15A.5 THE SOUTHERN OSCILLATION AND U.S. AGRICULTURE

Mark D. Brusberg * and Bradley R. Rippey
U.S. Department of Agriculture, Washington, D.C.

1. INTRODUCTION

The term El Niño (for "Christ child") was coined in the 1800s by sailors and fishermen who noticed that during some, but not all Christmas seasons, an unusual "counter-current" developed in the ocean off the coast of Peru. This occurrence coincided with other unusual events, including rain in usually arid areas (Philander, 1990) and, more importantly to the local economy, smaller catches experienced by local fisherman (Stefanski, 1992). In the decades that followed, a better understanding of the phenomenon was developed as researchers identified other anomalous conditions that could be attributed to El Niño, which was associated with above-normal sea surface temperatures. At the same time, another phenomenon gaining attention was the Southern Oscillation, or the fluctuation in the atmospheric pressure differences between the western tropical Pacific and the eastern Indian Ocean (Philander, 1990). This was eventually shown to have a relationship with sea surface temperatures in the tropical Pacific, and El Niño was identified as the "warm phase" of the Southern Oscillation. Similarly, La Niña was found to be the "cool phase" in the Southern Oscillation cycle. The Southern Oscillation Index (SOI) was defined as the normalized difference in atmospheric pressure between Tahiti, French Polynesia, and Darwin, Australia, and the term ENSO (El Niño / Southern Oscillation) was developed to describe the full range of variability observed in the SOI, which has recently been mapped to include oceanographic fields (McPhaden, 1993). As noted by Philander (1990), the aforementioned terms are frequently interchanged and have become general and qualitative.

In this study, the authors discuss both the importance of, and difficulties in, trying to correlate ENSO with agricultural production in the United States. Specifically, Montana will be highlighted as an area experiencing a relatively strong relationship with ENSO. The authors have chosen to primarily investigate the warm phase of the cycle (El Niño), which reflects the mild El Niño signal experienced during the northern hemisphere summer of 2002 (the time of this study). In addition, to stay consistent in identifying El Niño seasons, the authors followed the approach outlined by the Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration's National Weather Service (NOAA/NWS), whereby sea surface temperature reanalyses are subjectively categorized by season as having a neutral ENSO signal, or as a warm/cool episode of varying strength (NOAA/CPC, 2002).

* *Corresponding author address*: Mark D. Brusberg, U.S. Dept. of Agriculture, Rm. 5133 USDA South Building, Washington, DC 20250; e-mail: mbrusberg@oce.usda.gov.

2. El NINO IMPACTS SPECIFIC TO THE U.S.

In 1987, Ropelewski and Halpert published their seminal work defining global precipitation and temperature impacts experienced during El Niño and La Niña. Upon cursory examination, inferences can be made between the type and timing of the correlations and their potential effects on agriculture. For example, major crop areas in the southern hemisphere, notably Australia and southern Africa, tend to experience unseasonable warmth and dryness during El Niño growing seasons, which translate to lower-than-expected agricultural production. In the northern hemisphere, the Asian monsoon cycle is disrupted, sometimes resulting in drought and depressed agricultural output over portions of southern Asia.

The correlations between sea surface temperatures and rainfall and temperature anomalies are generally calculated using data from specific regions of the eastern Pacific Ocean, with major ENSO impacts generally concentrated in those areas influenced by tropical air masses. Consequently, in the United States, the impacts from El Niño are not as evident during the growing season as in some parts of the world, although an event can still have a significant impact on agricultural production at a regional level. Figures 1 and 2 depict those regions in the United States experiencing consistent impacts during El Niño winters (the most statistically significant period), with the highest correlations occurring in the northern Plains and the Gulf Coast. These anomalies can be traced to departures from the expected flow pattern in both the mid-latitude and tropical jet streams caused by the disruption of the tropical trade winds (Wallace and Vogel, 1994). Specifically for El Niño, NOAA (2002) has identified the following winter (October through March) impacts:

- A drier-than-normal fall and winter in the U.S. Pacific Northwest;
- A wetter-than-normal winter in the Gulf Coast States (Louisiana to Florida) and, if the event is strong, wet conditions in central and southern California; and
- A warmer-than-normal autumn and winter in the northern Great Plains and upper Midwest.

Impacts potentially occurring during the summer growing season (April through September) include:

- A reduced number of tropical storms and hurricanes in the Atlantic; and
- A drier-than-normal North American monsoon, especially in Mexico, Arizona, and New Mexico.

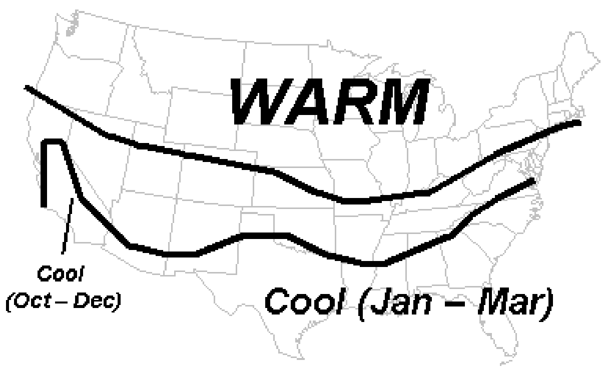

Figure 1. Winter (Oct-Mar) temperature anomalies associated with El Niño (from NOAA/CPC, 2002).

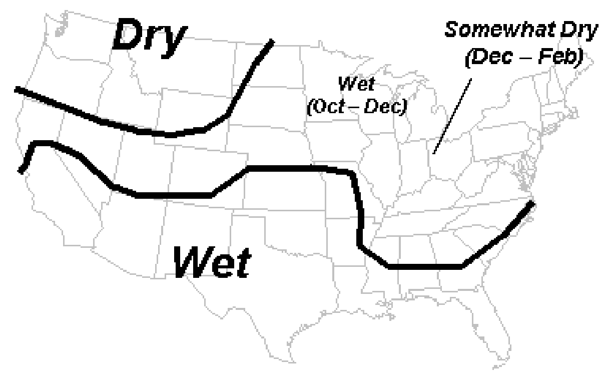

Figure 2. Winter (Oct-Mar) precipitation anomalies associated with El Niño (from NOAA/CPC, 2002).

It should be noted that while a literature review will uncover locally significant associations with ENSO and agriculture in the Southeast, relationships do not always exist between winter rainfall and non-irrigated summer crop production. In addition, El Niño has been shown to result in a reduction in overall tropical storm activity in the Atlantic, but its existence does not preclude storm development that could impact to the Southeast (Pielke and Landsea, 1999).

3. IMPLICATIONS FOR U.S. AGRICULTURE

Attempts to relate ENSO parameters to crop yields in those areas exhibiting a strong response to El Niño or La Niña have had some success (Cane, et. al. 1994; Rosenzweig, et. al. 1998). However, even in some of the highest correlating areas, El Niño does not result in the expected anomalies every year. Also, the relative strength of the event does not necessarily reflect the intensity of the anomaly. For example, the Asian drought of 1987 related to the monsoon failure was roundly referred to as the "drought of the century" in the press of the day, but the El Niño itself was not as strong as the 1982/83 event (NOAA/CPC, 2002).

In the United States, economic impacts from ENSO are thought to offset each other (NOAA, 2002), as losses in one sector (energy production, for example) can be realized as gains in another (lower energy costs for businesses and individuals). However, the surpluses or deficits experienced on a local level would tend to be irreversible within a region, as gains from one region would not be shifted to areas experiencing a shortfall. Mitigation activities or relief may therefore be required to offset regional deficits. This would hold especially true for agriculture and related industries.

ENSO impacts on agricultural production in the United States are tempered somewhat by the temporal and spatial extent of the effects. Unlike other nations affected by the phenomenon, the United States experiences its largest statistical influence outside of the growing season. In addition, the broad expanse of the Nation's farmland offers some protection that weather problems in one part of the country will not have a devastating effect on total national production. This does not mean, however, that production would not be affected at all, or the impacts would not be significant on a local level. It is also possible for agriculture to be "indirectly" affected by unfavorable aspects of the winter weather that carry over into the spring growing season.

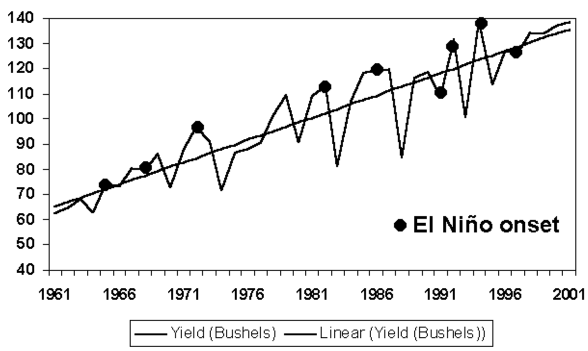

Figure 3. U.S. corn yields (USDA/ERS).

Since relationships between El Niño and U.S. weather are relatively minor during the growing season (May-September), one would expect low direct correlations between El Niño and agricultural production. However, some trends have been noted, leading to expectations of crop performance based on positions in the ENSO cycle. For example, as depicted by Figure 3, corn yields tend to be above trend in the year of an El Niño onset, and many commodity analysts will use this observation as the basis of early season crop estimates (NFO, 1998; Cooper, 2002). However, "false alarms" can be sounded on El Niño development, and events which appear to be incipient may fail to form. Or, as in the case of the 1997/98 growing seasons in Australia and South Africa, and the 2002 season in the United States, the El Niño does not produce the expected outcome. It is also worth noting that differing (sometimes conflicting) opinions have been offered as to why corn yields would be affected by El Niño, especially when the physical explanations cannot always be supported by historical data.

Rather than pursue more of these statistical correlations, the authors sought to look for potential agricultural impacts in locations exhibiting discernable changes in weather patterns during neutral, warm, or cool phases of ENSO, as defined by NOAA/CPC.

3.1 CASE STUDY: MONTANA

A region with well-documented ENSO impacts is that portion of the United States lying west of the Mississippi River (WRCC, 1998), although the effects can be difficult to quantify. In the Southwest, intensive irrigation demands and subsequent water management strategies are reflected in the streamflow data and make assessments of moisture for agriculture difficult. An exception is California, where wetness associated with El Niño is well documented. In the Pacific Northwest, the area affected is relatively small compared with the previously mentioned areas, and correlations may not exist in both warm and cool phases of ENSO.

Given the location and timing of the ENSO impacts, the authors hypothesized that a significant correlation might exist in Montana between El Niño and winter wheat or livestock production, two industries that can experience weather-related damage during instances of extreme rainfall or temperature departures from normal. Data (WRCC, 2002) were obtained for several weather and moisture parameters in hopes of establishing a discernable link. Cursory review of the agricultural statistics (USDA/NASS, 2002) showed no direct relationship between crop or livestock production and ENSO. However, the authors did find relationships between parameters that influence certain aspects of production, potentially resulting in costly mitigation.

3.1.1 SNOWFALL AND STREAMFLOW

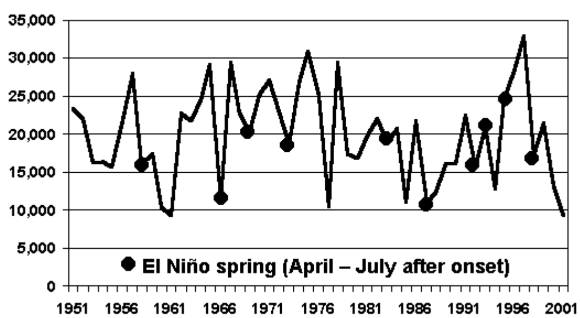

Figure 4. Streamflow at Miles City, Montana (Yellowstone River) in cubic ft/s.

During El Niño winters, recorded snowfall over Montana tended to be below both the average and previous season's amount. As would be expected from the snowfall data, streamflow values during the months of highest runoff also tended to be lower in El Niño years with respect to the previous season's levels. As depicted in Figure 4, runoff dropped from the previous season's levels in 8 of 10 El Niño seasons. However, due to water management programs in place throughout the western United States, it could not be determined whether or not reservoir maintenance or irrigation management practices played a role in the recorded levels downstream. The differences in response can be significant: in Montana, farmers typically irrigate 20 percent of their total agricultural output, and limitations in available irrigation could raise irrigation costs during times of drought. Changes in irrigation availability can potentially alter production from -8 to +13 percent (EPA, 1997).

3.1.2 WINTER WHEAT ABANDONMENT

As mentioned earlier, winter wheat yields in Montana showed no correlation with ENSO, presumably since the effects of the phenomenon diminish in the spring, coinciding with the beginning of the spring rainy season. However, the amount of the crop that was planted but not harvested (referred to as abandonment) is commonly related to "overwintering" conditions, including temperature severity and winterkill.

Category	Years	Average Abandonment	No of years with following % of abandonment:		
			< 10 %	10-20 %	> 20 %
Neutral	31	12.6%	17	10	4
La Niña	14	12.7%	7	4	3
El Niño	10	7.2%	8	2	0

Table 1. Montana winter wheat abandonment (USDA/NASS).

Comparisons were made between the amount of abandoned acreage in years experiencing El Niño, La Niña, or neutral ENSO conditions. As shown in Table 1, abandonment was lower than usual in El Niño years, compared with neutral or La Niña years, and no warm phase winter suffered more than 20 percent abandonment. During 10 El Niño seasons, average abandonment was 7.2 percent (compared with just over 12.5 percent in non- El Niño years), or 161,600 acres. Of the 45 years defined as neutral or La Niña years, actual average abandoned acreage was very similar (283,484 acres in 31 neutral years versus 216,500 acres in 14 La Niña years), as were the highest abandonment figures for each case (43.1 percent abandonment the neutral 1984-85 season compared with 40.0 percent abandonment in the La Niña season of 1988-89). The highest percentage of abandonment in El Niño seasons was only 13.5 percent (1991-92 growing season), which is comparable to the *average* abandonment during the neutral or La Niña conditions. The authors speculate that this is due to a reduction in winterkill during the milder winters, but more information at local levels would be required to substantiate this conclusion.

4. ENSO FORECASTS AND AGRICULTURAL DECISION MAKING

NOAA has outlined some of the potential economic benefits of better El Niño forecasting in leading to potential improvement in economic decision making (NOAA, 2002). However, problems arise in making consistent forecasts and conveying them to the public.

To begin with, long-term outlooks issued by CPC do not predict El Niño, but rather rely on independent forecasts of El Niño (and La Niña) as an input (Monastersky, 1999). Models used to successfully predict El Niño onset (Cane, et. al., 1986) have been observed to have some limitations in predicting changes in intensity. Crop analysts using these tools have also noted the lack of incorporation of newly discovered phenomenon as a companion to forecasting El Niño development, as well as the difficulty experienced in trying to understand long-term forecasts (Garnett, undated). In addition, recently published skill scores for those long-term forecasts depict limited utility as a tool for long-term agricultural planning (CPC, 2002). It is worth recalling that in Montana, a correlation between El Niño and winter dryness does not translate to a correlation between El Niño and crop yields. Therefore, the potential for misinformation or a "bad forecast" to cause a farmer not to maximize his output potential would make preemptive actions a risky decision.

Weather forecasts notwithstanding, prevailing economic conditions may not support a change in cropping patterns, as prevailing commodity prices and availability of crop insurance also figure prominently in farm-level planning. It should also be noted that droughts or flooding that commonly appear during an El Niño in other countries can indirectly benefit U.S. farmers. For example, countries that experience profound negative growing-season impacts on agricultural output (Australia and South Africa, for example) will likely experience reductions not only in crop production but in supply as well. This could create higher-than-usual demands for U.S. commodities, push prices up to more favorable levels, and help to open new international markets for U.S. exports.

5. SUMMARY

El Niño has been shown to have at least a localized impact on U.S. agriculture, although the overall impacts to total national production of a given commodity are considerably less than in some other countries. In the case of Montana, significant weather anomalies exist during El Niño events, but the impact can be indirect and difficult to quantify. As with most weather phenomenon, forecasting variations in the ENSO cycle could help influence long-term planning for El Niño or La Niña scenarios, but long-term forecasts as a planning tool are limited by the skill of those forecasts in their utility for making decisions prior to the start of the growing season. In addition, it is extremely difficult to quantify the economic impacts of ENSO events, especially in sectors where gains can offset losses.

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