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WEATHER AND YIELD VARIATION IN THE MIDWEST: SO, SUNSPOTS, OR WHAT?

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Introduction

Corn production throughout the Midwest has been variable during the last 3 decades after a fairly stable time which extended from the late 1950’s through 1973. The stable period was described by Carlson (1990) and Baker et al. (1993), and others. Historically, corn production also varied before that time, but with yield levels at a lower potential. Some of this year-to-year yield variation has been apparently caused by the Southern Oscillation (SO) (Carlson et al. 1996) or sea surface temperature variation (Handler, 1984 and Thompson, 1990). The SO is closely related to El Niño and La Niña conditions (anomolusly warm and cold sea surface temperatures in the Equatorial Pacific, respectively). An excellent general reference for this is given by Diaz and Markgraf (1992). Weather impacts of these phenomena throughout the world are detailed by Ropelewski and Halpert (1986, 1987). Other information regarding these topics and crop yields are given by Carlson et al. (1996).

To evaluate these relationships, corn yield data were obtained for the 12 north central states for the period 1900-1996. The data for each state were fitted with a “Dose Response Logistic Curve” using regression analysis. This is illustrated in Fig. 1 for Iowa state-wide corn yields. This permitted the computation of relative corn yields for each year, thereby accounting for technological advances which have occurred over this long time period. Additionally, yield levels 10% above and below the trend line were computed to further segregate the relative corn yield data into 3 groups.

The data for SO (5 month moving averages) were obtained and used to code each year based upon summer SO values using the procedure described by Carlson et al. (1996). Cold event years (La Niña) were coded for years with summer SO values > 0.8, and < - 0.8 SO summer value years were coded as warm events (El Niño). Additionally, a sunspot number code was assigned to each year as is illustrated in Fig. 2 because other researchers (i.e., Thompson, 1973) have noted yield variations associated with various phases of this solar phenomena. The solar code grouped years according to 3 arbitrary criteria:

1) ± 2 years around the zero point year proceeding from a minor maximum to a major maximum (code 2),
2) ± 2 years around the zero point year proceeding from a major maximum to a minor maximum (code 4),
3) all other years (code 3).

Relative corn yield means were computed over these codes for each state and tested using t scores to evaluate statistical significant differences between means.

Results

It was found that SO impacted corn in all 12 north central states except the states in the southwestern part of this area, Nebraska, Kansas, and Missouri. Relative corn yields trended above average when the summer SO was negative (< - 0.8) and vise versa when it was positive (> 0.8). Positive yields were
generally associated with cooler and wetter summer weather conditions. Hotter and drier summer weather conditions usually produced below trend relative corn yields. With summer SO values between these limits, the relative corn yields averaged near zero with both positive and negative relative corn yield departures from trend.

The response to sunspot solar coding over the region was nearly the opposite of the SO-relative corn yield result. In this case, significant relative corn differences were found in the southwestern section of this region. Significantly lower relative corn yields were observed on average, when the solar configuration was code 2; and vice versa when the solar configuration was code 4. When the sun was active with many sunspots, the relative corn yields averaged near zero with both positive and negative departures throughout the region.

This is not to imply that a physical link exists between solar sunspot activity and the weather and yields of the midwestern United States. The results just show mean values resulting from this type of coding. It does appear that in the states exhibiting a significant result under solar code 2, the weather was warmer and drier during the summer months, and vice versa during solar code 4. The physical link between the sun and the earth remains elusive relative to this response. Other unknown solar attributes related to sunspots may be involved. Other cycles exist of comparable length, i.e., the lunar cycle of 18.6 years, and may be associated with this yield response.

To see how these two factors could be used to predict relative corn yields, two procedures were used. First, the data were categorized using three-way contingency tables. This is given in Table 1 for all north central states except North Dakota and Michigan. Data from those two states were not available when these analyses were computed. Over the 10 states, the results can be summarized as follows:

1. Under solar code 2, relative corn yields have difficulty rising above the 10%-higher-than-trend line.
2. Under solar code 4, relative corn yields remain above the less-than-10%-of-trend line more than 80% of the time.
3. Under solar code 3, relative corn yields are uniformly distributed above and below the trend line.
4. The SO signal of < -0.8 SO summer values favoring relative corn yields and > 0.8 SO summer values not favoring relative corn yields is present when the solar-code is either 2 or 4 (quiet sun), but vanishes when the solar code is 3 (active sun). In fact with this solar code, summers with SO values > 0.8 do rather well in terms of relative corn yield. The reason for this behavior is unknown.

A second way of characterizing the data involved counting positive relative corn yields over these 10 states using the two categorizations, SO and solar code. These results are given in Table 2 with the following conclusions:

1. When summer SO values were < -0.8 (El Niño), corn producers fared well under most solar configurations, especially when under solar code 4.
2. When summer SO values were > 0.8 (La Niña), corn producers did not fair well if the sun was quiet (low number of spots). They did produce above trend 2/3 of the time, if the sun was active. This is an unexpected result that is not understood at this time.
3. With summer SO values intermediate, producers did very well under solar code 4, but fell below trend two times out of three under solar code 2.
Table 1. Percent of years falling into the three categories based upon the SO, solar code, and relative yield based upon data from 10 states and 97 years.

<table>
<thead>
<tr>
<th>Solar Code</th>
<th>SO</th>
<th>Yield Compared to Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.8</td>
<td>&gt;10%</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;0.8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>IB</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;0.8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>&gt;0.8</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>IB</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;0.8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>&gt;0.8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>IB</td>
<td>25</td>
</tr>
</tbody>
</table>

<sup>1</sup> IB means in between designated limits

<sup>2</sup> Numbers may not sum to 100% in each sub-table because of rounding.

Table 2. Yield categorization with respect to trend using both the SO and solar code. Numbers are percent of years with a positive yield response over 10 states and 97 years.

<table>
<thead>
<tr>
<th>Solar Code</th>
<th>SO &lt; -0.8</th>
<th>IB&lt;sup&gt;1&lt;/sup&gt;</th>
<th>SO &gt; 0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>67</td>
<td>37</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>54</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>78</td>
<td>5</td>
</tr>
</tbody>
</table>

<sup>1</sup> IB means in between designated limits.
Literature Cited


State Wide Average Corn Yields

Iowa

Bushels/Acre

1900 1920 1940 1960 1980 2000

Years

0 40 80 120 160
Relative Sunspots Numbers

Years (1900---->1995)

Sun code
- = 4
● = 2
○ = 3

Fig. 2