The 1987–88 Drought in Selected North-Central United States: The Dimensions of Precipitation Deficiency

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ABSTRACT

The north-central United States, namely Iowa, Minnesota and Wisconsin, experienced a severe drought during 1987–88 crop year. Monthly precipitation data of the crop year (September through August) were analyzed for 58 stations over the period 1964–65 through 1987–88 to quantify the intensity and extent of this drought. With the exception of a narrow strip in northern Minnesota the entire study area was affected by this drought. More than 92 percent of the stations experienced seven to eleven months of precipitation deficiency during this drought. Approximately 50 percent of the study area experienced precipitation deficiency of over 30 percent. South-central Iowa was affected severely with precipitation deficiency in excess of three standard deviations below normal, an extreme event that may occur one year in over 500 years.

KEY WORDS: Midwest, upper Mississippi basin, precipitation deficiency, drought, weather.

INTRODUCTION

Drought is a complex and naturally occurring phenomenon of widespread significance. It is also a temporary feature of the climatic system of a given region (Olapido 1985), which is usually caused by precipitation deficit (Gregory 1986). Intensification of precipitation deficits, which may result in drought conditions, may be triggered by changes over the rainy season or the year as a whole (Dennett et al. 1985; Gregory 1983).

The states of the upper Mississippi basin, namely Iowa, Minnesota and Wisconsin are contained within the upper part of the Mississippi River drainage system. This region is a major producer of basic products such as corn, dairy products, beef, and pork, all of which are affected by the amount and variability of precipitation. The tri-state area was severely affected by the drought of 1987–88 causing significant reduction in (a) crop yields which, in turn, affected the agriculture-related industries, including
crop insurance industry (Kunkel and Angel 1989, Changnon 1990), (b) barge traffic on the Mississippi (Changnon 1989), and (c) municipal water supplies in some communities (Kunkel and Angel 1989). The chronological development of this drought was studied by Trenberth et al. (1988), which showed that the drought conditions prevailed on the west coast and northwestern parts of the United States as early as April of 1987. These conditions intensified on the west coast, and in the northern and southeastern parts of the United States by April, 1988. During the April–June period of 1988, the drought spread rapidly in the northeast, midwest and northern plains. Many areas of Iowa, Minnesota and Wisconsin experienced the driest April–August period in more than 100 years (Trenberth et al. 1988, Kunkel and Angel 1989). Possible causes of this drought were discussed by Trenberth et al. (1988) and Trenberth (1989). The interplay between the atmosphere and the sea surface temperatures (SST) over the eastern part of the equatorial and tropical Pacific was the ultimate cause of the drought of 1988 over the north-central United States. Below normal SST over the eastern part of the equatorial Pacific, and warmer than normal SST over the area east of Hawaii between 10° N and 20° N led to the formation of a lower than normal pressure along the west coast of North America and a strong anticyclone over the central United States. As a result, the jet stream was displaced farther to the north of its normal location, over Canada. Consequently, the southerly winds, carrying moisture from the Gulf of Mexico, were deflected to the southwestern United States, increasing summer monsoon activity there, and inhibiting precipitation in the north-central United States. It was asserted that the greenhouse effect was not the fundamental cause of this drought.

Although a drought can be recognized readily when it envelopes a given region, there is no universal definition of this term. A very simple definition may be a prolonged period with below normal precipitation. However, there is a problem of precisely defining a "pro-

longed period." In a humid region, with more or less evenly distributed precipitation during the growing season, a period of several weeks without precipitation may constitute a drought. On the other hand, in semi-arid areas like the Sahel region of west Africa, droughts may be recognized after two or three summer seasons without precipitation (Olapido 1985). Various characteristics of droughts, including definitions and their meteorological, hydrological and economic aspects were discussed by Doornkamp et al. (1980), Landsberg (1982), Gregory (1983), Dennett et al. (1985), and Olapido (1985), and reviewed extensively by Gregory (1986).

To quantify the climatological aspects of droughts, many indices have been developed which vary in their degree of complexity. The simple indices are based on the computation of deviation from normal or mean precipitation (Rooy 1965, Tabony 1977, Bhalme and Mooley 1980). The more elaborate crop-water parametric models incorporate land use management and soil moisture conditions for a homogeneous climatic region (Burt et al. 1981). The most complex is the Palmer drought index which incorporates rainfall, potential evapotranspiration, potential soil moisture recharge, and potential runoff (Palmer 1965). Olapido (1985) evaluated three types of indices of drought, ranging from very simple to very complex, and concluded that simple indices with precipitation as the only input, are as efficient as the complex ones in depicting the intensity of drought.

The dimensions of precipitation deficiency that affected the north-central United States during the drought of 1987–88 crop year are discussed in this paper. The study is based on the statistical analysis of monthly precipitation data of selected weather stations for a 24-year period to observe the spatial variation of the intensity and extent of precipitation deficiency during this drought.

DATA AND ANALYSIS

Monthly precipitation data of 58 weather stations for the crop year (Sep-
tember through August) for a 24-year period (1964–65 through 1987–88) were analyzed in this study. The data were obtained from the National Climatic Data Center in Asheville, North Carolina. The stations were selected in such a way as to represent a wide scatter over the study area (Fig. 1). Statistical analyses were performed on the data set to quantify the dimensions of precipitation deficiency during the drought of 1987–88 crop year.

The analyses included the following calculations: (1) the mean ($\bar{x}$); and (2) standard deviation ($\sigma$) of the crop year precipitation for the period 1964–65 through 1987–88; (3) precipitation deficiency in 1987–88 (i.e., deviation from the mean, $x - \bar{x}$, where $x$ is the precipitation amount in 1987–88); (4) percentage deviation of 1987–88 precipitation from the mean ($\frac{x - \bar{x}}{\bar{x}}$); and (5) the standardized deviation of 1987–88 precipitation from the

![STATION LOCATIONS](image-url)

Figure 1. Location of selected stations.
calculated standard deviation \( \frac{(x - \bar{x})}{\sigma} \), i.e. z-score (Taylor 1983).

DISCUSSION

Spatial distribution of the mean crop year precipitation between 1964-65 and 1987-88 in the north-central states of the U.S. is shown in Figure 2a. In general, precipitation amount was relatively highest in southeastern Iowa (over 90 cm) and decreased toward the north and northwest region of the study area. Northwestern Minnesota received the lowest amount, averaging less than 50 cm. Figure 2b illustrates the distribution of total precipitation in 1987-88 crop year. During this year, the southern part of Wisconsin received the highest precipitation amount, over 80 cm, and the lowest precipitation occurred in the

![Figure 2](imageurl)

Figure 2. Selected precipitation parameters.
northwestern and southern parts of Minnesota and southern parts of Iowa (less than 50 cm).

The deviation of 1987–88 precipitation from the mean is shown in Figure 2c. Almost the entire tri-state area received far-below-normal precipitation. Only a narrow strip, stretching from the Detroit Lakes area in the west-central Minnesota to the Winton area in the northeastern Minnesota, received above normal precipitation. Precipitation deficiency was as high as 40 cm or more in southern Iowa. The amount of below-normal precipitation alone is not the sole indicator of the intensity of drought, as depicted by Figure 2c. The percentage deviation of precipitation is a better expression for such events. Figure 2d shows the percentage deviation of 1987–88 precipitation from the mean crop-year precipitation. Approximately 50 percent of the upper midwest states experienced a precipitation deficiency of over 30 percent. It appears that the area extending from east-central Minnesota and adjoining Wisconsin to south-central Iowa experienced the greatest drought in 1987–88.

The temporal extent of the drought is shown in Figure 3. The graph shows the percentages of stations having various lengths (in months) of precipitation deficiency. More than 92 percent of the 58 stations experienced seven to eleven months of precipitation deficiency during the drought of 1987–88 (sum of the last five columns).

Figure 4 represents the spatial variation of standardized deviation of 1987-88 precipitation from the mean annual amount, which is a measure of the intensity of the drought. This figure shows how many times the precipitation deficiency of 1987–88 exceeded the calculated standard deviation. The standardized deviation has statistical probabilistic implications, as expressed by z-scores. It expresses how frequently the precipitation deficiencies of the magnitudes of 1987–88 drought may occur (Taylor 1983). For example, a value of 1.28 stan-
standard deviations means that the corresponding magnitude of precipitation deficiency may occur one year in ten. A value of 2.325 standard deviations means that the corresponding magnitude of precipitation deficiency may occur once in 100 years. A value of 2.88 standard deviations represents a probabilistic occurrence once in 500 years. It is clear that the drought was severe in the area extending from east-central Minnesota and adjoining Wisconsin to south-central Iowa. Precipitation deficiency in this area was greater than two standard deviations below normal. South-central Iowa was the most severely affected area with precipitation deficiency in excess of three standard deviations below normal, which is an extreme event that may occur one year in over 500 years.

CONCLUSIONS

The climatological dimensions of precipitation deficiency that affected the north-central United States (i.e. Iowa, Minnesota and Wisconsin) during the drought of 1987–88 were derived statistically from the monthly precipitation data of 58 stations for a 24 crop-year period (1964–65 through 1987–88). The results revealed that almost the whole study area received far-below-normal precipitation during the 1987–88 drought. Only a narrow strip that extends from the Detroit Lakes area in west-central Minnesota to
the Winton area in northeastern Minnesota received above normal precipitation. Approximately 50 percent of the tri-state area experienced a precipitation deficiency of over 30 percent. The area stretching from east-central Minnesota and adjoining Wisconsin to south-central Iowa was severely affected by this drought, with precipitation deficiencies greater than two standard deviations below normal. However, the greatest drought area was in extreme south-central Iowa where precipitation deficiency was greater than three standard deviations below normal. Such an extreme event may occur one year in over 500 years.

REFERENCES


