NWS-CR-TA-89-35

CRH SSD
OCTOBER 1989

CENTRAL REGION TECHNICAL ATTACHMENT 89-35

PERSPECTIVE ON THE 1988 MIDWESTERN DROUGHT[1]

Kenneth E. Kunkel and James R. Angel
Midwestern Climate Center
Illinois State Water Survey
Champaign, Illinois

The drought of 1988 had widespread impacts in the midwestern United States. Crop yields were reduced significantly. Barge traffic on the Mississippi, Missouri and Ohio rivers was severely disrupted. Municipal water supplies in some communities were reduced to critically low levels. In the face of these and other serious impacts, it is worthwhile to examine the climatological severity of this drought. For instance, was this drought comparable to the worst droughts in this century, as was frequently stated in news reports? Or, alternatively, were these serious impacts at least partially the results of a lack of flexibility in our socioeconomic system and in the experience of decision makers to adapt to serious drought.

This analysis encompasses the nine-state region of Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. This includes about 68 percent and 62 percent of the United States' corn and soybean acreage, respectively (USDA, 1987). The analysis was based on the daily temperature and precipitation data collected by the National Weather Service's cooperative observer climatological network. This is a dense network that now includes about 1500 stations in the region, which corresponds to an average separation distance of about 30 km in an area of about 10^6 km^2. Each state is separated into four to ten climate divisions. For some of the results presented here, climate division averages were used; this is simply the arithmetic average of all stations in that division. Historical climate division averages for individual months were obtained from the National Climatic Data Center (NCDC) for the period 1895-1987. (Because of the lack of available digitized climate data for years prior to 1931, the climate division averages for that period were estimated by NCDC from statewide averages using regression formulae based on 1931-1982 data. These earlier climate division values are therefore somewhat less reliable.) Region-wide (nine-state) average values were estimated by calculating an areally weighted mean of the climate division averages.

Table 1 shows the region-wide monthly precipitation for January-September of 1988 as a percentage of the 1951-1980 normal precipitation. Precipitation was somewhat below normal in the early part of the year, but deficits became larger as summer approached. May and June were extremely dry, with the region

---

1 Reprinted from EOS issued September 5, 1989.

receiving only about a third of the normal rainfall. July was somewhat wetter as a result of rains in the last ten days of the month, but still significantly below average. August was near normal; however, most of the rainfall occurred in the latter half of the month, too late to be of significant help to crops. The most unusual feature of this drought was the extreme dryness in the spring. It is very unusual in the Midwest for a dry period of this length to occur in the spring. The practical impact on agriculture was that the early crop development in May and June rapidly depleted the soil moisture reserves. By July, when crops reached their stage of maximum moisture usage, soil moisture reserves were severely depleted.

Table 1. 1988 Monthly Average Precipitation for a Nine-State Midwestern Region Expressed as a Percentage of Normal Precipitation

Month	% Normal Precipitation
January	94
February	89
March	77
April	68
May	45
June	28
July	78
August	100
September	110

Figure 1 shows the spatial patterns of precipitation as a percentage of the 1951-1980 mean for the prime growing season of April-August 1988. Virtually the entire area received less than 75 percent of average precipitation. An area in the heart of the corn belt (eastern Iowa, northern Illinois, and western Indiana) received less than 50 percent of average precipitation. The climate division averages for April-August 1988 were compared with the historical climatic division averages for the entire 1895-1987 period. Figure 2 gives the rank of April-August 1988 precipitation as compared with the 93 years of historical records. A rank of 1 indicates the driest. Of the 75 climate divisions, 55 have a ranking of 9 or lower, which puts 1988 in the driest 10 percentile of years for those climate divisions. Ten divisions experienced their driest April-August period on record. These were located in eastern Iowa, southern Wisconsin, northern Illinois, and western Indiana.

Figures 3 and 4 show similar rankings for two other periods. May-June and June-August, respectively. The May-June period was the driest of this drought episode, while the June-August period constitutes the traditional summer season. About 50 percent of the entire nine-state region (41 divisions) experienced the driest May-June on record. More than 85 percent had values in the driest 10

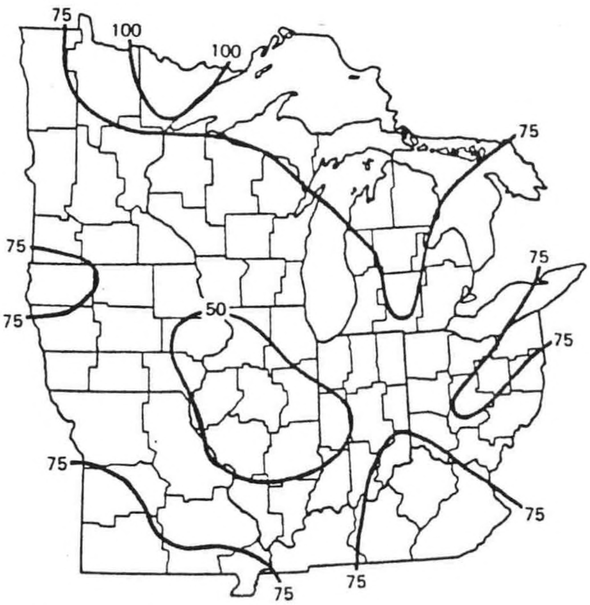

Fig. 1. Percentage of normal precipitation for April-August 1988 in the midwest.

Fig. 2. Rank of April-August 1988 precipitation compared to the 1895–1987 historical record. A rank of 1 indicates that 1988 was the driest year of the historical record.

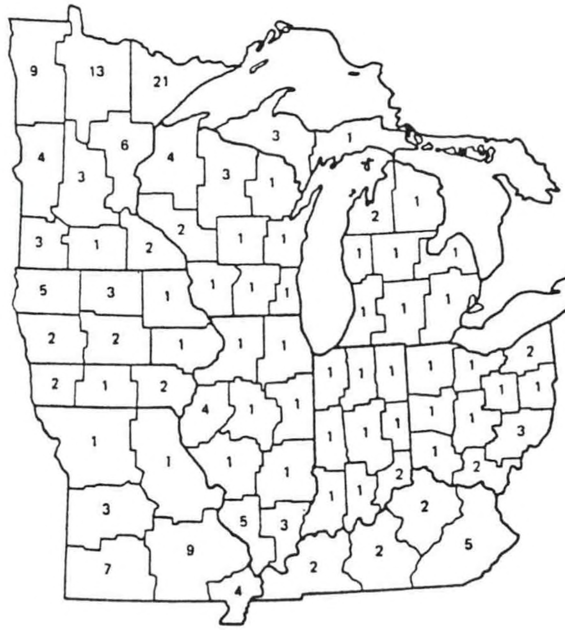

Fig. 3. Rank of May-June 1988 precipitation compared to the 1895–1987 historical record. A rank of 1 indicates that 1988 was the driest year of the historical record.

Fig. 4. Rank of June-August 1988 precipitation compared to the 1895–1987 historical record. A rank of 1 indicates that 1988 was the driest year of the historical record.

percentile. The June-August period was relatively wetter. However, 26 divisions (36 percent) were in the driest 10 percentile, with five divisions experiencing their driest June-August on record.

Figure 5 shows the deviation of average temperatures from the 1951-1980 mean temperatures during June-August 1988. Northern sections were typically 2°-$3^{\circ}C$ above average, whereas southern sections were 1°-$2^{\circ}C$ warmer than average.

These mean values mask the fact that the daytime maximum temperatures were much more above their averages than were the nighttime minimum temperatures. Figure 6 gives the rank of 1988 temperatures compared to 1895-1987 historical data. A rank of 1 indicates the warmest on record. Fifteen divisions in the northwest sector experienced their warmest summer ever, while 54 divisions were in the warmest 10 percentile (a rank of 1-9).

To provide an area-wide measure of the severity of the drought, region-wide precipitation averages were computed for the periods April-August, May-June, and June-August and compared with similar averages from the 1895-1987 historical data. A similar average was computed for June-August temperatures. Table 2 lists the driest ten years for the three periods and the warmest ten years for June-August. The year 1988 appears high on each list. In fact, for the May-June period, 1988 was easily the driest year of the 94-year record. For the other two periods, only a few of the 1930s drought years were drier. In terms of summer temperatures, only 1936 was warmer.

A common measure of drought severity is the Palmer Drought Severity Index. For each drought episode of this century the month with the maximum number of climate divisions in the severe or extreme drought category was chosen and ranked according to the number of climate divisions in severe or extreme drought (Table 3). In only three previous drought episodes have there been more extensive areas of severe or extreme drought. The prominent position of 1988 on these lists, along with the results presented in Figures 1-6, led to the following conclusions:

1. The 1988 drought was the worst short-term drought in the Midwest since 1936.

2. In this century, only the droughts of 1930, 1933, 1934, and 1936 have equaled or exceeded the combination of heat and dryness experienced in 1988.

3. Some of the driest areas in 1988 were in the heart of the corn and soybean belt.

The drought continues to have impacts on water supplies in some areas in 1989 with river flows and reservoirs well below seasonal averages. Although top soil moisture levels have rebounded in some areas, other areas (particularly Iowa, northern Missouri, western Illinois, and southern Minnesota) have received below normal precipitation in 1989. It is meaningful to ask what are the climatological chances for recurrence of summer drought. The following analysis of the historical data was performed. For each climate division, precipitation data were separated into three equally probably categories: above normal

Fig. 5. Deviation of June-August 1988 temperatures from 1951–1980 averages for the midwest.

Fig. 6. Rank of June-August 1988 temperatures compared to the 1895–1987 historical record. A rank of 1 indicates that 1988 was the warmest year of the historical record.

Table 2. Driest and Hottest Years for Various Periods in a Nine-State Midwestern Region

Precipitation, mm						Temperature, °C	
April–August		May–June		June–August		June–August	
276	1936	80	1988*	161	1936	23.5	1936
309	1930	106	1936	180	1930	23.2	1988*
319	1934	120	1934	186	1933	23.2	1934
321	1988*	152	1911	221	1988*	23.2	1901
339	1901	152	1966	221	1976	23.1	1921
359	1976	154	1901	226	1913	22.9	1983
384	1971	155	1922	226	1910	22.8	1933
386	1925	157	1910	228	1901	22.7	1955
391	1913	159	1987	228	1922	22.6	1949
392	1895	160	1972	232	1918	22.6	1931

Table 3. Number of Climate Divisions in Severe or Extreme Drought Conditions According to the Palmer Drought Severity Index

Month	Year	Number of Climate Divisions
July	1934	64
July	1936	63
December	1930	58
August	1988*	54
January	1954	50
January	1964	48

(wettest 1/3 of years), normal (middle 1/3 of years), and below normal (driest 1/3 of years). For the 30 driest summers (excluding 1988), we counted the number of times that the following summer experienced precipitation in each of the three categories. Figure 7 shows the result in terms of the probability for a below normal summer to follow a below normal summer. If the process were random, then the expected value would be 33 percent. Much of the region has probabilities in the 30-40 percent range. Parts of northern Wisconsin, western Missouri, and western Minnesota have probabilities of greater than 40 percent. However, because of the small number of samples (30), a chi-square analysis indicated that only values of around 50 percent or higher are statistically significant (at the 10 percent level). No areas have statistically significant probabilities of back-to-back dry summers. Although not shown, there also were no areas experiencing statistically significant probabilities for wet summers to follow dry summers. If we restrict our attention to the four driest past summers (1936, 1930, 1933, and 1976), the following summer was dry in two cases (1931 and 1934), normal in one case (1937), and wet in one case (1977); again, there is no strong tendency. In summary, there is no strong indication in the climate record as to the potential conditions following a summer drought.

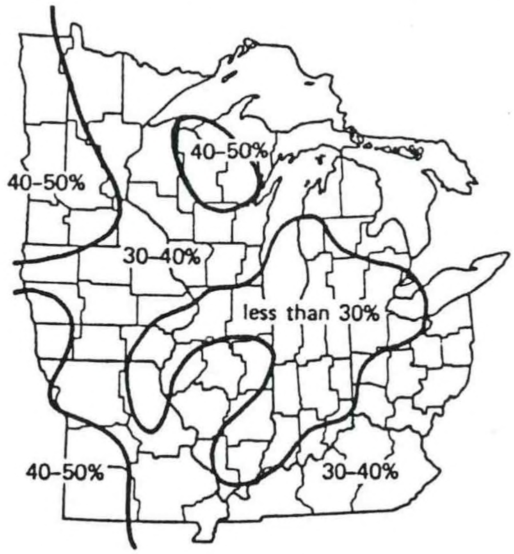

Fig. 7. Probability of experiencing a dry summer following a dry summer. If there were no correlation, a value of 33% would be expected. Only values near and above 50% are statistically significant at 10% level based on a chi-square analysis.

In conclusion, the drought of 1988 was of historic magnitude in the Midwest — the worst in over 50 years. In this context it is not surprising that the physical environment was severely impacted and that parts of our socioeconomic system functioned poorly during the drought. However, the drought illustrated our vulnerability and lack of flexibility to extreme drought conditions.

References

United States Department of Agriculture, 1987: Agricultural Statistics, 1987. Available from the United States Government Printing Office, Washington, D.C.