crores were reported in Kozikode and Trivandrum districts and Kottayam district, respectively. In 1989, drought resulted in the loss of 60% of the cropped area in Kerala, and about 3 million kilograms of tea, worth one crores rupees, withered under stress and drought.

Figure 2 shows the departure of seasonal rainfall from normal for different years (1981–87) in the region. Summer rains were deficient (-80%) in 1983. The southwest monsoon was about 40% of normal during 1989 in the state. Similarly, the northeast monsoon was highly deficient in 1986. Large rainfall deficiencies in the various districts of the state are shown in Table 1. Figures 3a–3c reveal large water deficits in almost all of the representative stations during December to April. The seasonal dry period and water deficits led to severe dry spells and droughts.

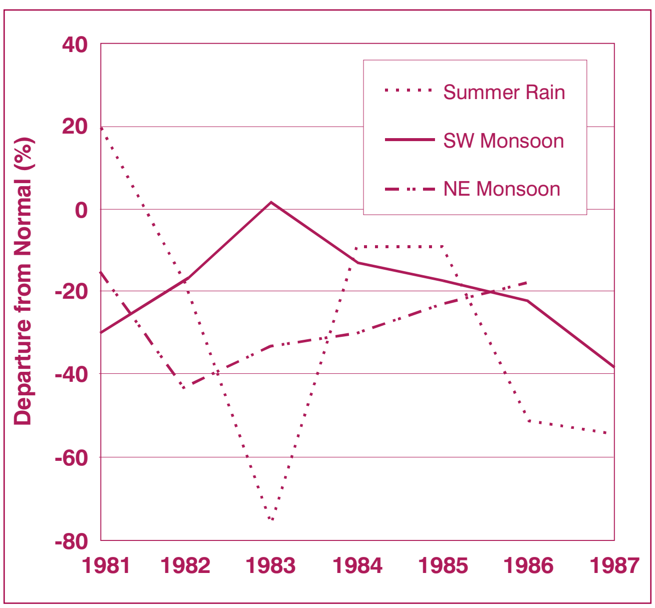

Figure 2. Precipitation departure from normal for Kerala, 1981–87.

Districts	1983	1984	1985	1986	1987
Alleppey	21	-17	-5	-26	-17
Cannanore	-5	-2	1	-15	-35
Ernakulam	16	9	1	19	-24
Idukki	-20	-3	1	1	-45
Kasargode	NA	-3	-14	-8	-33
Kottayam	-28	-15	-14	-15	-28
Kozikode	15	-7	-5	-14	-43
Mallapuram	12	19	-7	-18	-50
Palghat	17	4	2	-8	-48
Pattinamathi.	NA	-24	-21	-35	-50
Quilon	29	-18	-5	-21	-29
Trichur	2	-4	-5	-25	-23
Trivandrum	-22	-57	-29	-44	-37
Wayanad	-16	9	-18	-31	-68

Table 1. Percentage departure of rainfall from normal for districts of Kerala.

The low pressure waves from the east (the Gulf of Thailand), which move across the South Bay of Bengal toward Tamil Nadu, may temporarily increase rainfall over Kerala. Also, an upper tropospheric easterly jet stream with an axis of 12°N is believed to influence the rainfall over the state. However, a detailed study is needed to determine this.

During weak monsoons and droughts in Kerala, the orographic contribution is almost nil, but this is not attributed to a weaker westerly component during the dry spell. The Nepha (or cloud) analysis from satellite pictures over Kerala also gives good information about drought. During 1966, a year of weak monsoons and drought, satellite pictures showed a zone of cloudiness shifting far into southern India. During drought situations over the state, there is no high-level moving system of waves in the upper tropospheric easterlies.

During the drought of 1966, high-level wave flows were more or less straight easterly flows with less speed variation than in a good strong monsoon season. Cloud analysis during active and strong monsoons such as occurred in 1967 shows at least 7 oktas of cloudiness on any given day over the state, extending from the interior of the southern peninsula across

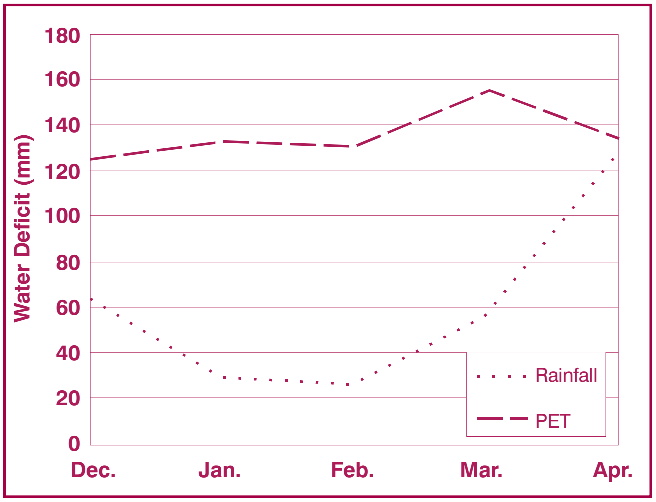

Figure 3a. Seasonal water deficit, Alleppey, Kerala.

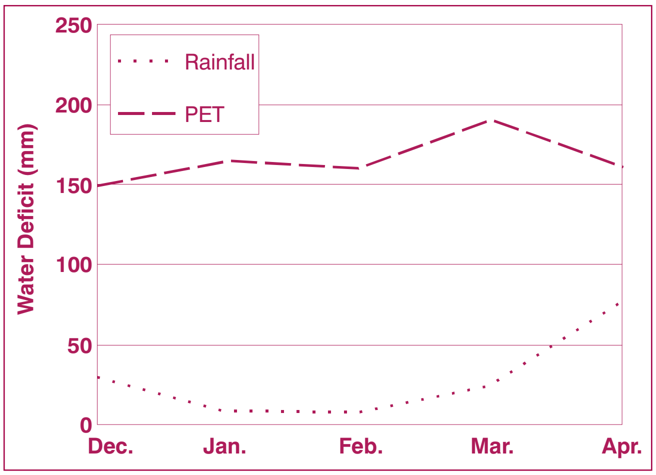

Figure 3b. Seasonal water deficit, Palghat, Kerala.

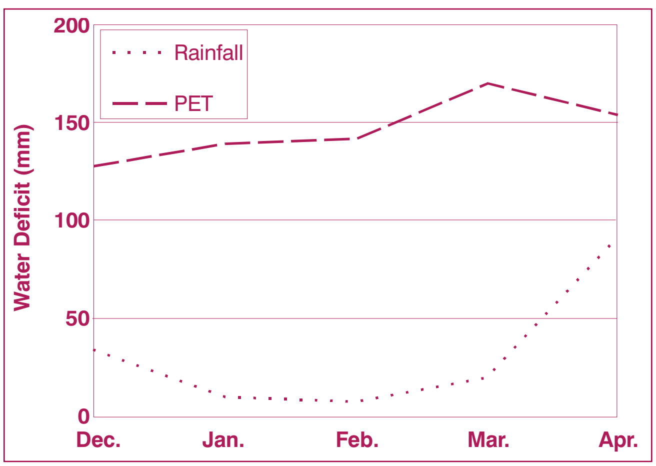

Figure 3c. Seasonal water deficit, Calicut, Kerala.

Kerala southward and westward (1,200 km from the Kerala coast of the Arabian Sea). There is also a secondary maxima of 7 oktas of cloudiness south of the equator. This type of situation did not exist during the 1966 drought over the state. Thus cloud analysis and orographic rainfall patterns may give a good indication of the drought situation in a wet state like Kerala.

K. K. Nathan
Water Technology Centre
Indian Agricultural Research Institute
New Delhi 110 012
India

Using the SPI to Identify Drought

This article was written in response to the recent analysis of drought in Turkey by Komuscu (1999). The study showed the relationship between drought duration, drought frequency, and drought time scale using the Standardized Precipitation Index (SPI):

$$SPI = \frac{(X_{ik} - \overline{X}_i)}{\acute{o}_i}$$

where

$\acute{o}_i$ = standardized deviation for the ith station
X_{ik} = precipitation for the ith station and kth observation
$\overline{X}_i$ = mean precipitation for the ith station

The index has the advantages of being easily calculated, having modest data requirements, and being independent of the magnitude of mean rainfall and hence comparable over a range of climatic zones. It does, however, assume the data are normally distributed, and this can introduce complications for shorter time periods. Komuscu claims that the SPI has not been widely applied or tested and employs the drought classes suggested by McKee et al. (1995), reproduced here in Table 1.

The SPI is of course the same as the Standardized Rainfall Anomaly, defined by Jones and Hulme (1996) and widely used in the analysis of desiccation in drylands. Figure 1 shows a typical example of such use, depicting the widely reported downward trend in Sahelian rainfalls (only continental Sahelian stations are employed after the suggestions of Ba et al. [1995], Janicot et al. [1998], and Nicholson and Palao [1993] that other parts of West Africa belong to a different climate regime). Komuscu's assertion that the SPI is underused for drought assessment appears to be correct, in that it is the persistence of the negative anomalies that receives most attention rather than an examination of their intensity or impact (for example, see Hulme, 1992). That is, rainfall anomalies are used to investigate desiccation rather than drought (see Agnew, 1995, for further discussion). The purpose of this paper is then to question the values assigned to the SPI for drought classes and to suggest alternative, more rational thresholds. The effect of using different drought classes is investigated using annual rainfalls from the Sahelian region of West Africa, and the

SPI	Probability of occurrence	Komuscu (1999) and McKee et al. (1995) drought classes	Proposed new drought classes
Less than -2.00	0.023	Extreme drought	
Less than -1.65	0.050		Extreme drought
Less than -1.50	0.067	Severe drought	
Less than -1.28	0.100		Severe drought
Less than -1.00	0.159	Moderate drought	
Less than -0.84	0.201		Moderate drought
Less than -0.50	0.309		No drought
Less than 0.00	0.500	Mild drought	No drought

Table 1. Probabilities for different standardized rainfall anomalies.

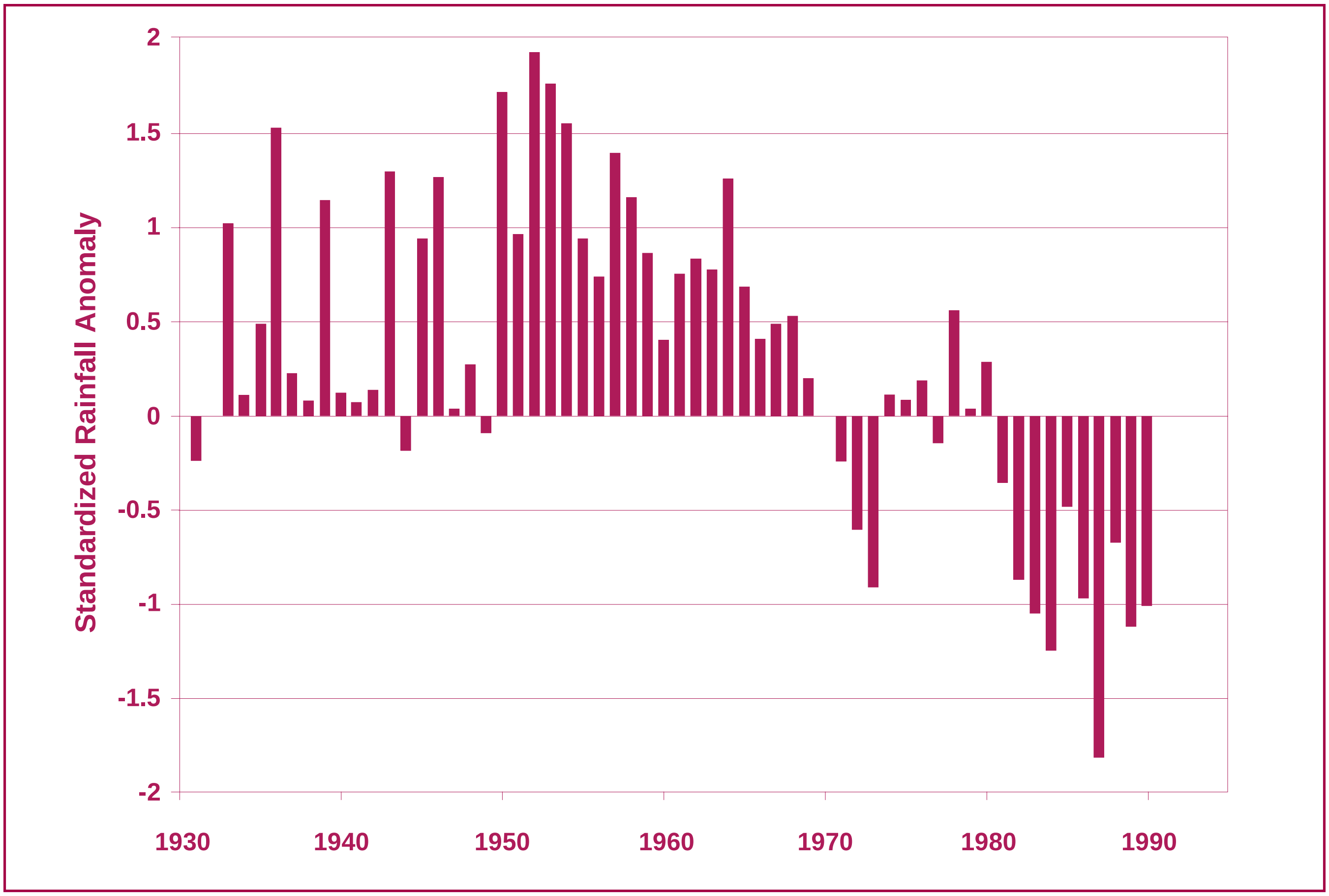

Figure 1. Standardized annual precipitation anomalies for the continental Sahel (Burkina Faso, Mali, and Niger), using the 1961–90 base period.

problem of changing the base averaging periods is presented.

What is Meteorological Drought?

This question has been addressed time and again (Agnew and Anderson, 1992; Wilhite, 1993), and it has often been stated that no universal definition of drought exists. There is little to be gained by reproducing a long list of conflicting definitions that merely illustrate the diverse interests of those who investigate drought. Most definitions anyway can be resolved into a generic statement that drought is caused by an imbalance between water supply and demand. Hence drought can be defined in terms of both supply reduction and demand increase, and there are numerous definitions of hydrological, agricultural, ecological, and economic drought that demonstrate this. Many, however, agree with Palmer (1965) and Beran and Rodier (1985) that drought is essentially a meteorological phenomenon. The analysis below adopts this perspective—that examining the occurrence of meteorological drought is the most fundamental requirement of any investigation.

The second premise of this account is that drought is an abnormal occurrence. This is an equally important point and it is the reason why it is suggested that Table 1 should not be used without modification for drought analysis. In McKee's classification (McKee et al., 1995), all negative indexes (SPI) are taken to indicate the occurrence of drought; this means for 50% of the time, drought is occurring. This is clearly nonsense! It also raises the notion of "persistent drought," which confuses drought with desiccation.

Based on Warren and Khogali (1992), drought can be distinguished from desiccation as follows:

- Drought occurs when moisture supply is abnormally below average for periods of up to 2 years.
- Desiccation is a period of aridization brought about by climate change lasting decades. Thus drought requires short-term relief, whereas desiccation requires longer-term measures such as resettlement and land use change.

When desiccation takes place, one can expect an increase in drought frequency, but a definition of drought that assumes any precipitation below the mean constitutes a drought will lead to exaggerated claims for climate change. Better that drought is defined as an abnormal event and that a significant change in climate is required for drought to become persistent.

New SPI Intensity Classes

The occurrence of drought has been widely reported for southern England in the 1990s, giving rise to concerns about low flows in the rivers of the region (Marsh et al., 1994; Acreman and Adams, 1998):

> The Environment Agency reported today that groundwater levels are so low in South East England that the environment and water supplies will be at risk next year if the weather remains drier than average this winter. *(Env. Agency Press Release 04/11/1997:113/97)*

Approaches to the definition of low flows can be divided into those that examine flow statistics, those that model hydrological processes, and those that employ biological/habitat conditions. Procedures for low flow estimation in gauged and ungauged catchments have been produced for the United Kingdom by the Institute of Hydrology (Gustard et al.,

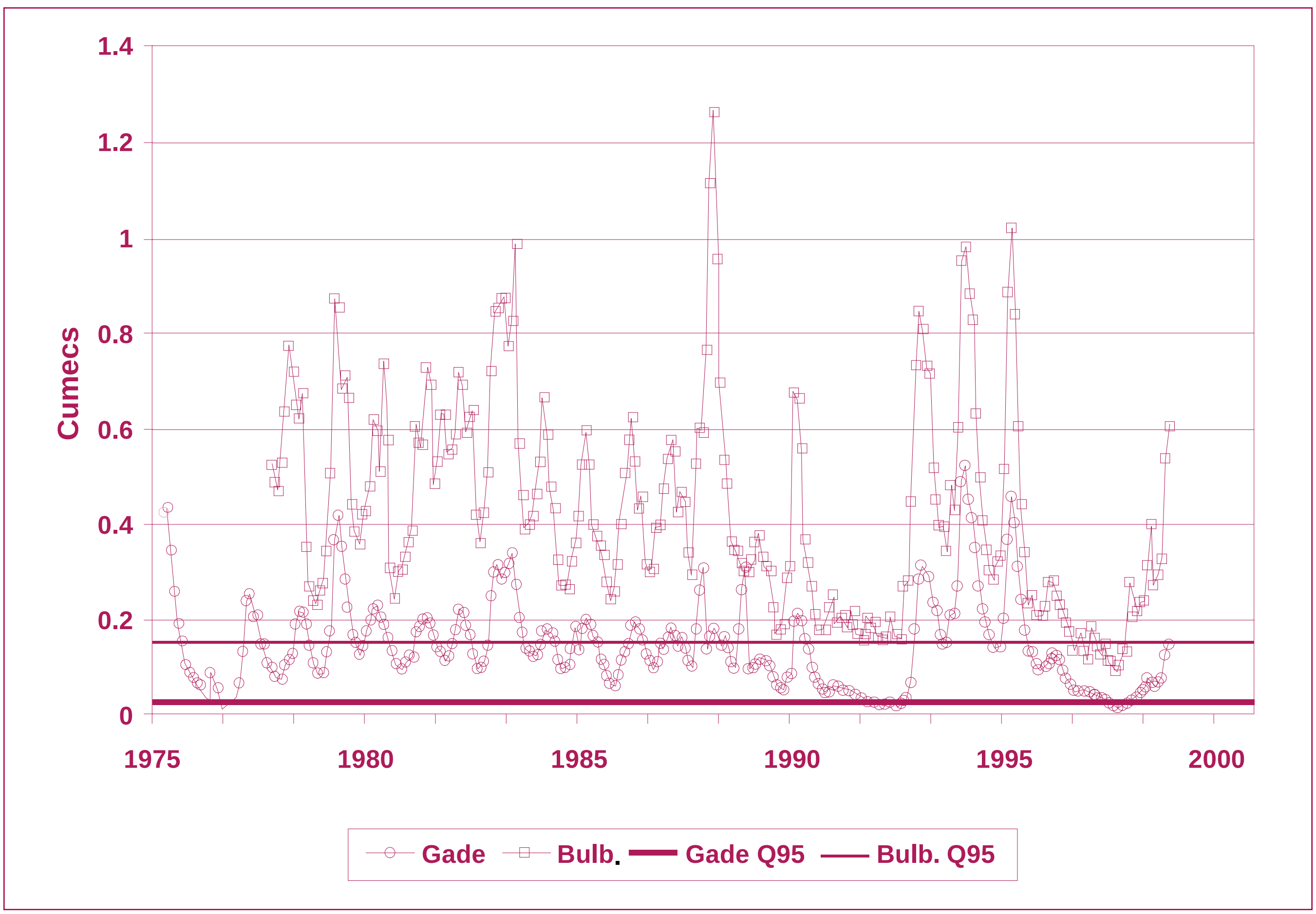

Figure 2. Daily flows for the Bulbourne and Gade rivers in Hertfordshire, with low flow thresholds Q95 plotted.

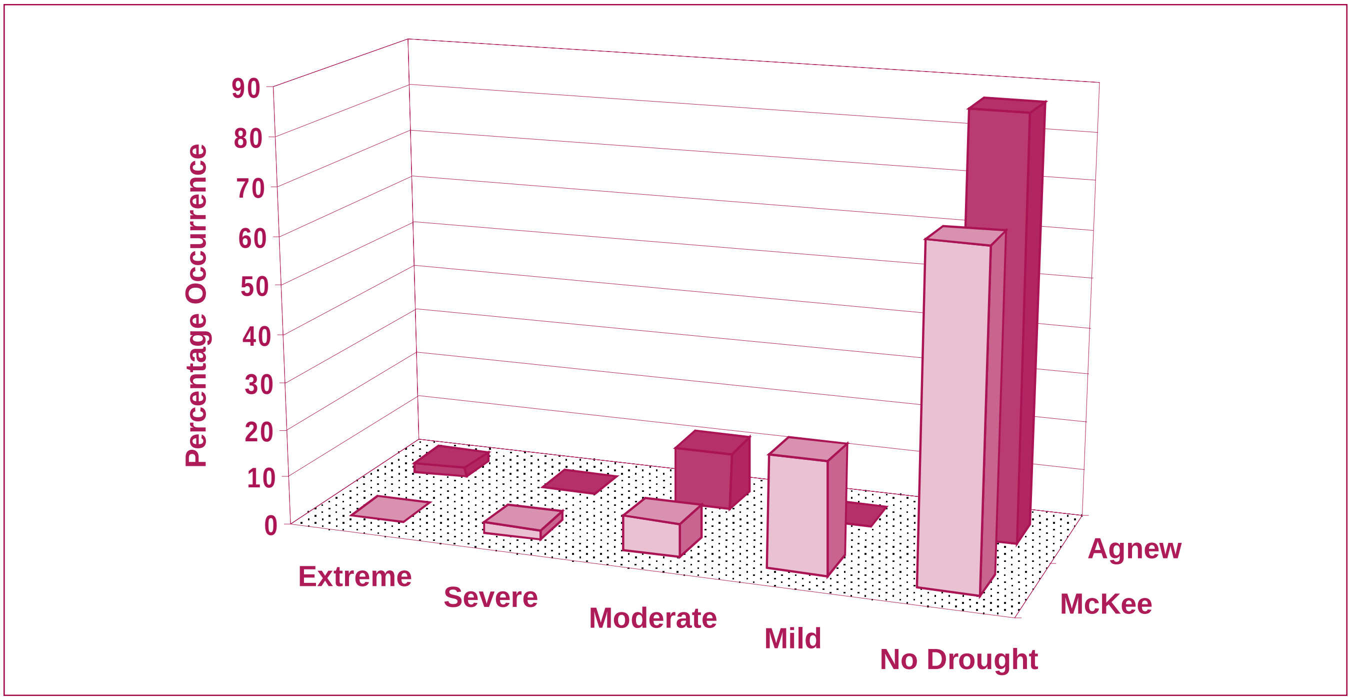

Figure 3. Drought classes (McKee et al., 1995, and author) for annual rainfalls in the continental Sahel region between 1931 and 1990, based on the 1961–90 averaging period.

1992). Claussen (1995) summarized the statistical approaches for low flow determination in gauged catchments:

- 7-day minimum (annual and 10-year minimum)
- 1-day minimum (median annual)
- 90% and 95% percentile exceedance
- Base flow index (ratio of baseflow to total flow)

The Q95(1) (the 95 percentile from the 1-day flow duration curve) is commonly used and is calculated here for two drought-prone rivers, the Gade and the Bulbourne, which flow in catchments some 40 km north of London. The Environment Agency (1997, p. 54) described conditions in this region:

> The cause of low flows in rivers is attributable to a combination of factors, which include lack of rainfall . . . seasonal fluctuations in the chalk water table, and water abstraction . . . Over the period October 1996 to September 1997, rainfall and groundwater recharge in the East Chilterns [were] 88% and 51% of the long-term average respectively.

Figure 2 shows the 1990s increase in low flows in these rivers and the use of the Q95 threshold to demarcate abnormal deficits (curiously, annual rainfalls have been increasing in this region during the 20th century, but the winter to summer rainfall ratio has also increased, as low rainfalls in summer are now more frequent). It is suggested that climatologists should learn from their hydrologist colleagues and employ a threshold similar to Q95 for defining meteorological drought.

The SPI drought thresholds recommended here therefore correspond to 5%, 10%, and 20% probabilities. Hence drought is only expected 2 years in 10 and extreme drought only 1 year in 20. This, it is believed, is a more realistic drought frequency than that used by Komuscu, and it corresponds to the employment of the term *abnormal occurrence*, as used in other branches of environmental science.

The impacts of changing the drought class boundaries are exemplified in Figure 3, based on the data used to draw Figure 1. It is evident that little change is made for extreme drought conditions, but the most important effect is to reduce the incidence of mild meteorological droughts. It may seem curious that there are a large number of no-drought years (68% or 86% for McKee et al. [1995] or the author's classes, respectively) given the widespread reports of drought

Drought class	McKee et al. (1995)	1961–90 base period	1931–60 base period	Agnew	1961–90 base period	1931–60 base period
	SPI value	McKee	McKee	SPI value	Agnew	Agnew
Extreme	<-2	0	1	<-1.65	1	3
Severe	<-1.5	1	5	<-1.28	0	6
Moderate	<-1.0	4	5	<-0.84	7	6
Mild	<0	14	30			
None	>0	41	19	>-0.84	52	45
Total		60	60		60	60

Table 2. The probability of different drought intensity classes based on the SPI, over the period 1931–60 for the continental Sahel.

in the Sahelian region (e.g., Nicholson and Palao, 1993, p. 371): "The Sahelian region of West Africa is well known for the extreme droughts it experiences. The current one has prevailed since the late 1960's." D'Amato and Lebel (1998, p. 956) note the "prolonged drought that has struck the Sahel for 25 years now."

Table 2 provides an explanation. The standard period for computing climatological averages has recently been changed by the WMO from 1931–60 to 1961–90 (Hulme, 1992). Because the 1940s and 1950s were wetter than normal in the Sahel, using a base period of 1931 to 1960 to calculate the SPI produces a higher average and hence a greater incidence of drought. Thus there are 41 no-drought years between 1931 and 1990, using McKee's classes (McKee et al., 1995) for the 1961–90 base period, but this drops to only 19 no-drought years using the 1931–60 base period. There is much less change using the author's suggested drought classes because shifting the base period largely affects drought classes that are closest to the mean rainfall. Thus the drought classes suggested by McKee are highly sensitive to the base averaging period. Nevertheless, no matter which drought classes are used, there is some impact in changing to the new 1961–90 averaging period, and in a recent analysis (Agnew and Chappell, 1999) it was found that more than 40 years of data were required to compute the mean rainfall in the Sahel that was independent of the base averaging period.

A final point concerning the use of the SPI as employed here is that it was used to compute average conditions across the region known as the continental Sahel. Thirty-five stations were used from Burkina Faso, Mali, and Niger. Figure 4 shows the standardized rainfall anomalies from Figure 1, but with the maximum and minimum anomalies from individual stations superimposed. The huge variations, both negative and positive, suggest that care needs to be exercised when using the SPI as a spatially averaged index and that it would be better to compute the occurrence for each station rather than the approach employed above of averaging anomalies.

Conclusions

A new classification for drought intensity has been proposed based on the Standardized Precipitation Index (SPI). This uses probability classes rather than magnitudes of the SPI for classification and is therefore suggested as a more rational approach. The effect is most noticeable at the demarcation of mild and moderate droughts. There are, however, significant flaws in this approach. First, it is based on a designation of what is abnormal. In drylands it is difficult to calculate precipitation averages with any certainty and it has been suggested that the use of the 1961–90 thirty-year averaging period is questionable.

The approach also takes no account of impacts. If the resilience of people or the ecosystem has been diminished, then even a moderate drought can have an impact. Downing (1992) has referred to this as "vulnerability," and this changes between parts of the community (e.g., children compared to adults) and

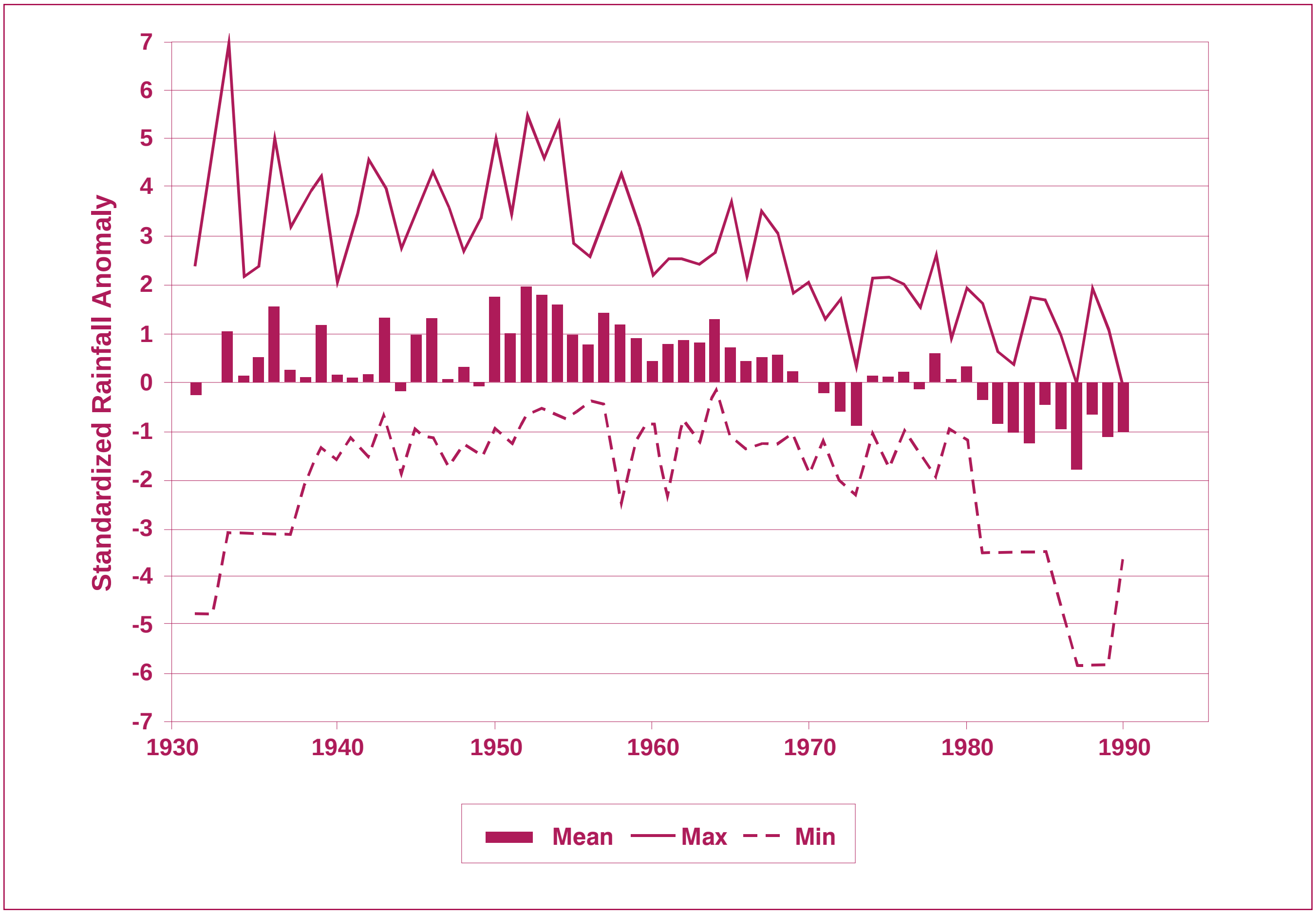

Figure 4. Average standardized precipitation anomalies for the continental Sahel using the 1961–90 base averaging period and the maximum and minimum anomalies observed at individual stations.

through time. Hence purely statistical definitions of meteorological drought should be treated with caution. Perhaps of equal significance is the omission within the SPI of any assessment of persistence. It is rare that drought in any one year causes major hardship. It is the sequence of low rainfalls that creates difficulties. For example, in England the drought of 1976 was really caused by the low rainfalls in the preceding year, while the drought of 1992 was the result of the low rainfalls from 1988. The SPI therefore needs to be developed from merely classifying intensities to include drought sequences, and the selection of appropriate averaging periods needs more attention.

Acknowledgments

The annual rainfall totals were generously provided by the Climate Research Unit at the University of East Anglia. The river flow data was provided by the Environment Agency, United Kingdom.

C. T. Agnew
Department of Geography
University College London
26 Bedford Way
London
WC1H OAP
United Kingdom

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Revisiting the SPI: Clarifying the Process

The number of applications using the Standardized Precipitation Index (SPI) around the world continues to increase (e.g., Agnew, pp. 6–12 of this newsletter, and Komuscu 1999). However, there are relatively few publications explaining the SPI, and occasional misconceptions about the index have occurred.

When the SPI was first developed by McKee et al. (1993, 1995), it was meant to address some of the limitations that exist within the Palmer Drought Index (PDI). These first publications were relatively simple introductions of the SPI to the scientific community, appearing in the *Proceedings* of the Eighth and Ninth Applied Climatology Conferences, respectively, sponsored by the American Meteorological Society. In both cases, the authors define the SPI as the "difference of precipitation from the mean...divided by the standard deviation." It is this equation, given by Komuscu (1999) and repeated by Agnew, that causes confusion about the SPI.

Agnew is correct to point out that the "difference of precipitation from the mean divided by the standard deviation" standardizes the data and has been called the "Standardized Rainfall Anomaly" by Jones and Hulme (1996). Variations of standardized rainfall anomalies have been used with data sets, especially analyzing African rainfall. It is important to point out, however, that this is not the SPI! There is a difference between standardizing precipitation data using the equation above and the SPI, and it is easy to miss this difference. In the cases of McKee et al. (1993, 1995) and Komuscu (1999), the authors briefly mention that the long-term data sets used to determine the SPI at any time scale must first be normalized. Readers of these articles may overlook this step. The normalization procedure using a probability distribution is a very important feature of the SPI and makes it unique. Edwards and McKee (1997) first highlight this important distinction and give a detailed description of how this is done for the SPI. People will frequently ask, "What is the equation of the SPI?" Edwards and McKee (1997) illustrate that it is more of a "process" to determine an SPI value.

In 1998, Guttman wrote an article comparing the SPI with the PDI that contained a more detailed explanation about determining the SPI. Hayes et al. (1999) also contains a detailed description of the process. Guttman (1999) went into the specifics about different probability distributions applied to the long-term data sets and examined the impact of six distributions on the SPI. The recommendation from Guttman (1999) is that the Pearson Type III distribution is "best" suited to normalize the long-term data sets when calculating the SPI. Edwards and McKee (1997) used the two-parameter gamma distribution to calculate the SPI. Guttman (1999) also recommended that the procedure be uniform for everyone so that applications of the SPI would be consistent. Different software versions to determine the SPI are now available from Colorado State University and the National Climatic Data Center.

Agnew makes another very good point about identifying appropriate drought categories, and points out that the initial categories identified in the original McKee et al. (1993, 1995) articles had a location for any time period in some stage of "drought" 50% of the time. Table 1 below shows the NDMC modifications to the categories identified by Agnew in his table on p. 6 of this issue. The term *dry* is used because that is more appropriate for short time scales, and the categories reflect the lower percentages that should occur with dry periods, especially with the labels *severe* and *extreme*. These categories are also the basis for the monthly national SPI maps that are displayed on the National Drought Mitigation Center's website (http://enso.unl.edu/watch/). Guttman (1999) uses the same categories. The Western Regional Climate Center

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**

Table 1. SPI values.

uses a slightly different set of categories in monthly national SPI maps displayed on their website (http://www.wrcc.sage.dri.edu/spi/spi.html). Finally, Agnew suggested the classification of categories based on the 5%, 10%, and 20% occurrence probabilities, which is also a very good system (see Agnew's second table on p. 10 of this issue).

In his article, Agnew brings up another important point that needs to be emphasized. Precipitation normals do shift at all locations depending on the period being considered "normal." Such shifts would certainly have an impact when standardizing precipitation data, but they also can affect the SPI. This is why it is hoped that the data sets of 100 years, or as long as possible, could be used in determining the SPI. Guttman (1999) recommends at least 50 years of data to compute SPI values for time periods smaller than 12 months, and a longer record to compute multiyear SPI values is desired.

Finally, Agnew reminds everyone that indices based on precipitation alone do not take into account specific drought impacts. These impacts will vary based on the vulnerability of the society and environment of each particular region. The SPI and other indices are only tools to help decision makers understand events that are taking place. It is good to have one or more of these tools, but the decision makers have to become familiar with how to apply these tools and understand their strengths and limitations in local situations.

The articles by Komuscu (1999) and Agnew demonstrate that the number of drought monitoring applications using precipitation indices is increasing. We welcome the discussion of indices and their applications in future issues of *Drought Network News*. It is very important that this information relating to "lessons learned" from a drought monitoring perspective is shared with the drought planning community.

Michael Hayes
National Drought Mitigation Center
239 L. W. Chase Hall
University of Nebraska–Lincoln
Lincoln, Nebraska 68583–0749
USA
e-mail: mhayes2@unl.edu

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An Introduction to the Drought Monitor

Origins

The idea of better monitoring and assessing drought has been a quest of NDMC director Don Wilhite for more than two decades. He has been an advocate of better climate monitoring, particularly drought monitoring, because drought is a normal, recurring hazard in virtually all of the United States. The challenge is to recognize drought, a slow-onset or "creeping" natural disaster, before a region is in the middle of one.

The most recent surge in interest in drought arose during the 1995–96 drought in the Southwest and southern Great Plains states. At the NDMC we discussed how we could do a better job of tracking and assessing the severity of droughts. One question we often hear is "How does this drought compare, or rank, to other droughts or the drought of record for this region or state?" Or "Just how strong or severe is this drought?" These are complicated questions to tackle. We have to take into account spatial extent, intensity, duration, and impacts on people and the affected environment. That discussion is for another time.

For purposes of understanding vulnerability or risk, another question we have tried to address is "What is the degree of usualness or unusualness of various droughts now and in the past?" How frequently or rarely do we see a drought of this magnitude, and does it occur often enough that we should plan for it rather than simply acknowledge it when it occurs? In short, can we define the difference between perception and reality? Our hope is that the Drought Monitor and future research will begin to let us find some of the answers to these questions.

Until recently, there were no comprehensive nationwide efforts to consolidate or centralize drought monitoring activities being conducted by or between various federal, state, or regional entities. In the summer of 1998, I began to correspond with Doug LeComte, senior meteorologist with the National Centers for Environmental Prediction/Climate Prediction Center (NCEP/CPC), who shared his ideas with us on how we might come up with a classification system for droughts, much in the same way the Fujita Tornado Intensity Scale (F0–F5) categorizes tornadoes and the Saffir-Simpson Hurricane System (Category 1–5) rates hurricane strength. Based on LeComte's first draft, and with the help of others, we worked on a classification scheme criteria, and as a result the Drought Monitor was created.

In spring 1999, Don Wilhite and I met with scientists at the U.S. Department of Agriculture's Joint Agricultural Weather Facility (USDA/JAWF) and the National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA/CPC) to discuss working together to address the issue of tracking drought. How could we better collaborate and implement an integrated drought monitoring system? The signing of the National Drought Policy Act in the summer of 1998 and the subsequent formation of the National Drought Policy Commission (NDPC) and its working groups in 1999 no doubt helped speed up the process and fueled interest in such an effort. Monitoring and Prediction was one of the NDPC working groups. Many of the key players in the climate monitoring realm were exposed to the Drought Monitor concept and initial prototypes through this working group. We introduced the drought classification system to them and welcomed the many suggestions that followed in this informal peer review process.

As a result of the meetings in spring 1999, an agreement was reached between the NDMC, USDA, and NOAA to produce and maintain a drought monitoring product that would incorporate climatic data and professional input from all levels. Requests for input were initially sent out to National Weather Service field offices. This was followed up by contacting NOAA's six regional climate centers (RCCs). We have invited state climatologists to comment on and review the weekly product (both map and narrative). Our intent was to create a general assessment of drought conditions in the United States using the most relevant and current data that each entity involved had to offer. The selected data were then put into an experimental product using a new drought classification system approach. The first experimental drought map was put out for internal review and comment in May 1999. An e-mail exploder group was set up and is maintained at the NDMC. This allows all reviewers and authors of the product to discuss and share their relevant expertise, viewpoints, and concerns.

The experimental tag was short-lived. The Drought Monitor quickly evolved into a more permanent product as a result of the efficient partnerships between USDA, NOAA, NDMC, RCCs, and a few state climatologists. No doubt the drought in the Northeast in summer 1999 provided an extra incentive for the map. The Drought Monitor was officially launched at a joint White House press conference between the Department of Commerce (NOAA) and USDA in August 1999. The Drought Monitor had gone from an experimental bi-weekly map to a full-fledged operational product in a few months. With the support of USDA's chief meteorologist, the National Drought Mitigation Center at the University of Nebraska–Lincoln agreed to set up and maintain the home page for the Drought Monitor (http://enso.unl.edu/monitor/monitor.html).

Since its unveiling, the Drought Monitor has been well received by people from a wide variety of backgrounds and trades. The media has been especially quick to pick up on and use the new product to inform their readers and listeners. Producers, commodity brokers, congressional delegations, and federal/state agencies also are using this product. They seem to like the simplicity and ease of use of the product (see Figure 1), rather than having to learn about another new index.

The Concept

The Drought Monitor consists of a color map, showing which parts of the United States are suffering from various degrees of drought, and accompanying text. The text describes the drought's current impacts, future threats, and prospects for improvement. The Drought Monitor is a synthesis of several different scientific drought indices. It is by far the most user-friendly national drought monitoring product, and it is particularly well suited for use by mainstream media because it represents state-of-the-art scientific expertise and is packaged as a timely, colorful, unambiguous map. Currently, the World Wide Web is the main means of distributing the Drought Monitor. NOAA also distributes the map through their internal channels. The obvious advantages to using the web are that there are no distribution costs and the information is instantly available and always current. The obvious disadvantage is that not everyone has access to the web. Our focus to this point has been how to best disseminate the product in the most timely manner.

No single definition of drought works in all circumstances, so water planners rely on indices or data in various forms, and most often depicted in map or graphic form, to recognize droughts. The authors of the Drought Monitor also rely on the input of several key indices and ancillary indicators from different agencies to create the final map, which is posted each Thursday. The seven key parameters making up the current scheme are the Palmer Drought Index, Crop Moisture Index, CPC Soil Moisture Model (percentiles), USGS Daily Streamflow (percentiles), Percent of Normal Precipitation, USDA/NASS Topsoil Moisture (percent short and very short), and a remotely sensed Satellite Vegetation Health Index. The final color map summarizes all of this information in an easy-to-read format that shows where drought is emerging, lingering, and subsiding.

Classification: D0–D4

The idea is to classify droughts on a scale from zero to four (D0–D4), with zero indicating an abnormally dry area and four reflecting a region experiencing an exceptional drought event (likened to a drought of record). The drought intensity categories are based on six key indicators and many supplementary indicators. The Drought Monitor summary map and narrative identify general drought areas, labeling droughts by intensity from least to most intense. D0 areas (abnormally dry) are either drying out and

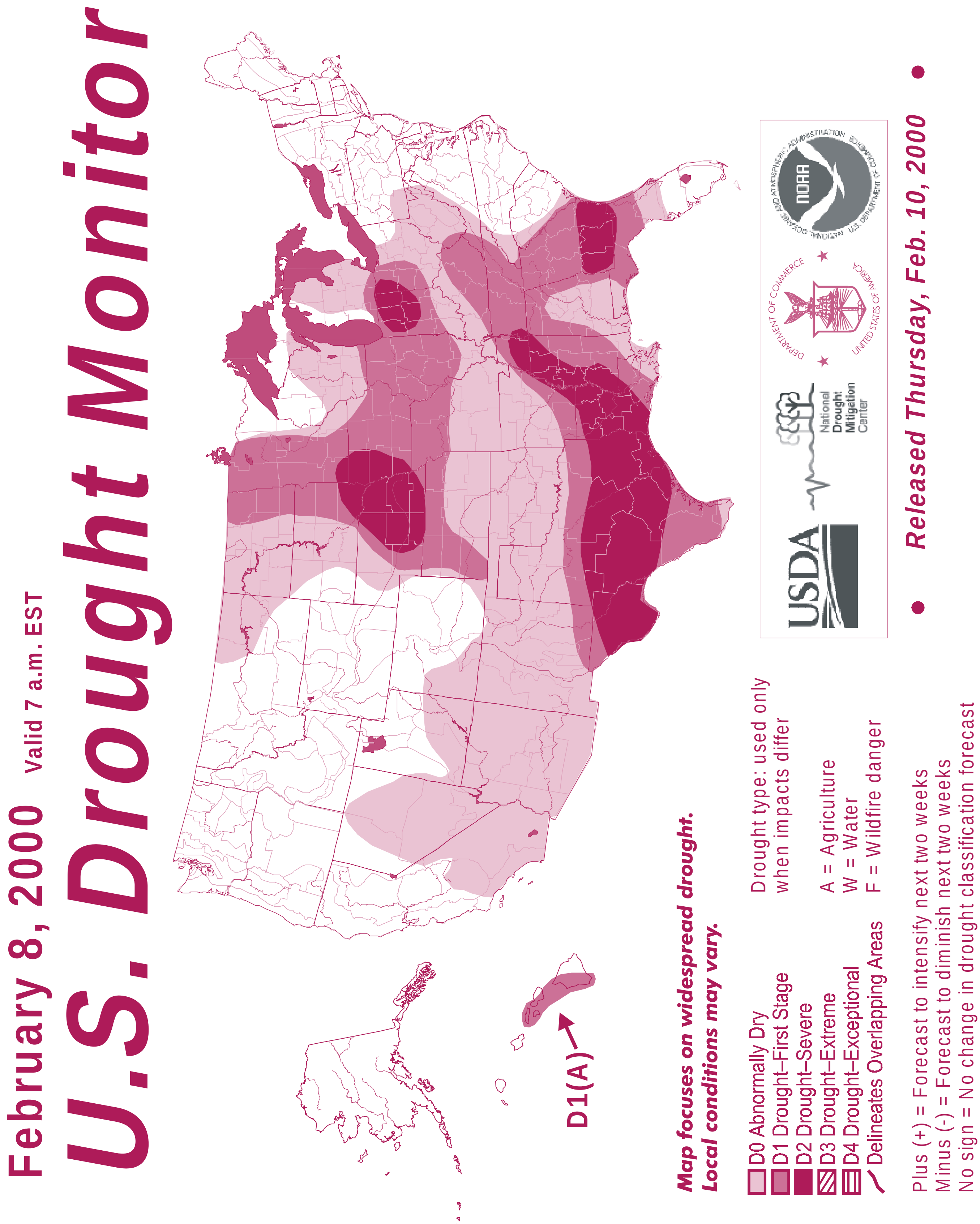

Figure 1. The Drought Monitor (http://enso.unl.edu/monitor/monitor.html).

possibly heading into drought or recovering from drought but still experiencing lingering impacts (or not yet back to normal or wet conditions).

Categories: A, W, and F

The Drought Monitor also shows which sectors are presently seeing the majority of impacts due to drought, using labels of *A*, *W*, or *F*. An *A* represents impacts on agriculture (crops, livestock, range or pasture). Water (*W*), or hydrological, impacts show that the region is experiencing an impact on some part of the water supply system. In determining whether to use this label, we look at how droughts affect streamflow, snowpack, groundwater, and reservoirs. An *F* is used when abnormally high risks of fire danger are observed.

Forecasts

We use the two week forecasts (5 day and 6–10 day) to determine if the drought is intensifying or dying out. Intensifying drought is indicated by a plus (+) sign after the drought classification; decreasing drought is indicated by a minus (-) sign after the drought classification.

An Example

An area shaded and labeled as D2 + (A) is in general experiencing severe drought conditions that are affecting the agricultural sector but at present are not affecting water supplies. The area is not seeing a heightened fire risk in association with this dryness. In addition, the drought looks like it will intensify in the next two weeks, according to the forecasts.

Droughts are generally slow in developing and can be slow in receding, but there are cases (like the hurricanes in the Northeast this past summer) in which a drought-breaking type of event can speed up the recovery process. Even after the physical event is over, impacts may linger for months or years, depending on the timing, duration, and intensity of the drought. Efforts are underway to better forecast, with higher confidence, further into the future.

Currently, seasonal forecasts issued by the CPC are taken into account, but they are not used in determining intensity trends. We do know that some strong relationships exist between dryness or drought in certain parts of the United States, depending on the season and whether or not we are in an El Niño or La Niña phase. The relationship isn't nearly as strong, however, in the continental grain-producing regions that make up our corn and wheat belts. The problem is addressing the non-phase year, especially in the summer. In fact, the summer months are the toughest to predict, regardless of whether an ENSO event is taking place. Today's models are much better than ever before, and they will continue to improve as computing power increases and we better identify and understand the complex relationships that exist between our oceans, continents, and atmosphere.

Classification Parameters

Table 1 illustrates the drought severity classification system that exists now. The system was intended to be flexible, allowing it to continually evolve by responding to and incorporating the latest technologies and data available in the monitoring world.

The Future

The CPC has been experimenting with blending up to three inputs to produce a weighted objective drought index, but this is continually going through adjustments and is only one part of the equation we look at when making the Drought Monitor. We expect to see CPC and others improve the accuracy and confidence of forecasts at all time scales. This process and product are still evolving as both monitoring and forecasts improve. For example, we also hope to integrate USDA and other soil moisture network data into the Drought Monitor in the near future. Interestingly, it is the availability and input of these parameters (i.e., soil moisture) that in turn serve as inputs into better models at better resolutions. We

Table 1. Drought severity classification.

Category	Description	Impacts	Palmer Drought Index or Crop Moisture Index	CPC Soil Moisture Model (Percentiles)	Daily Streamflow (Percentiles)	Percent of Normal Precipitation	USDA/ NASS Topsoil Moisture (% short & very short)	Satellite Vegetation Health Index
D0	Abnormally Dry	Short-term dryness slowing planting, growth of crops or pastures; fire risk above average; or recent drought relief, some lingering water deficits; pastures not fully recovered	-.6 – -1.9	21–30	21–30	<50% 30 days	25–50%	36–45
D1	Drought	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent; or voluntary water-use restrictions in some locations	-2.0 – -2.9	11–20	11–20	50-60% 2–3 months	51–65%	26–35
D2	Severe Drought	Moderate crop or pasture losses likely; fire risk very high; water shortages common; or water restrictions imposed in many areas	-3.0 – -3.9	6–10	6–10	40-50% 3–4 months	66–80%	16–25
D3	Extreme Drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or water restrictions	-4.0 – -5.0	2–5	2–5	30-40% 4–5 months	81–90%	6–15
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, wells creating water emergencies	-5.0 or less	0–1	0–1	<40% 6 months	>90%	1–5

would like to include seasonal (long-lead) forecasts in the Drought Monitor to give people as much information as possible (and as soon as possible) to use in decision making.

Although the maps are based on many inputs, the final maps are tweaked to reflect real-world conditions as reported by numerous experts throughout the country. States or water suppliers may be looking at our indicators while also using many other local data resources and tailored drought triggers. Our intent is not to replace any local or state information or subsequently declared drought emergencies or warnings. Instead, we are providing a general assessment of the current state of drought around the United States, Pacific possessions, and Puerto Rico.

We hope we have found a way to better picture this "freeze-frame" disaster and relay the information to users. Ultimately, it is the users who determine how to use the information; it is our job to provide them with the best available data and product in a timely fashion.

Mark Svoboda
National Drought Mitigation Center
107 L. W. Chase Hall
University of Nebraska–Lincoln
Lincoln, Nebraska 68583–0749
USA
e-mail: msvoboda2@unl.edu

Announcements

New Books

Droughts: A Global Assessment

Droughts: A Global Assessment has been published in two volumes by Routledge as part of a series of definitive works on major hazards and disasters. The series is being published to mark the end of the International Decade for Natural Disaster Reduction.

Donald Wilhite of the National Drought Mitigation Center is the editor of *Droughts*. More than 75 leading international researchers in the field contributed to the volume. Through an extensive range of case studies covering the most drought-prone and most drought-affected countries, the contributors examine new technology, planning methodologies, and mitigation actions from recent drought experiences worldwide.

Following a discussion of the critical concepts of drought, the book is divided into seven additional parts that address causes and predictability; monitoring and early warning techniques; impacts and assessment methodologies; adjustment and adaptation strategies; policy, mitigation techniques, and preparedness methodologies; links between drought and other global issues; and conclusions and future challenges. With its emphasis on both the physical and social dimensions of drought and proposed management actions and policies, this volume will be helpful to those seeking a greater understanding of this complex natural hazard.

The cost of the two-volume set is US$275/UK£225. The ISBN (International Standard Book Number) of *Droughts* is 0–415–16833–3. In North America, copies may be ordered from Routledge at 1 (800) 634–7064. Routledge's United Kingdom customer hotline is 01264 342939 (+44 1264 342939), or fax: 01264 343005 (+44 1264 343005). Their website is www.routledge.com.

Proceedings of the National Workshop on Dynamic Crop Simulation Modeling for Agrometeorological Advisory Services

The *Proceedings of the National Workshop on Dynamic Crop Simulation Modeling for Agrometeorological Advisory Services* has been published. The workshop was conducted at the National Centre for Medium Range Weather Forecasting (NCMRWF), Department of Science and Technology, New Delhi, in January 1999. The volume includes papers presented at the workshop on various themes of crop modeling and the recommendations that evolved from the deliberations of the workshop. S. V. Singh, L. S. Rathore, S. A. Saseendran, and K. K. Singh are the editors; the volume is published by the NCMRWF. For further information and copies of the publication, please contact Dr. S. A. Saseendran, Scientist, NCMRWF, DST, Mausam Bhavan, Lodi Road, New Delhi–3, India; e-mail: saseendransa@hotmail.com.

Conferences

Central and Eastern European Workshop on Drought Mitigation

The Central and Eastern European Workshop on Drought Mitigation will be held April 12–15, 2000, in Budapest, Hungary. The workshop is being presented by the Ministry of Agriculture and Rural Development; Ministry of Environmental Protection; and Ministry of Transport, Communication and Water Management of the Hungarian Republic.

The workshop will provide a forum for discussing various aspects of drought monitoring, strategies, impact assessment, and mitigation, with special regard to the central and eastern European (CEE) region. Topics will include the status of national drought mitigation strategies in the CEE countries and impacts of drought on different areas of the economy. For more information, contact the Budapest Station for Plant Health and Soil Conservation, Department of Informatics, Budaörsi út 141–145, H–1118 Budapest, Hungary; telephone: (36–1) 309–1000; fax: +36–1–246–2942.

11th Global Warming International Conference and Expo

The 11th Global Warming International Conference and Expo will be held April 25–28, 2000, in Boston, Massachusetts. The objective of the conference is to provide a comprehensive international and interdisciplinary review forum for resource and technology managers on global warming, its impacts on all economic sectors, its effective mitigation, and each nation's compliance with the Kyoto Protocol to reduce greenhouse gas emissions. Topics include Global Warming and Climate Change; Global Surveillance: Climate Future; Education: Global Change; Human Health in a Changing Climate; Energy and Natural Resource Management; International Law and Policy Making; and State and Local Government Actions. For more information, contact the Global Warming International Center, P.O. Box 5275, Woodridge, Illinois 60517–0275, USA; fax: +1 630–910–1561; website: http://GlobalWarming.net.

New Products

GLOBE Data Set

The NOAA National Geophysical Data Center (NGDC) has released the Global Land One-kilometer Base Elevation (GLOBE) digital elevation data set. GLOBE is an international effort to create a global digital elevation model on a nominal 1-kilometer grid. Source data for GLOBE include satellite imagery, aerial photography, satellite altimetry, cadastral survey data, and hardcopy topographic maps converted to digital format. There are two versions of GLOBE: an unrestricted version with full global coverage and no copyright or security restrictions on its distribution, and a version with high-quality data that honors copyright. GLOBE data can be obtained via the web and as a CD collection. GLOBE data, documentation, and visualizations are available at no charge at http://www.ngdc.noaa.gov/seg/topo/globe.shtml. The CD-ROM collection (four CDs), with documentation, is available from NOAA/NNDC/National Geophysical Data Center. For more information, contact the National Environmental Satellite, Data, and Information Service, NOAA National Data Centers, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, USA; telephone: (303) 497–6277; e-mail: seginfo@ngdc.noaa.gov; website: http://www. ngdc.noaa.gov/store/.

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Drought Network News is published three times a year by the International Drought Information Center (IDIC) and National Drought Mitigation Center (NDMC). The IDIC and NDMC are part of the School of Natural Resource Sciences at the University of Nebraska–Lincoln. Funding for the newsletter is provided by the International Activities Division, National Weather Service/NOAA, through their cooperative program with the World Meteorological Organization, and Cooperative State Research, Extension, and Education Service, U.S. Department of Agriculture.

Drought Network News encourages readers to submit information on current episodes of drought and its impacts; timely reports of response, mitigation, and planning actions of governments and international organizations (successes *and* failures); recent research results and new technologies that may advance the science of drought planning and management; recent publications; conference reports and news of forthcoming meetings; and editorials. If references accompany articles, please provide *full bibliographic citations*. All artwork *must* be *camera-ready*—please provide clear, sharp copies (in black/gray and white only—we are unable to reproduce color artwork) that can be photocopied/reduced without losing any detail. Correspondence should be addressed to

Drought Network News
IDIC/NDMC
239 L. W. Chase Hall
University of Nebraska
P.O. Box 830749
Lincoln, NE 68583–0749
USA

Telephone: (402) 472–6707
fax: (402) 472–6614
e-mail: ndmc@enso.unl.edu
www: http://enso.unl.edu/ndmc

Subscriptions to ***Drought Network News*** may be obtained, free of charge, by contacting Kim Klemsz at the street or e-mail address or the telephone or fax number to the left.

Director: Donald Wilhite
Climate Impacts Specialist: Michael Hayes
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