Crop Weather Update and Outlook

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Mild winter, wet spring, summer floods, fall drought all describe Iowa in 1998. This session will help your understanding of the uncertainties of weather and the tools needed to manage crop production risks in 1999 and beyond.

Crop Yield: Variability and Trends

The primary concern in this discussion is the influence of weather on crops and on crop production. Weather is the major uncontrollable factor that influences the development of crops. Initially, we will look at some of the historical trends in crop yield. We often hear about deviation from yield trend. This is a concern as we have been seeing greater deviation from yield trends during the past few years than were experienced during the sixties and the early seventies. We attribute much of this to weather patterns and the interaction of the weather with the soils and the crops.

Yield Trends

The United States Department of Agriculture (USDA) publishes several charts that have to do with yield trend. Typically, the USDA depicts yield trend as a straight line, averaging the yields of the past several years, usually a 20- or a 30-year period. The most recent USDA trend estimate for corn was from 1970 through 1997 (Figure I-1).
A straight-line yield trend may not be the most realistic depiction. If we look at the actual yields for the state of Iowa as they have been observed this century (Figure I-2), we find that the yields were really quite flat, around 40 bushels to the acre, from the turn of the century until about 1940. There was variability year to year according to weather conditions. Some years the crop was reduced by almost 50%. During the Dust Bowl years, especially the more severe year of 1936, the yield was reduced by more than 50 percent.

Following 1940, there was a rapid increase in crop yield, largely due to technology. Some have attributed it almost entirely to an improvement in hybrids. With the introduction of hybrid seed and hybrid vigor, we began to see a great improvement in crop yields from 40 bushels to the acre, to 80, and finally to well over 100 bushels to the acre (6,273 kg/ha). During this period, chemical fertilizers and pest control materials were implemented in production management, contributing to the yield increase.
The yield increase was almost linear from 1940 through 1970. In the years since 1970, we see some leveling of the trend. The reason for this leveling is not well understood. We will consider some factors that may result in the leveling of crop yields. The yield trend depicted in Figure I-3 can be described over the entire time series with a logistic expression (Carlson, Todey and Taylor, 1996) as:

\[ y = 38.27 + \frac{85.78}{1 + \left(\frac{\text{year}}{1965.45}\right)^{-217.01}} \]

where \( y \) is yield in bu/acre and "year" is any year in the time period. Yield trends in the other Corn Belt states (Missouri, Illinois, Indiana, and Ohio) are similar. The leveling of yield trends is more pronounced in the west half of the Corn Belt. Figure I-3 shows actual yields by year and indicates deviations of \( \pm 10\% \) from the trend.
Some significant variations in trend may be found within each state. In the southeast portion of Iowa, the trend line has become almost horizontal since 1980 (Figure I-4), whereas in the west central and southwest portions of Iowa, the trend line is almost linear. This indicates continuing improvement in crop yield in western Iowa, but not in eastern Iowa (Figure I-5).
Southeast Iowa

West Central Iowa
The yield charts have a double trend line, one being 10% below the average yield, and another line representing yields that are 10% above. These give us some indication of variability in the weather, and how that variability influences the crop. Occasionally yields exceed the trend line by more than 10%, but only by a slight amount. Often yields are depressed by 10%, 20%, or 50%. It is not uncommon to have the depression of yield deviate from normal more than the enhanced yields deviate from the long-term average (Figure I-3).

It is clear that the bad years are hurting yields more than the good years are helping. I liken this to a person riding a bicycle into the wind. The wind slows the bicycle rider down. Turn around and go the other way. The wind at the cyclist's back is a great asset and a help to cycling along, but all in all, if a person were to time how long it takes to ride from home to work and back home again on a still day, the time would be better than on the windy day. In other words, the wind at your back does not make up for the adverse weather conditions when you're riding into the wind. Uphill, downhill, has the same influence, and the bad years versus the good years are having the same effect on crops. The reason we see our crop yields leveling off during the past few years is an increasingly common occurrence of bad years, if you want to look at it that way. Perhaps it is better stated as increasingly erratic climatic conditions.

Potential yield appears to have increased in a linear manner since 1930 even though yield trends show
diminished rates of increase. A straight line (Figure 1-6) connecting the highest yields appears to indicate the yield potential when weather conditions favor crop growth and development. If weather were ideal each season, crop yield trends would likely show a linear increase during years from 1930 through 1996. It is probable that the cause of the leveling of yield trends, though not uniform within the Corn Belt nor even within a state, is caused by increasingly uncertain weather conditions.

There can be many reasons for this leveling of the yield trend. It can be direct impact of increased variability of the weather. It can be changes in the severity and number of pests. It can be water stress and perhaps many other factors. We will consider the effects of water stress and temperature stress mainly as they influence crop yields.

The weather influences the development and growth of the crop. Dr. Louis Thompson (1986, 1988) developed charts, based on statistics that express crop yield as influenced by monthly average temperature. The polynomial expression and coefficients for the temperature and precipitation relationships were given by Thompson (1986) and are summarized in Note 1 at the end of this chapter. He noted that across the Corn Belt, if the temperature is average, we will have the optimal contribution to yield during the month of June (Figure 1-7).
The equation for Figure I-7 is given as:

\[ y = a + bx - cx^2 \]

where \( y \) is simulated corn yield (kg ha\(^{-1}\)), \( x \) is the departure from normal for temperature (°C) or rain (mm), and "a" is yield trend value (kg ha\(^{-1}\)).

<table>
<thead>
<tr>
<th>Variable</th>
<th>( b )</th>
<th>( c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preseason precipitation</td>
<td>-0.404</td>
<td>-0.0022</td>
</tr>
<tr>
<td>June temperature</td>
<td>-2.5176</td>
<td>-27.5150</td>
</tr>
<tr>
<td>July rain</td>
<td>+9.5604</td>
<td>-0.0416</td>
</tr>
<tr>
<td>July temperature</td>
<td>-101.7318</td>
<td>-7.6832</td>
</tr>
<tr>
<td>August rain</td>
<td>+1.0902</td>
<td>-0.0026</td>
</tr>
<tr>
<td>August temperature</td>
<td>-90.8361</td>
<td>-16.2131</td>
</tr>
</tbody>
</table>

Temperature is °C deviation from the long-term normal; rain is mm deviation from the long-term normal. For example, to calculate the departure from average yield: set "a" to 0; then if July precipitation was 40 mm above normal, the departure will be +316 kg ha\(^{-1}\).

If the June temperature is 2° C warmer than average, it results in a reduction in potential crop yield, and if the temperature is 2, 3, 4° C cooler than usual in June, it results in a decrease in June's contribution to the crop yield. Also, precipitation for April, May, and June, being normal or slightly below normal, seems to contribute to crop yield.

In July, the effect of temperature becomes very different from that of June. In July a normal temperature (an average July) results in average contribution to crop yields. Should July be warmer than usual, the potential July contribution to crop yield drops off significantly. A cooler than usual July (2 or 3° C cooler than usual) contributes substantially (or enhances substantially) the yield of the crop. A cool July would indicate better growth of the crop.

Moisture in July is also very significant. Average July precipitation gives an average contribution to yield. Extra moisture during the month will substantially increase the July contribution to yield. In Figure I-7, it would appear that the more precipitation that falls in July, the better and, in fact, some of the estimates that are used for assuming what a crop will be, assume just that -- "the more rain, the more grain." We know from 1993 that this is not so. There can be a point at which there is absolutely too much moisture around. But only twice in the past 100 years have we clearly observed a case where too much moisture reduced the state yield. The years were 1915 and 1993 in Iowa.

For the most part, although too much moisture may reduce the yields on the low-lying areas, it is more than compensated for by increased yield on upland portions of the state. So we will assume that up to a certain point, increased July moisture helps the state yield and below normal July moisture depresses the potential yield. August is about the same as far as corn is concerned in the Corn Belt. A cool August is an enhancement to yield. A hot August depresses the potential yield. The same picture is true with rainfall, but for corn it is not as sensitive to August rain as it is to July rain. The most sensitive time is at the time of flowering, or pollination, if you will, and there the crop is most sensitive to the amount of water and to the temperature that is influencing the state or the area.

If we were looking at soybeans, the July pictures would be more appropriate for August (Figure I-7). In other words, the soybean in August is responding much as corn is responding in July if we look at the temperature and the moisture responses for our crop.
Of the factors that we could consider here, we emphasize temperature and moisture. There are many other factors that influence the development of the crop. The primary one, of course, is light. We make the assumption in the U.S. Corn Belt that sunlight is sufficient for the growth of the crop. It is not always so. Maybe one year out of four we will have a month when light is not sufficient for optimal crop growth. If we were working in England, or even in some other parts of the United States, we would find that light is often the limiting factor and very much needs to be considered. However, at this time, we are not going to consider the factor of light or of wind or of relative humidity or any of a number of other factors that tend to be minor if we are just considering the development and growth of the crop in the Corn Belt.

Note: This is a extract from the video-tape-booklet series, “The Effect of Weather on Crops and Crop Production” by Elwynn Taylor. The tape and booklet are available from the Field Extension Education Laboratory, 2104 Agronomy Hall, Iowa State University, Ames, IA 50011-1010 at a cost of $65.