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WEATHER AND YIELD TRENDS

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Introduction

Yield trends and yield variability are strongly influenced by weather. It is extraordinary for a statewide corn yield to exceed the established trend by more than 10%. It is not uncommon for yields to be diminished by more than 10% of the trend. Geographically, yields are differentially influenced by the ENSO (El Niño/Southern Oscillation). Differential influences appear to have a lesser yield reducing impact in the eastern portion of the corn belt. Climate dynamics appear to be impeding the rate of yield increase in the central U.S. Advancements in long-lead forecasting are beginning to benefit efforts to assessment risks associated with crop production.

Yield Trends

The concept of "trend" is not well established. A forecast for "yield to exceed trend" must indicate the nature of the "trend" used as a reference. The USDA trend of corn and soybean yield is represented by a linear fit to the yields of the past 30 years (Figs. 1, 2). It is not clear that a linear fit gives an accurate picture of the future trend in yields. Then again is there any trend model that can be relied upon to do so? Ecologists have demonstrated that an increasing population is best modeled by a logistic expression. Corn yield data over the past 90 years would appear to conform better to the logistic trend than to a linear trend.

Historical yields in the central U.S. appear to conform to the typical model of a growing population approaching carrying capacity. Historical corn and soybean data for Iowa, Illinois, Missouri, Indiana, Ohio were fitted with a logistic type model by Carlson, et al. (1996)(Fig. 3-7). Indicators of the trend plus 10% and the trend less 10% are shown on the plots.

Cause of Trend Leveling

When yield trends for each crop reporting district of Iowa were drawn, it appeared that the corn yield was leveling in east Iowa more abruptly than was apparent in western Iowa (Fig. 8-9). The differential tendency appears to be caused by the impact of drought in east Iowa during 1983 and 1988. Because the trend difference is influenced by only two events that were more severe in the east than in the west portion of Iowa, little confidence should be placed in either the trend differences between east and west Iowa or in the general shape of the trend lines. It may even be that the linear trend is as valid as is a trend curve.

When yields over the past 100 years are considered, however, it is obvious that a single linear trend across the period is not justified. The rapid increase of the yield trend during the 1950s and 1960s showed a clear response to technological advances in crop attributes and in management tools and methods. The interannual variability of the climate was, however, a contributing factor as well.
If a line is drawn connecting the Iowa corn yield of 1932 with 1994, it might be argued that potential yield, under favorable weather is increasing according to a linear trend (Fig. 10). This would also imply that the 1950s and 1960s had no seasons of near ideal crop production weather. The reduced yield variability during the period would also imply that there were likewise no seriously adverse seasons during the interval. After 1972, yields became relatively erratic. Observed weather conditions likewise became more erratic during the years subsequent to 1972. Perhaps it is better stated that the variability of weather after 1972 returned to conditions observed previous to 1950.

During periods of increased weather variability, there appears to be a decline in the trend toward higher yields. It may be concluded that a favorable year does not fully compensate for yield lost during an unfavorable year. Accordingly the trend toward higher production is diminished.

**Trend Extrapolation**

Prediction of future yields, or of potential future yields based on trend analysis may be unwise. Technically there is no justification for extrapolating a trend line even one year beyond observations. Never the less, some inferences may be drawn: If the erratic behavior of the weather continues, the apparent leveling of yield trends is likely. Second, if climate becomes less erratic, the slope of the current yield trend may change dramatically.

We cannot help but notice the timing and apparent relationship of the initiation of the "global cooling" scare of the 1950s and 1960s to the observed yield trends in the mid-west. The initiation of "global warming" around 1972 was likewise accompanied by a dramatic shift in the yield trend and in yield variability. If the present episode of global warming continues through 2010 or so, we might expect the trend lines given by Carlson et al. (1996) to be representative of yield responses during the period.

Yearly "trend yields" may be calculated according to the formula given by Carlson et al.(1996). Considering the inadvisability of extrapolating trend lines, a notable result can be observed if it is assumed that the trends may be meaningful through the year 2005. Table 1 shows the trend yield for the corn belt states analyzed. In 2005, Indiana would lead in the "trend line" production of corn. The reason being that Indiana appears to be less adversely influenced by "bad" crop years than are the other corn belt states. This inference is strongly influenced by 2 or 3 extreme years, hence, the observed trend differences may not be meaningful indicators of future responses.

**Cause of Variability**

"Climate is changing, climate has always changed and climate will always change," was one of the phrases that, as a student of David M. Gates, echoed in the halls of learning. Some have speculated that global warming is influenced by human activity. If so, some speculate, that the warming may be more extreme and more abrupt than would occur under natural conditions. Some "warming" models indicate that the corn belt may become so "hot and dry" as to severely limit crop yields, other models indicate a "warmer and wetter" central U.S. Whatever the case, Iowa has experienced rapid and significant climate change during the past 30 years: weather conditions have become increasingly extreme and precipitation (mainly summer precipitation) has increased about 10% (Fig. 11).

It may be that a result of the present global warming is a modified precipitation pattern, and strong temperature effects that may result in mesoscale hot or cold spots from season to season across the U.S. The pattern was not observed during the 1900-1940 warming episode. The cause may be
unrelated to the global warming. Never the less, variability in the 70s, 80s and 90s to date, exceeds that of the 50s and 60s.

**El Niño Connection**

The climatic event known as the El Niño, historically refers to the rain in the deserts of Peru about Christmas time. This unusual event is related to the sea level, the trade wind strength, the pressure difference between the central Pacific Ocean and an area north of Australia and to 6 or 7 other observable parameters. There is no clear way to extrapolate the precipitation event of Peru to the widely distributed weather anomalies attributed to the El Niño. Progress is being made in the defining of events that can be directly related to weather conditions in distant localities. Some effort has been made to refer to the El Niño as the "ENSO" (El Niño/Southern Oscillation). The "SO" is measurable where the El Niño itself is not.

Carlson et al. (1996), compared monthly SO values with precipitation, temperature and crop yield in the central United States. They found that a negative SO was associated with an August precipitation increase in southeast Iowa and with decreased maximum August temperatures from Iowa to North Dakota. They also found that corn yields were enhanced by 4% to 6% across the corn belt. When the SO was significantly positive (associated with the so-called La Niña), yields diminished by 2% to 6%. Occasionally yield responses deviated from the trend line by more than 10%.

**SO**

The SO (southern oscillation) is measurable and to some extend is predictable. Therefore, if the SO has a reliable cause/effect relationship to corn yield, the skill (or reliability) of seasonal yield outlooks or forecasts may be enhanced. We found that during 22 observed seasons when the SO was negative (-0.8 or less) there were 7 when yields exceeded the trend by more than 10% and only 3 when the yield was diminished by 10% or more (Table 2). This trend is generally true across the states evaluated. During the 15 seasons when the SO exceeded +0.8, yields in Iowa exceeded the trend by 10% only once and were reduced on 6 occasions. This negative yield effect was not general across the corn belt, Indiana went 3 and 3, that is: no discernable negative effect. This is likely the reason that the Indiana corn yield trend through 2005 is more favorable than for other corn belt states.

In summary a negative SO indicates an enhanced probability of greater than trend yields in the corn belt. Conversely a positive SO indicates a greater probability of reduced yield in some states.

**Deviation from Trend**

It is apparent by inspection, that yield variability about the trend has increased during the past 20 years. Computed percentage deviation (or standardized deviation from the trend) gives a more concise depiction of variability. The period from 1940-1972 exhibited considerably less variability than previous or recent periods.

There is an apparent similarity between episodes of global warming and cooling and variability of crop yields. (Fig. 12 global temperature). It is supposed that global warming is associated with abnormally erratic weather and periods of global cooling, conversely, associated by minimal interannual weather (and crop) variability.
ENSO

The ENSO (El Niño Southern Oscillation) refers to the El Niño and related events. The SO part is quantified and is published daily. Because the SO is the difference in atmospheric pressure between the central Pacific Ocean and the north coast of Australia, the daily value is subject to every little storm that comes along. The 30 day moving average is more representative of what is happening and was used in a research effort at Iowa State University to evaluate the possible influence of the SO on mid-west crop yields. The 90 day average may be the more meaningful but has not been evaluated fully as of this time.

Production Risk Assessment

Subsoil Moisture

The Iowa subsoil moisture situation is evaluated during November. This fall moisture survey is the earliest indication of the crop production outlook for the coming year. If subsoil moisture is in a depleted status the probability of achieving full recharge of the subsoils by July first is reduced. Iowa normally does not receive sufficient precipitation during the months of July and August to meet crop water requirements (there are notable exceptions such as 1993 when mid-season precipitation was greatly in excess).

Subsoil moisture normally increases by approximately one to two inches of plant available water in the top five feet of soil between November first and April 15. The mid-April assessment is the second indicator of the production risk for the crop year.

Planting Date and Maturity Class

The date of planting and the maturity class of the planted crop comprise the third and fourth factors useful in assessing production risk. Early planting is associated with risk damage to the crop by spring frost events. Late planting is associated with probabilities of achieving crop maturity before the end of the growing season. Planting date also impacts the probability of the crop being at a stress sensitive developmental stage during the season when heat stress is most likely to be significant. Maturity class also impacts the latter two considerations.

Long-Lead Climate Forecast

The National Weather Service releases a "Multi-Season Long-Lead Climate Outlook" on the Thursday nearest the middle of each month. The outlook includes probabilities for above or below median precipitation and above or below average temperature for North America during the following month and for each 3 month period through a 14 month outlook calendar. No assessment is given if no statistically significant trend has been identified for a parameter and period in relation to existing weather conditions. The outlook is more definitive when strong ENSO conditions exist or are expected.

A long-lead forecast for cool and moist summer conditions would usually indicate favorable crop production conditions; hot and dry, a possibility of heat and water stress. During years when soil moisture in the spring is sufficient, crop yields can be very good even if summer precipitation is below the median, provided temperatures are not excessively high (1994 was a good example). When used
together with the subsoil moisture and planting information a reasonable production risk assessment can be formulated.

**On-Going Assessment**

Crop growth and development depends on numerous factors beyond soil moisture and monthly temperature and rainfall. Some years solar radiation has limited crop growth. Day to day temperature effects are often crucial to crop development. Because of the complexity of the climate interactions with crop growth and development on going assessments of crop conditions are essential to update projected crop yields.

**Reference Cited**


**CAPTIONS**

Figure 1  Corn yield for the U.S. is expressed by the USDA as a linear trend.

Figure 2  Soybean yield for the U.S. is expressed by the USDA as a linear trend.

Figure 3  Yield trends for Iowa corn production do not appear to be linear.

Figure 4-7  Yield trends for Illinois, Missouri, Indiana and Ohio corn yield.

Figure 8-9  District yield trends, Southeast and Southwest Iowa.

Figure 10  Iowa corn yield 1870-1995.

Figure 11  Iowa precipitation trend.

Figure 12  Global temperature estimates, 1860-1995.

Table 1  Extrapolated yield trends.

Table 2  Cross tabulation of corn yield and SO index.
Figure 1

USDA - National Agricultural Statistics Service

U.S. Corn Yield
1970 to Present

Bushels

160.0

140.0

120.0

100.0

80.0

60.0

Year


Chart last updated October 11, 1996

Figure 2

USDA - National Agricultural Statistics Service

U.S. Soybean Yields
Time Series

Bushels

45.0

40.0

35.0

30.0

25.0

20.0

Year

66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96

Chart last updated October 11, 1996
State Wide Average Corn Yields

Iowa

Bushels/Acre

1900 1920 1940 1960 1980 2000

Years
State Wide Average Corn Yields
Missouri

Figure 4

State Wide Average Corn Yields
Illinois

Figure 5
State Wide Average Corn Yields
Indiana

Figure 6

State Wide Average Corn Yields
Ohio

Figure 7

183
Iowa Corn Yield
1870 to 1995

Figure 10
ANNUAL PRECIPITATION FOR IOWA
AVERAGE OVER ALL 9 DISTRICTS

MOVING MEAN
30 YEARS

INCHES

YEARS (1900---->1992)
Table 1. Extrapolated yield trends.

<table>
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<tr>
<th>Year</th>
<th>IOWA CORN</th>
<th>ILLIN.</th>
<th>INDIANA</th>
<th>MISSOURI</th>
<th>OHIO</th>
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TREND MODEL BY CARLSON 1996
ENTER YEAR TO START ANALYS: 1995
Table 2. Cross tabulation of corn yield and SO values.

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<td>6</td>
<td>15</td>
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<tr>
<td></td>
<td>in between</td>
<td>14</td>
<td>30</td>
<td>7</td>
<td>51</td>
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<tr>
<td></td>
<td>Total</td>
<td>22</td>
<td>50</td>
<td>16</td>
<td>88</td>
</tr>
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<td>1</td>
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<td>3</td>
<td>7</td>
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<td>15</td>
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<td></td>
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<td>Total</td>
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<td>50</td>
<td>15</td>
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<td>14</td>
<td>56</td>
<td>18</td>
<td>88</td>
</tr>
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</table>

† 10% above or below yield expectation ($\bar{y}$) defined by Eq. 1.
‡ Standardized monthly air pressure difference occurring during any of the summer months.