CORTEVA agriscience

Impacts of the El Niño Southern Oscillation on Crop Production

CROP BULLETIN

Mark Jeschke, Ph.D., Agronomy Manager

SUMMARY

- The El Niño Southern Oscillation (ENSO) is a natural cycle involving interactions between the ocean and the atmosphere in the tropical Pacific Ocean that affects atmospheric circulation and weather patterns globally.
- El Niño is the most well-known of the three phases of the El Niño Southern Oscillation, which also includes its opposite phase La Niña and a neutral phase.
- El Niño and La Niña events typically reach their peak strength during the late fall or early winter months in the tropical Pacific Ocean.
- El Niño and La Niña have their strongest influence on U.S. seasonal climate during winter, in the months shortly following the peak. Effects during summer are mostly weak or insignificant.
- Weather during the winter and early spring can have important effects on conditions going into the start of the summer growing season; however, ENSO phase is not strongly predictive of U.S. corn and soybean yields.

EL NIÑO SOUTHERN OSCILLATION

The El Niño Southern Oscillation (ENSO) is a natural phenomenon that involves the interaction between the ocean and the atmosphere in the tropical Pacific Ocean. ENSO is characterized by irregular fluctuations in sea surface temperatures, atmospheric pressure, and winds in the equatorial Pacific region, which occur over a period of two to seven years. This change in ocean temperature and current affects atmospheric circulation and weather patterns globally. The impacts of ENSO can be significant and can have widespread effects on ecosystems, agriculture, and human activities.

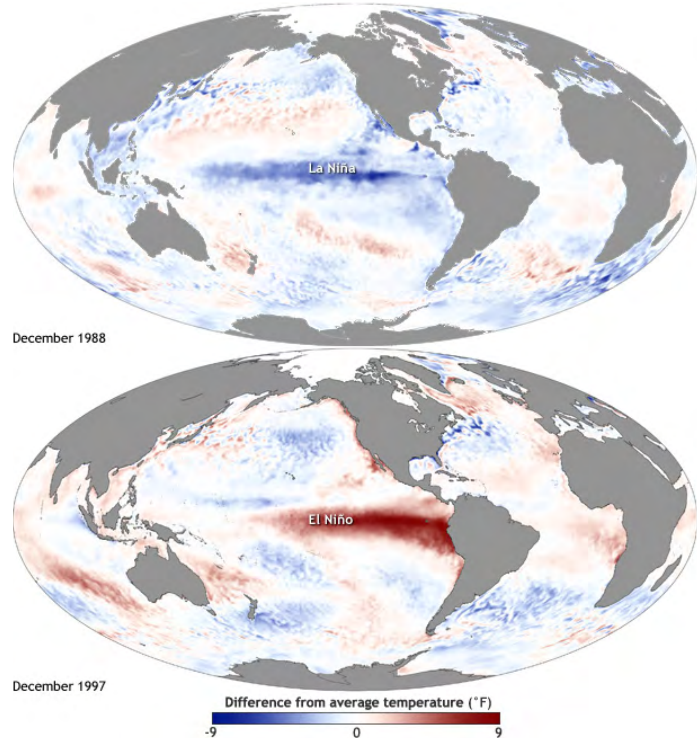

Figure 1. Sea surface temperature across the tropical Pacific Ocean in December 1988 (top) during a strong La Niña and in December 1997 (bottom), during a strong El Niño.

Maps by NOAA Climate.gov, based on data from NOAA's Physical Science Lab.

'YO SOY EL NIÑO'

The phenomenon of El Niño was first observed centuries ago by fishermen off the coast of Peru, who noticed occasional periods of abnormally warm waters that would reduce the abundance of fish. This phenomenon was dubbed El Niño, a Spanish language reference to the Christ child, because it typically began to appear around Christmas.

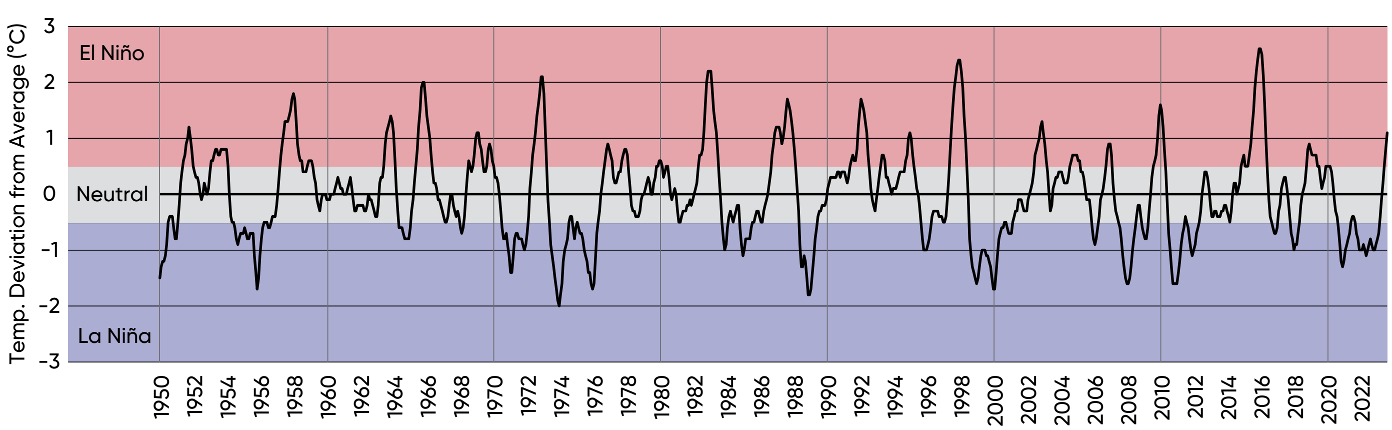

Figure 2. Oceanic Niño Index (ONI) values from January 1950 through July 2023, showing 3 month running mean of sea surface temperature anomalies in the Niño 3.4 region, based on centered 30-year base periods updated every 5 years.

NOAA National Weather Service Climate Prediction Center, https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

As better weather records became available for the South Pacific during the 19th Century, a consistent negative correlation was noticed between atmospheric pressure in the western and central South Pacific – high pressure and drought conditions recorded at Darwin in the Northern Territory of Australia often coincided with low pressure and wet conditions in French Polynesia (near the center of the South Pacific). This phenomenon was first documented by British climatologist Sir Gilbert Thomas Walker and named the Southern Oscillation. Further work by Walker showed that the impacts of the Southern Oscillation extended far beyond the South Pacific, with statistical evidence that climate anomalies around the world were associated with it.

It wasn't until the 1960s that meteorologist Jacob Bjerknes recognized that El Niño and the Southern Oscillation were actually components of the same large interacting system of atmospheric and ocean circulation, now referred to as the El Niño Southern Oscillation. Scientific interest and study of ENSO increased following the strong El Niño event of 1982-1983 and it entered the popular consciousness in the 1990s following a rapid succession of El Niño events and one particularly memorable Saturday Night Live sketch in 1997.

ENSO PHASES

El Niño is the most well-known of the three phases of the El Niño Southern Oscillation, which also includes its opposite phase La Niña and a neutral phase. El Niño is not necessarily more important or impactful than La Niña; it is more well-known because it was the part of the cycle that was discovered and named first.

Neutral phase: This is the normal state of the tropical Pacific, where the trade winds blow from east to west, causing warm surface water to accumulate in the western Pacific and cooler water to upwell in the eastern Pacific. During this phase, sea surface temperatures are relatively stable.

El Niño phase: During an El Niño event, the trade winds weaken, and the warm surface water in the western Pacific flows back towards the east, causing sea surface temperatures to rise in the eastern Pacific. This results in changes in atmospheric circulation and weather patterns globally, such as droughts in Southeast Asia and Australia and wetter conditions in western South America.

La Niña phase: During a La Niña event, the trade winds strengthen, causing even more warm water to accumulate in the western Pacific and cooler water to upwell in the eastern Pacific. This leads to cooler sea surface temperatures in the eastern Pacific and affects atmospheric circulation and weather patterns differently than during El Niño events.

MONITORING ENSO

El Niño and La Niña events can vary in strength. The ocean temperature component of ENSO is characterized by the Oceanic Niño Index, which is a 3-month rolling average of sea surface temperatures in the east-central region of the equatorial Pacific (Figure 2). Temperatures within +/-0.5 °C of the 30-year average are considered neutral, more than 0.5 °C above average is considered El Niño conditions and -0.5 °C or lower is considered La Niña. The greater the deviation from average, the stronger the El Niño or La Niña event is considered to be. The strongest El Niño event in recent history occurred during the winter of 2015-2016 when the ONI peaked above +2.5°C from November through January, and the strongest recent La Niña was in winter of 2010-2011 with a peak of -1.6°C from September through December 2010.

ENSO follows a regular cycle, but the timing and pattern of the cycle can vary considerably, with the time between El Niño events ranging from 2 to 7 years in most cases. Episodes of El Niño and La Niña typically last 9 to 12 months but can sometimes last for years.

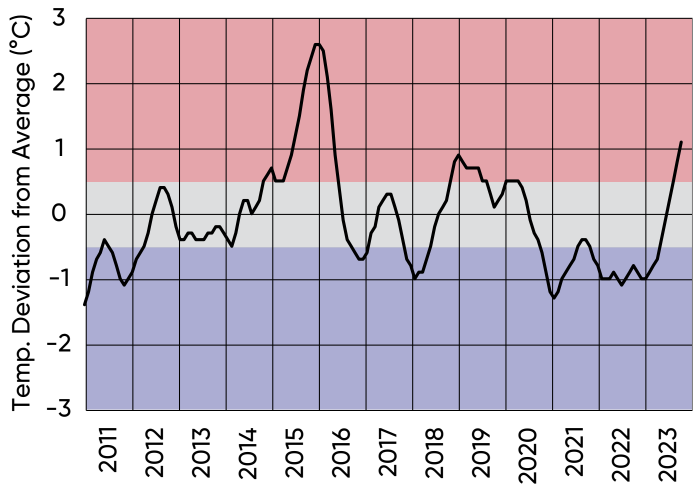

Figure 3. Oceanic Niño Index (ONI) values from 2011-2023, showing the most recent El Niño phases in 2015-2016 and 2018-2019, the extended La Niña phase that began in 2020 and continued through early 2023, and the shift to El Niño that occurred in mid-2023.

El Niño and La Niña events typically reach their peak strength during the late fall or early winter months in the tropical Pacific Ocean when sea surface temperatures in the central and eastern equatorial Pacific Ocean are at their warmest and coolest, respectively. While the peaks may occur during this period, the impacts of El Niño and La Niña on global weather patterns, including changes in precipitation and temperature, can extend into the following months, affecting various regions around the world. The specific timing and intensity of El Niño events can vary from one occurrence to another, and their effects on weather patterns can also be influenced by other atmospheric and oceanic factors.

IMPACTS ON WEATHER IN NORTH AMERICA

ENSO has significant impacts on weather patterns around the world, including North America. El Niño and La Niña have their strongest influence on U.S. seasonal climate during winter. The effects of the El Niño phase on North America can vary depending on the strength and timing of the El Niño event, but common impacts include:

- Increased rainfall in the southern U.S., particularly in the winter months. This can lead to flooding in some regions (Figure 4).
- Warmer-than-average temperatures in the northern U.S. and Canada during the winter months.
- Drier and warmer conditions in the Pacific Northwest and parts of the Midwest, which can lead to drought conditions and an increased risk of wildfires.

- Milder winters to the northern U.S., reducing the chances of heavy snowfall and colder temperatures in regions like the Midwest and Northeast.
- Suppression of Atlantic hurricane activity, reducing the number and intensity of hurricanes in the Atlantic Basin.

La Niña is the counterpart to El Niño and its climate impacts tend to be the opposite of the El Niño phase of the cycle. Common impacts of La Niña on the climate of North America include:

- Wetter-than-average conditions in the northern U.S., particularly in the Pacific Northwest and northern Rockies during the winter months. This can result in above-average snowfall (Figure 5).
- Colder-than-average temperatures in the northern U.S. during the winter. This can lead to prolonged periods of wintry weather.
- Drier conditions in the southern U.S., including the Southwest, Southern Plains, and Southeast. This can result in drought conditions, reduced water availability, and an increased risk of wildfires.
- Increased likelihood of an active Atlantic hurricane season. Warmer waters in the tropical Atlantic can fuel the development of hurricanes, potentially affecting the Gulf of Mexico and the southeastern U.S.
- Enhanced potential for severe weather outbreaks, including tornadoes, in the southern and central United States during the spring.

IMPACTS ON CROP PRODUCTION

ENSO is a major source of climate variability that has impacts on crop production regions around the world, and numerous studies have examined its effects on regional and global crop yields. In the U.S. and Canada, yields of summer annual crops such as corn and soybean tend to be less affected because the strongest effects of ENSO do not occur during the growing season.

In general, ENSO-related temperature and precipitation impacts across the U.S. and Canada occur during the cold half of the year – October through March. Usually, El Niño or La Niña episodes attain peak strength in autumn or early winter and the most reliable climate impacts in the U.S. and Canada are during winter, within a few months after the peak. ENSO effects during summer are mostly weak or insignificant; however, they can be more substantial and consistent in other regions of the globe.

Effects on weather during the winter and early spring can have important effects on conditions going into the start of the summer growing season. For example, recharge of water in the soil profile following a drought and overwintering of insect pests are both factors that are affected by temperature and precipitation patterns during the winter. However, temperature and precipitation during the summer months – which are the greatest drivers of yield – are not as directly and consistently affected.

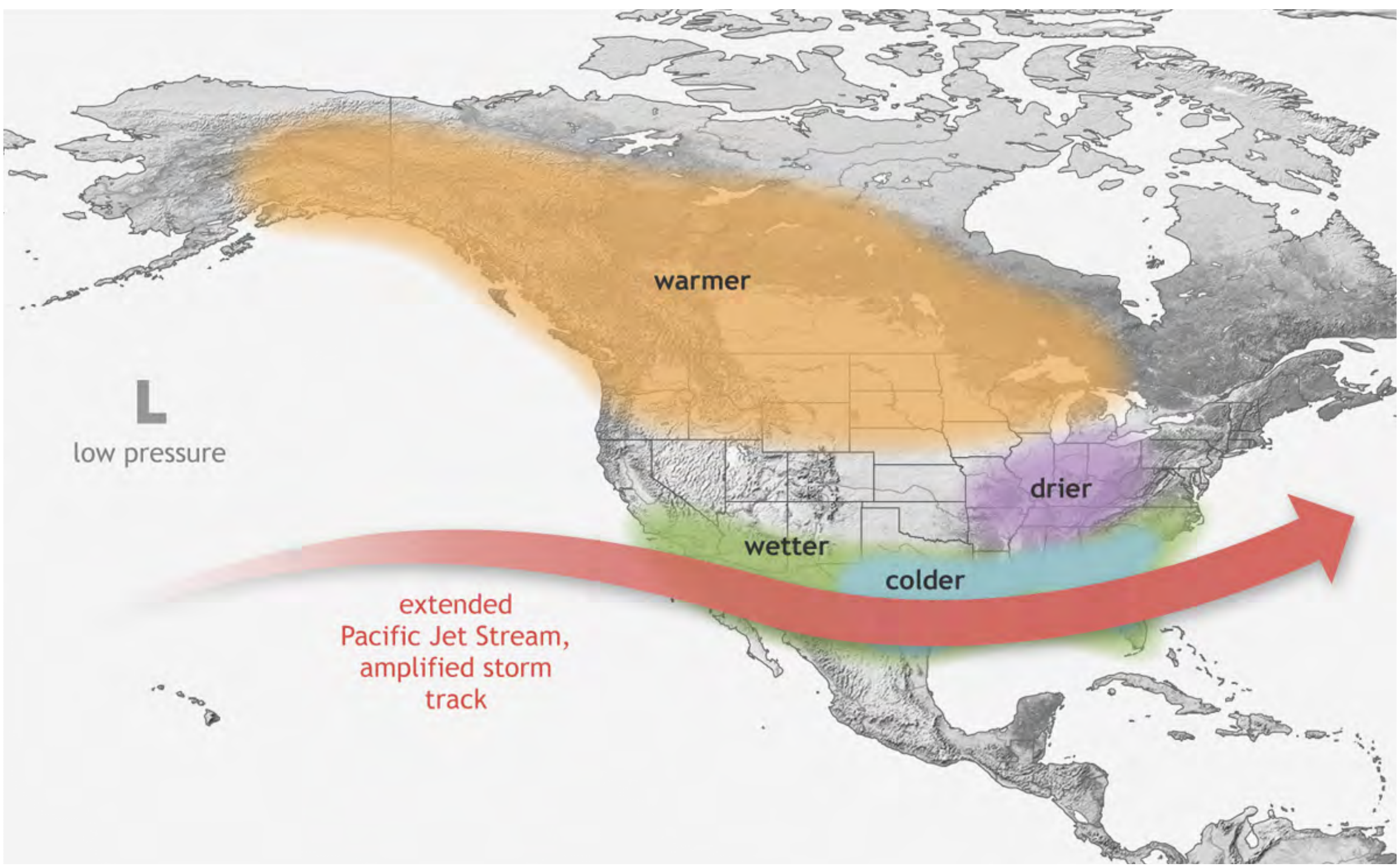

Figure 4. Typical impacts of El Niño on winter weather in North America. Source: NOAA Climate.gov

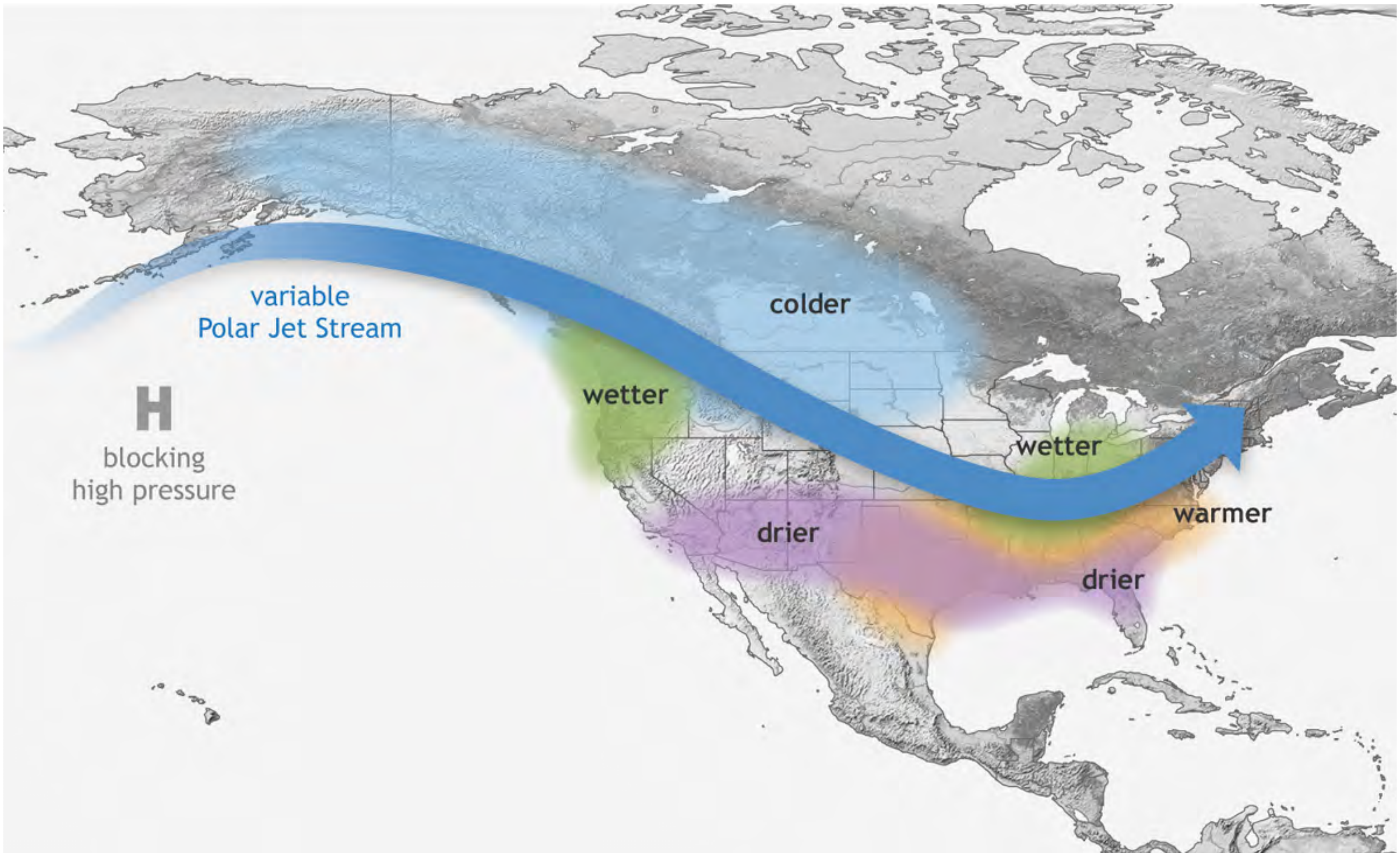

Figure 5. Typical impacts of La Niña on winter weather in North America. Source: NOAA Climate.gov

CORN AND SOYBEAN YIELD TRENDS

A 2016 analysis by the University of Illinois (published during the last major El Niño event) looked at the impacts of El Niño on U.S. corn and soybean yields the following season (Irwin and Good, 2016a; Irwin and Good, 2016b). The authors calculated the deviation of yearly corn and soybean yields from the long-term trendline and summarized numbers for crop years following strong El Niño events (>1.0°C ONI) to see if yields tended to be above or below trendline in those years. Results suggested a slightly elevated risk of below trendline yields following an El Niño event for both corn and soybeans on average, but results varied widely, with yields above trendline occurring with about the same frequency as below trendline.

The following charts and tables provide an update and expansion of the University of Illinois analysis to include crop years up through 2022 and a summary of yield trends following both El Niño and La Niña events. Figures 6 and 7 show U.S. average yields from 1960 to 2022 for corn and soybean, respectively. Yields of both crops increased linearly over this period, by an average of 1.86 bu/acre/yr for corn and 0.45 bu/acre/yr for soybean.

Tables 1 and 2 show corn and soybean yield deviations from the 1960-2022 trendlines (calculated as % above or below) for growing seasons following strong El Niño and La Niña events.

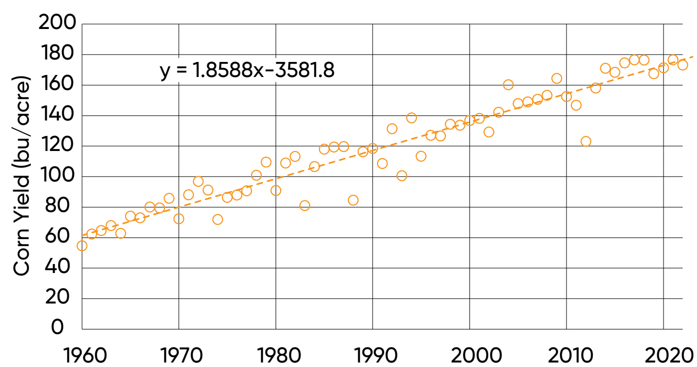

Figure 6. Average U.S. corn yields, 1960-2022. Source: USDA National Agricultural Statistics Service.

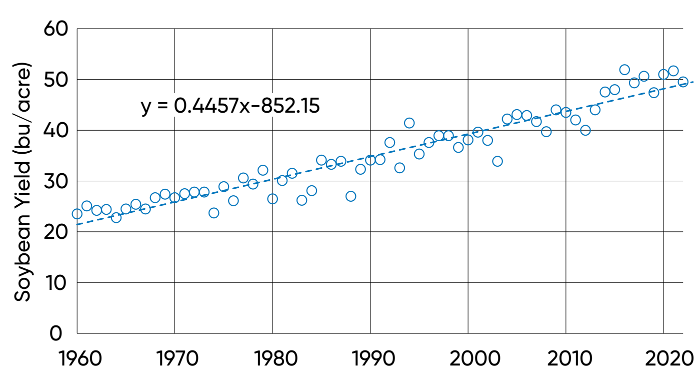

Figure 7. Average U.S. soybean yields, 1960-2022. Source: USDA National Agricultural Statistics Service.

Table 1. El Niño events exceeding +1.0°C ONI from 1960 to present, and U.S. corn and soybean yield deviations (%) from trendline yield in the following crop year.

El Niño Event	Peak Temp. Dev.	Peak Months	Crop Year	Yield Dev. From Trend	
				Corn	Soy
	°C			– % –	
1963-64	1.4	Nov 63	1964	-8.7	-1.7
1965-66	2	Oct - Nov 65	1966	0.7	5.4
1968-69	1.1	Jan - Feb 69	1969	9.9	7.7
1972-73	2.1	Nov - Dec 72	1973	6.6	2.1
1982-83	2.2	Nov 82 - Jan 83	1983	-22.2	-17.3
1986-87	1.2	Dec 86 - Feb 87	1987	7.3	1.3
1987-88	1.7	Aug 87	1988	-25.5	-20.4
1991-92	1.7	Jan 92	1992	8.7	5.4
1994-95	1.1	Dec 94	1995	-10.3	-4.7
1997-98	2.4	Nov - Dec 97	1998	1.8	1.4
2002-03	1.3	Nov 02	2003	0.6	-16.5
2009-10	1.6	Dec 09	2010	-1.2	-0.5
2015-16	2.6	Nov - Dec 15	2016	5.5	11.9
Average Deviation from Trendline Yield				**-2.1**	**-2.0**
Number of Years Above Trendline				**8**	**7**
Number of Years Below Trendline				**5**	**6**

Tables 1 and 2 also show the peak ONI temperature for each event and the month or months in which that temperature peak was recorded. In some cases, that peak temperature was sustained for multiple months, sometimes extending from the end of one year into the beginning of the next.

Results show yields slightly below trendline on average for both corn and soybean following both El Niño and La Niña events. However, much like the University of Illinois analysis, results show a mixed picture, with above trendline yields occurring with around the same frequency as below trendline.

The worst years for corn yields since 1960, in which average yield was more than 10% below trendline, included 3 El Niño years (1983, 1988, 1995), 2 La Niña years (1974, 2012), and 2 neutral years (1960, 1993). The best corn yield years (more than 10% above trendline) included 1 La Niña year (1972), and 4 neutral years (1979, 1982, 1994, 2004).

For soybean, the worst yield years included 3 El Niño years (1983,1988, 2003), 3 La Niña years (1974, 1984, 2012), and 1 neutral year (1980). The best years included 1 El Niño year (2016), and 2 neutral years (1961, 1994).

Overall, results show that ENSO phase is not strongly predictive of U.S. corn and soybean yield performance in the subsequent growing season.

Table 2. La Niña events below -1.0°C ONI from 1960 to present, and U.S. corn and soybean yield deviations (%) from trendline yield in the following crop year.

El Niño Event	Peak Temp. Dev.	Peak Months	Crop Year	Yield Dev. From Trend	
				Corn	Soy
	°C			– % –	
1970-71	-1.4	Jan - Feb 71	1971	7.6	4.5
1971-72	-1	Nov 71	1972	15.8	3.8
1973-74	-2	Dec 73	1974	-17.8	-14.3
1975-76	-1.7	Dec 75	1976	-3.5	-8.6
1983-84	-1	Nov 83	1984	0.6	-12.5
1984-85	-1.1	Dec 84	1985	9.3	4.7
1988-89	-1.8	Nov - Dec 88	1989	0.8	-6.0
1995-96	-1	Oct - Dec 95	1996	-1.0	0.4
1998-99	-1.6	Dec 98	1999	-0.1	-5.7
1999-00	-1.7	Dec 99 - Jan 00	2000	0.8	-2.9
2007-08	-1.6	Dec 07 - Jan 08	2008	1.7	-7.3
2010-11	-1.6	Sept - Dec 10	2011	-6.0	-4.9
2011-12	-1.1	Nov 11	2012	-22.1	-10.3
2020-21	-1.3	Nov 20	2021	1.1	6.4
2021-22	-1	Nov 21 - Jan 22	2022	-1.9	0.9
2022-23	-1	Sept - Oct 22	2023		
Average Deviation from Trendline Yield				**-0.7**	**-2.8**
Number of Years Above Trendline				**9**	**7**
Number of Years Below Trendline				**7**	**9**

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