The Journal of the Iowa Academy of Science: JIAS

Volume 97 | Number Article 6

1990

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Jour. Iowa Acad. Sci. 97(3):88-90, 1990

Impact of Global Warming and Cooling on Midwestern Agriculture[1]

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The global warming since 1980 has been greater than it was during the warming trend from 1880 to 1940. This has caused concern that the very warm years of 1987 and 1988 might have been associated with greenhouse warming. However, the cooling trend from 1940 to 1980 occurred during a rapid buildup in greenhouse gases in the atmosphere. Although there may have been some greenhouse warming since 1880, the unusual warmth of 1987 and 1988 may have been caused by changes in the temperature of the equatorial Pacific Ocean, and changes in transparency of the atmosphere or other phenomena acting on the atmosphere.

There have been changes in weather variability associated with the global warming and cooling. The unusually benign period of weather in the Midwest from 1956 to 1973 occurred at the end of a brief period of global cooling. Since 1973, there has been increased weather variability like that experienced in the 1930's.

The most important factor in weather variability in the Midwest has been associated with the El Niño cycle. Crop production appears to be favored in years of El Niño events. All the major droughts in the Midwest since 1891 have occurred between El Niño years. The El Niño event starts about every 3 to 7 years and lasts 1 to 2 years. In the Midwest the year after an El Niño event tends to be warmer and drier than normal and is sometimes a drought year.

INDEX DESCRIPTORS: Global warming, El Niño, weather variability, drought frequency.

A global warming trend from 1880 to 1940 preceded a global cooling trend through the late 1970's. Since 1980 there have been 5 years when the global temperature was above the highest year of the 1930's. A new record was set in 1987, and 1988 was slightly warmer than 1987 (6,8). Figure 1 shows the steep warming trend that started after the unusually cool period that occurred from 1965 to 1976. Figure 1 also shows the great variability in global temperature from one year to the next as well as the long term trends.

During the 1988 drought, there was much publicity regarding the greenhouse effect as the cause of the rapid global warming of the past 3 years. Although there has been a gradual increase in gases that absorb heat in the lower atmosphere (particularly carbon dioxide, methane, and nitrous oxide), there are other possible causes of warming that should be mentioned. One factor is the changing transparency of the atmosphere. Another is changing temperature of the equatorial Pacific Ocean (1). During the past 3 years, there has not been a major volcanic eruption, and the atmosphere has become more transparent (5).

Budyko (2) attributes much of the global warming trend that ended in 1940 and the cooling that occurred after 1940 to decreased volcanic activity until 1940 and increased volcanic activity after 1940. Volcanic aerosols in the atmosphere generally cause back-scattering of the sun's rays and have a cooling effect and may cause an increase in rainfall (5). Handler (4) has provided evidence that volcanic activity has been associated with El Niño events and might be the cause of the onset of an El Niño if the eruptions occur at lower latitudes. He has shown that in years of El Niño the U.S. Corn Belt receives more rain in he spring and early summer and has higher corn yields as a result (3).

If the increase in greenhouse gases were the only factor in the warming trend, there would not be the wide swings in global temperature because the accumulation of greenhouse gases has been gradual. The wide swings in temperature, like from 1985 to 1988, are caused by factors that have greater immediate effect than the greenhouse gases.

The greenhouse gases have been accumulating for more than a century. The end of the cool spell in 1980 was warmer than it was in 1880 (which was also the end of a cool spell) so there may have been some greenhouse warming over the past century. The significant fact is that we had a cooling trend after 1940, which was caused by factors that outweighed the effect of the accumulation of greenhouse gases in the atmosphere.

CHANGES IN WEATHER VARIABILITY

The global warming and cooling trends may have caused changes in weather variability. The 1930's were especially variable with both severe winters and hot summers, as well as droughts and unusual floods. The cooling trend coincided with declining weather variability. The period from 1956 to 1973 was a time of rather benign weather in the Midwest. There were no widespread droughts in the U.S. Corn Belt in that period, and there were very few days when the tempera-

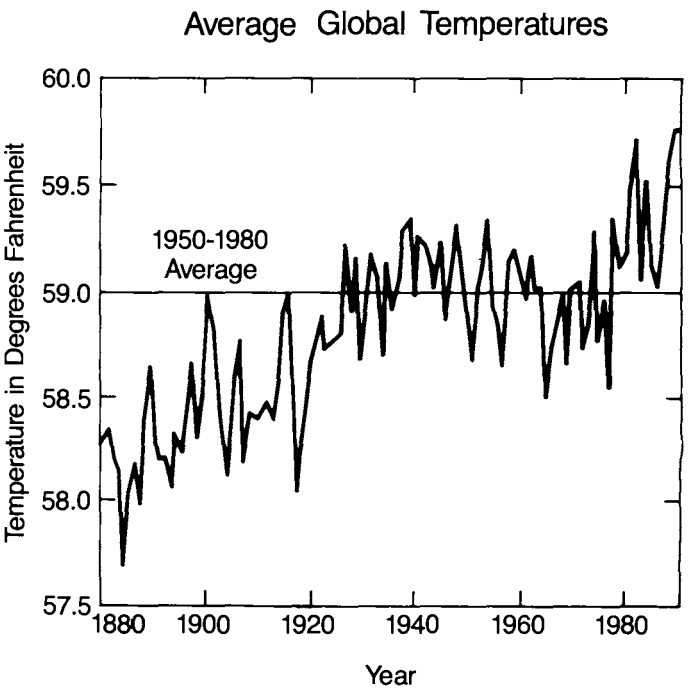

Fig. 1. Average global temperatures from 1880 to 1988.

[1]Journal paper No. J-13664 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50011. Project No. 2683.

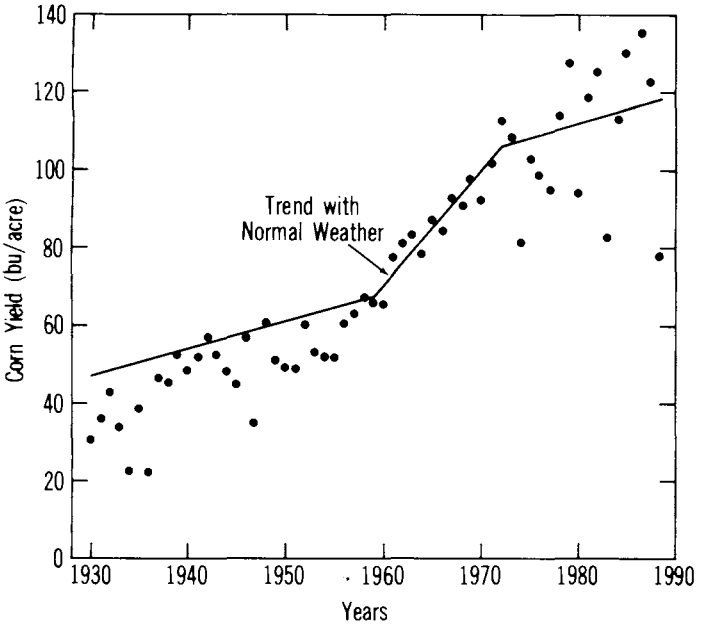

Fig. 2. Trends in yield of corn in Iowa and Illinois averaged together from 1930 to 1988.

ture was above 90°.

Figure 2 shows the average corn yields for Iowa and Illinois (combined) from 1930 to 1988. The changes in trends were calculated with a crop/weather model (10). The weather for corn from 1930 to 1960 was mostly warmer and drier than normal. The trend was very steep from 1960 to 1972 because the favorable weather each year resulted in excellent response to increasing technology. There was little deviation from normal weather each year; all the yield values were close to the trend line. Farmers used more fertilizer and planted higher populations each year from 1960 to 1972. The average amount of nitrogen used on corn in the U.S. Corn Belt increased from 40 pounds per acre in 1960 to 120 pounds per acre in 1972.

Since 1973 there seems to have been a change in climatic variability in the Midwest, starting with a drought in the midsummer of 1974 after an unusually wet spring. There have been five summer droughts since 1973: 1974, 1977, 1980, 1983, and 1988. Each drought has been more severe for corn production than the previous one. Figure 2 shows the increased variability in corn yields since 1973. Our winters have been more variable also, with record cold periods and record warm periods (7). Yet in this period since 1973, we have had some of the most favorable weather of the past century. The years 1978, 1979, 1981, 1982, 1985 and 1986 were quite favorable and resulted in record yields of corn in Iowa and Illinois.

THE EL NIÑO

Most of the variability associated with corn yields since 1973 can be attributed to the El Niño cycle. El Niño is Spanish for "the boy." For several centuries, the Pacific waters off the coast of Peru have been known to turn warm periodically. The warming often occurs at Christmas time; hence, the term El Niño means the "Christ Child."

The El Niño is characterized by warming of the surface of the Pacific Ocean along the equator. There is a flip-flop of the pressure patterns on either side of the Southern Pacific Ocean (Tahiti and Darwin, Australia). During the El Niño period, low pressure occurs on the east side of the Pacific, and high pressure occurs on the west side of the Pacific in the Indonesian area. Indonesia tends to be droughty while flooding occurs in Peru. The El Niño cycle is a phenomenon that affects many parts of the world. India and the Sahel area of Africa tend to have monsoon failures during the El Niño event. The gulf coastal area of the United States tends to be cold and wet during the winter of the El Niño (9). The U.S. Corn Belt has a cooler and wetter spring and early summer during the El Niño (3).

It is now believed that, when the surface of the Pacific Ocean along the equator is colder than normal, the effect on weather around the globe is somewhat opposite from that of the El Niño (11). In 1988, the water along the equator was colder than any time in the past decade, and the term La Niña became popular. It means "the girl" in Spanish and is opposite of El Niño.

The El Niño/La Niña cycle also impacts global warming and cooling (1). After the Pacific Ocean turns warmer along the equator during the El Niño event, the land area of the tropical and subtropical regions of the globe turns warmer. Likewise, the area of the same regions turns cooler than normal if the water along the equator turns colder than normal after the El Niño fades away. Nearly half the land area of the globe lies in these regions between 25°N latitude and 25°S latitude.

The five droughts in the U.S. Corn Belt since 1973 were all in years following El Niño events. The closest exception was 1983, which came at the end of the most severe El Niño on record.

The last El Niño began in 1986 and faded away at the end of 1987. During 1987 India had the worst drought in a century. The drought in the Corn Belt in 1988 was expected, though it was more severe and more widespread than expected.

Figure 3 shows simulated yields of corn calculated from weather data for Illinois and Iowa at a constant level of technology, at the 1983 level (10). For this use, the El Niño years identified by Handler (3) have been encircled. All the major drought years (those with the lowest yields) occurred between El Niño events. All the years between El Niño years were not drought years but the tendency was for the year after an El Niño event to be warmer and drier than normal.

The study published in 1988, from which Figures 2 and 3 were obtained, indicated a cluster of very favorable years in every cycle of 18 to 19 years. When an El Niño cycle occurred in this favorable cluster, there was little chance of drought. But the period from about 1984 to about 1993 is in that part of the 18- to 19-year cycle when the Corn Belt is most vulnerable to drought.

An El Niño cycle begins about every 3 to 7 years. When the next El Niño occurs we should see the U.S. Corn Belt favorably affected. The next El Niño year could come as early as 1990. But then, when the El Niño fades away, we should recognize our vulnerability to another drought. This is not to predict a drought but a warning to watch for the signs. If we should have a lot of volcanic activity over the next few years, we might not have a drought. So we should recognize that volcanic activity and El Niño events provide clues for forecasting long-range weather events.

SUMMARY

The global warming that we have had in 1986, 1987, and 1988 should not be called the beginning of greenhouse warming. They may have been unusually warm for reasons in addition to greenhouse warming. The global temperatures of the next several years will depend to a great extent on whether we have much or no major volcanic activity and on the next El Niño event. Although we cannot predict the year the El Niño will begin, we do know that they typically develop every 3 to 7 years. The last El Niño started in 1986. We can now watch for signs of another El Niño.

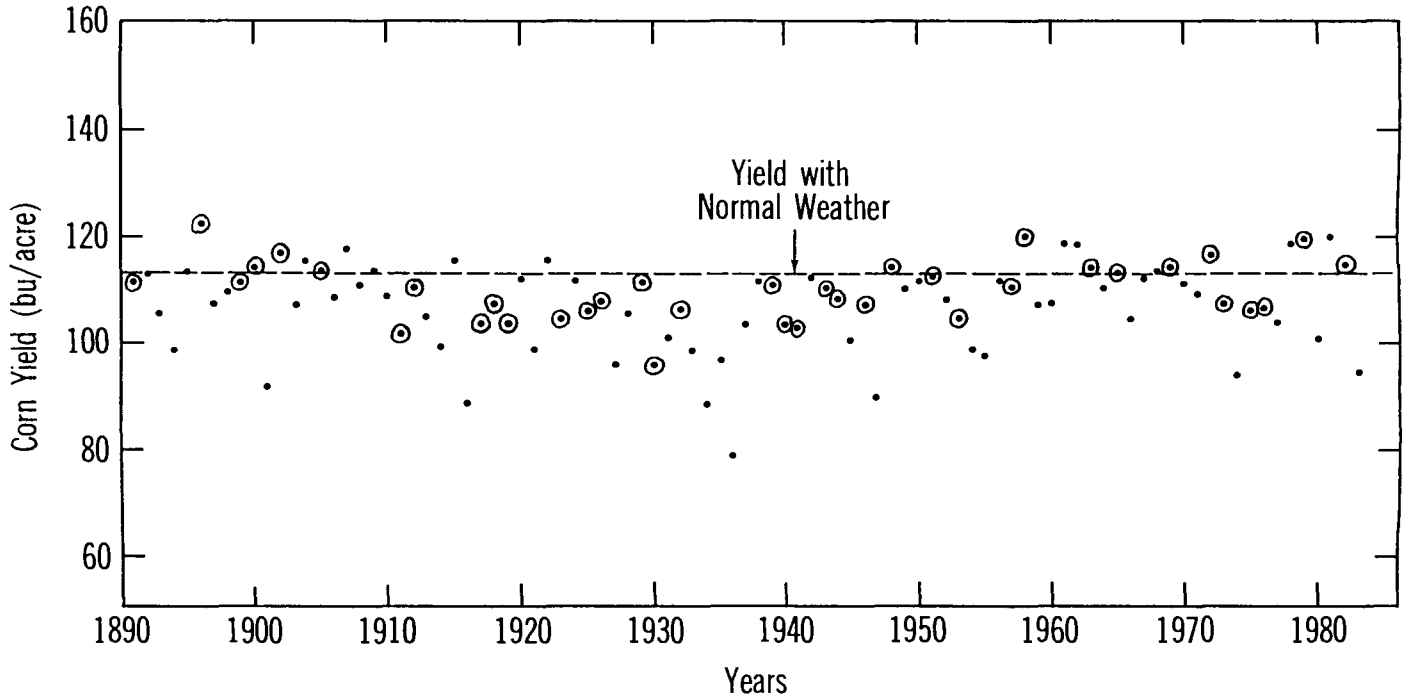

Fig. 3. Simulated corn yields for Iowa and Illinois calculated from weather data at a constant level of technology from 1891 to 1983.

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