EL NIÑO AND THE EFFECTS ON HORTICULTURE IN NORTH AMERICA
LITERATURE REVIEW
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El Niño may be the only climate event that needs its own press agent. Once it was determined that there will be a strong El Niño, it has dominated the headlines. Some of these headlines are intelligent warnings and others are exercises in attention-grabbing hyperbole. Climate probability is a mosaic of factors.

El Niño 1997/98, defined "the climate event of the century" did not have major impacts on the agricultural areas of the world. The reasons are not completely clear. El Niño 1997/98 started at the same time as El Niño 1991/92 in April/May/June with a similar duration (only two months shorter) at almost twice the intensity, but had very little influence on agriculture: El Niño 1991/92 caused drought in approximately 350 million hectares while El Niño 1997/98 affected 80 million hectares (77 percent less). Additional information is necessary (beyond the ENSO indices ONI and SOI) to capture the complexity of the interaction between agricultural production, climate and oceanic temperatures and currents.

Any characterization of El Niño and connection with its impacts on agriculture is difficult to ascertain because many variables also have a sway in each event, including the gestation period, which may start from a neutral, positive (La Niña) or negative (El Niño) phase and in the onset time, intensity and duration of an El Niño occurrence. All these variables, in turn, interact with other dynamic variables of vegetation development. The real numbers of variables are unknown, making the situation more complex, while atmosphere, ocean and crop dynamics interact at different moments of time. The whole situation is similar to trying to solve Rubik's Cube.

The "Godzilla" El Niño of 2015-2016 is expected to be one of the strongest on record, having large consequences on global weather. But not all of El Niño's impacts are monstrous, and some can even be positive.

Currently, two major climate factors will shape global weather. In the tropics is a strong El Niño event that some headlines have described as a "Godzilla El Niño." To the north, swirling in the Arctic air is the sulfuric debris from the giant eruption of Iceland's Bárðarbunga volcano. The tropics and summer in the Southern Hemisphere will be shaped by the El Niño. Winter in the Northern Hemisphere could be shaped by the combined impact of both events.

According to NOAA's latest monthly outlook (December 10, 2015), El Niño conditions are expected to remain strong through the winter of 2015-16, transitioning to neutral conditions (neither El Niño nor La Niña) by late spring or early summer 2016. The 2015-16 El Niño event will likely end up as one of the three strongest El Niños since 1950. Outlooks generally favor cooler and wetter than usual conditions

across the southern U.S., and drier and milder than average conditions over the northern tier of states. The only El Niño events in NOAA's 1950-2015 database comparable in strength to the one now developing occurred in 1982-83 and 1997-98.

Despite record global temperatures in 2014, an El Niño did not appear; nevertheless, in an unusual development, the climate in many parts of the world behaved as if one was occurring and growing seasons were seriously disrupted, mainly by drought. Temperatures continued to soar in 2015 and now an El Niño has indeed developed. It could be the most powerful since 1997–98, which caused climate chaos and humanitarian disasters in many countries. With the boost of El Niño, unprecedentedly high temperatures are likely to continue during 2016.

Scientists are warning that recent events could signify that big changes may be underway in the Earth's climate system, driven by rising surface temperatures and changes in major atmospheric and oceanic circulation systems such as those which give rise to El Niño. The combination of record warmth one year followed by an El Niño the next is unique and the climatic implications are uncertain. If 2016 follows a similar pattern we are entering uncharted waters.

The planet has changed a lot in 15 years, since the last big El Niño in 1997–1998. We have had years of record Arctic sea ice minimum. We have lost a massive area of northern hemisphere snow cover, probably by more than 1 million square km in the past 15 years. We are working on a different planet and we fully do not understand the new patterns emerging. This is a new planet. Will the two patterns reinforce each other or cancel each other? We have no precedent. Climate change is increasingly going to put us in this situation. We don't have a previous event like this' - David Carlson, Director of the WMO co-sponsored World Climate Research Programme, speaking recently.

2014 was a very unusual year. It was the hottest yet, despite the fact that there was no El Niño to boost temperatures. The Pacific Ocean warmed up to an unprecedented degree with sea surface temperatures exceeding those reached in 1997–19988. This seemed likely to lead to an El Niño developing, but it fizzled out. Nevertheless, the climate in certain parts of the world behaved as if one was occurring: significantly, and peculiarly, 'the performance of the 2014 growing season in many places around the globe was similar to that of under a typical El Niño'. The heat of 2014 continued into 2015. Now, to the surprise of some observers, an El Niño which has been building up since March 2015 has indeed developed – potentially one of the most powerful on record, and likely to boost global warming to make 2015 even hotter than 2014.

Scientists say that this year's event is likely to be at least on a par with these and possibly stronger than in 1997–1998. Even when an El Niño occurs there are many other influences on the world's weather, and every El Niño is different in its effects, so it is not possible to say exactly what will happen in 2015–2016 or blame El Niño for every extreme event. The impacts on agriculture will also vary. According to the UN Food and Agricultural Organization (FAO), the impact of an El Niño on crops 'depends on timing and duration, as well as climatic modifications produced by El Niño together with the sensitivity of the crops during the peak period of influence of the event'.

WHAT IS EL NIÑO?

El Niño is the name given to a periodic heating-up of the surface of the tropical Pacific Ocean, which happens as trade winds weaken and warm water that is usually confined to the western Pacific flows eastwards, away from Indonesia and towards Peru. This creates a huge release of heat into the

atmosphere that influences global weather patterns. It is a natural phenomenon and an El Niño happens approximately every seven or eight years. These events are usually weak or moderate, but occasionally an extra-strong or 'super' El Niño happens.

There were super El Niños in 1972–73 and again in 1982–83. The strongest El Niño in recent times occurred in 1997–1998. This brought record global temperatures and droughts, floods and massive forest fires. It caused 2000 deaths and at least $33bn in property damage.

Strong El Niños reinforce the likelihood of certain climatic events – and the chances of severe droughts in particular - happening in specific parts of the tropics (covering about 20–30 percent of land areas).

A La Niña event is an intensification of the normal Walker cell. This results in warmer and drier conditions than normal, rarely with serious consequences for Mexico. However, during an El Niño Southern Oscillation (ENSO) event, the Walker circulation pattern is essentially reversed. Early in the year, warm ocean water extends much further east, causing warm moist air to rise off the coast of South and Central America, bringing heavy rainfall to areas along the west coast of Mexico.

The effects of an ENSO event are also felt on the Gulf coast. The low pressure area resulting from the air rising off the western coast causes air from further east to be dragged across Mexico. This means that more cold fronts or nortes enter north and central Mexico. Winter precipitation in these areas increases significantly, especially in the north, and temperatures are much cooler than usual. Flooding can result in coastal areas. ENSO effects are also felt in other parts of the world.

In Mexico, ENSO events not only affect winter precipitation but also summer precipitation, which is more critical for farmers. This is because they push the equatorial Intertropical Convergence Zone (ITCZ), where the north-east and south-east trade winds meet, further south. This reduces the convective activity and rainfall in Mexico's central highlands. Furthermore, this may reduce cloud cover and therefore increase solar radiation and evapotranspiration, making the ground even drier.

EL NIÑO AND NORTH AMERICA (WITH A FOCUS ON MEXICO)

- Canada enjoys warmer weather in an El Niño year, and in particular a greater return from its fisheries.
- For Mexico we observe fewer hurricanes on the east coast and more hurricanes on the west coast, which brings generally stability to the oil sector and boosts exports (oil revenue is around 8% of GDP in Mexico).
- For the United States, El Niño typically brings wet weather to California (benefiting crops such as limes, almonds and avocados), warmer winters in the Northeast, increased rainfall in the South, diminished tornadic activity in the Midwest, and a decrease in the number of hurricanes that hit the East coast.
- In North America, heavier precipitation and cloud cover usually cools the southern tier of states but most of Canada and portions of the northern states are warmer and drier. In North America, there is usually more autumn rainfall, but fewer hurricane landings in the southern tier of states and warm, dry conditions in Western Canada and parts of the Pacific Northwest. Precipitation is only part of the picture. The warm offshore waters heat nearby land masses, making it hotter in India, Southeast Asia, Australia, and the western portions of Canada, Central America and South America.

- In northwestern Mexico there is a clear tendency for more winter precipitation, which has resulted in positive trends in river-water level.
- Extensive studies of the Caribbean watersheds of Mexico and other countries show compelling evidence of more winter and less summer precipitation; in addition, the most severe droughts in Mexico in recent decades have occurred during El Niño years.
- A strong El Nino this winter usually leads to warmer conditions in the northern tier of states and most of Canada. This should lead to lower heating demand, as well as fewer travel and transportation difficulties. The southern tier of states should get cooler, wetter conditions, usually enough to end drought conditions in all but Southern California. California should expect more precipitation but not enough to end the drought.
- North American winters are shaped by what is happening in the Atlantic and Arctic as well as the Pacific. Even in the Pacific, El Niño is not the only factor affecting the West Coast. The West Coast – The Region Most Affected by El Niño - …historical evidence gives a more than 90% probability that there will be good rainfall in California this winter but it will only partially relieve drought conditions.
- History suggests that Central and Southern California should have heavy rainfall while Northern California good rainfall. Historically much of this rainfall comes in the form of torrential rains and flash flooding from tropical streams of moisture called atmospheric rivers. Meanwhile, the coastal Pacific Northwest and British Columbia get heavy rains. Inland, the Northwest and Alberta and Saskatchewan, have an 80% chance of a warm, dry winter.
- The economic impact of the El Niño is widespread. It is benign for most of US agriculture and lowers winter heating demand for most of Canada and large portions of the Western and Northern US. However, the impacts on other portions of the North American economy are not as favorable.
- According to NOAA analysts, nearly 25% of the US GDP is directly or indirectly affected by weather and climate. El Niños usually provide a favorable climate. Their impact is less benign on other North American countries.
- Although the ENSO phenomenon occurs in the tropical Pacific, the associated climate effects occur on a more global scale, and, in turn, have broad regional implications for crop yields. Mexico is one country where ENSO-related climatic disturbances have been observed. Variations in climate characteristics and reservoir inflows for some regions of Mexico have been reported for the three ENSO phases (El Niño, La Niña and Neutral). In addition, there are variations in weather patterns across Mexico during a given ENSO phase. These changes in seasonal weather patterns and stream flows have been associated with alterations in agricultural yields in important agricultural regions of Mexico.
- In Mexico, while there is a net decrease in hectares during El Niño years (and a slight net increase during La Niña and Neutral years) the net change in individual crops does not always follow that pattern. In El Niño years, these changes in hectares planted also have an impact on total production of each crop. There is an increase in the quantity produced of most crops, with the largest increases being in broccoli, a minor crop, and soybeans, and a reduction in the production of some crops, such as barley grain, oat silage, and wheat.
- A Mexican agriculture and climatic sensitivity (1999) study of the impacts of the El Niño phase on Mexican climate indicates that most El Niño years exhibit reduced summer months precipitation, and reduced winter season inflows to reservoirs (by about 40%).
- This year's El Niño is expected to be one of the most intense in half a century, and will deliver a "conveyor belt" of storms to California, according to a NASA climatologist. But what does it mean for Mexico? Probably more rain and fewer fish, according to the Center for Scientific Investigation and Higher Education of Ensenada (CICESE). The prospects don't sound as potentially disastrous as predictions for California, where heavy rains could wipe out crops, cause mudslides and batter

beachside communities, says a report by the Los Angeles Times. El Niño has already affected Mexico, most notably in the form of Hurricane Patricia, which ravaged part of the Pacific coast last month. Stronger effects are already being felt elsewhere, some good, others not. Predictions by the World Meteorological Organization (WMO) put El Niño 2015-16 as one of the most powerful since 1950 with effects that will be increasingly evident in the next four to eight months.

- An examination of historical agricultural statistics show El Niño phases have been associated with crop failures, increased idling of land and reductions in agricultural yields. For example, during the 1982, 1986 and 1987 El Niño years, 97, 86 and 73% of land under rainfed crops in the semiarid north central region of Mexico was idled, compared to 13% on average over the past three decades for dryland crops in Mexico (SARH, 1986). The impacts of ENSO events on rainfed agriculture in Mexico are important, given that approximately 80% of land in Mexico is non-irrigated.
- Historical analysis combined with greater climatological understanding shows that many of the worst droughts and floods in Mexico have been associated with either ENSO events or with the related Pacific-North American Oscillation. Perhaps 65% of the variability of Mexican climate results from changes in these large-scale circulations.
- The strongest ENSO signal in Mexico is found across the important agricultural states of Jalisco, Guanajuato, Mexico, Michoacan, and Tamaulipas. These states are located in the temperate to subtropical central portion of Mexico and produce a wide range of crops. In aggregate they produce over 30% (by value) of national agricultural production in Mexico.
- Weather and climate sensitive industries directly impacted by weather (such as agriculture, construction, energy distribution, and outdoor recreation) account for nearly 10 percent of GDP. Further, weather and climate indirectly influence an even larger portion of the nation's economy, extending to parts of finance and insurance, services, retail and wholesale trade, as well as manufacturing. El Nino affects important business variables like sales, revenues, and employment in a wide range of climate-sensitive industries and sectors. Overall, total U.S. economic impacts of the 1997-1998 El Nino were estimated to be on the order of $25 billion."

The following are some of the historical effects El Niños have had on the economy:

- **Agriculture:**
  El Niños tend to have a beneficial impact on summer crops in the Northern Hemisphere, especially in the US and Canadian grain belts. Precipitation is plentiful and there are usually few, if any, heat waves. Winter crops fare less well. The phenomenon brings cooler wetter winters to southern states. Statistics show a drop in cotton production in the Southeast during El Niño years. Similarly, Central California fruit and vegetable crops have had problems with low temperatures. An average event historically lowers crop production by 1 — 2 %. (The cold in California should be balanced out by heavy, perhaps drought-breaking, rainfall.) If the event lingers into springtime, it provides ample moisture and excellent cover for most winter wheat. However, the Western Provinces and parts of the Pacific Northwest historically have soil moisture deficits during their planting season. Typically, the most negative impacts of El Niños are on tropical agriculture — particularly in Indonesia and parts of Latin America.

- **Energy:**
  El Niños typically produce warmer winter weather for Western Provinces and the northern states from the West Coast to the Great Lakes. Large El Niños warm the entire US/Canadian border region. The regions that face the most reliable warming tend to heat with propane and natural gas. Further east, the heating industry uses a greater variety, from gas to heating oil. Normally El Niños bring down demand for natural gas, causing lower prices for consumers.

Historically moderate El Niños produce a "double dip" winter in the Eastern Provinces and Northeast and Mid-Atlantic states. These regions experience cold, even Nor'easter conditions in early and late winter but less heating demand in mid-winter when the warming impact of an El Niño has expanded to its greatest extent.

- **Electricity:**
  El Niño events typically bring dramatic changes in precipitation that affect hydro-electricity. The Tennessee Valley Authority, for example, has historically shown that it has increased reserves and production capacity during these events. The same is true for most of the Southeastern states. Unfortunately, for British Columbia and the Pacific Northwest, the opposite is true and this normally leads to higher summertime electrical costs in California. Cooler summers lower the Great Lake temperatures. Cooler waters are more effective in cooling coal and nuclear power plants, increasing generating efficiency for plants throughout the Midwest and Ontario. Southern and East Coast utilities normally face increased wintertime ice and snow line damage during these events. (Even areas in Quebec and Ontario are affected.) Gulf States have more winter tornadoes and the Mid-Atlantic and Northeast usually have more ice storms. Additionally, moderate El Niños frequently generate late winter and early spring Nor'easters. During larger El Niños, the ice storms extend to Ontario and Quebec.

- **Insurance:**
  El Niños usually reduce insurance payouts due to hurricanes but can increase late and early winter payouts due to Nor'easters. Crop insurance payouts are usually reduced during El Niño events.

- **Exports/Imports:**
  El Niño years are usually excellent for US agricultural exports. Typically, US crop yields are good while their potential customers have problems. El Niños usually hurt agriculture in India, large portions of China, the Philippines and Indonesia. Most El Niños concentrate their most severe effects in tropical regions, raising the cost of tropical imports

A paper from the IMF employs a dynamic multi-country framework to analyze the international macroeconomic transmission of El Niño weather shocks. This framework comprises 21 country/region-specific models, estimated over the period 1979Q2 to 2013Q1, and accounts for not only direct exposures of countries to El Niño shocks but also indirect effects through third markets.

The results show that there are considerable heterogeneities in the responses of different countries to El Niño shocks. While Australia, Chile, Indonesia, India, Japan, New Zealand and South Africa face a short-lived fall in economic activity in response to an El Niño shock, for other countries (including the United States and European region), an El Niño occurrence has a growth-enhancing effect.

These extreme weather conditions can constrain the supply of rain-driven agricultural commodities, create food-price and generalized inflation, and may trigger social unrest in commodity-dependent countries that primarily rely on imported food. It has been suggested, by both historians and economists, that El Niño shocks may even have played a role in a substantial number of civil conflicts. Despite their importance, the macroeconomic effects of the most recent strong El Niño events of 1982/83 and 1997/98, along with the more frequent occurrences of weak El Niños, are under-studied.

Overall, the development of an El Niño brings drought to the western Pacific (including Australia), rains to the equatorial coast of South America, and convective storms and hurricanes to the central Pacific. These changes in weather patterns have significant effects on agriculture, fishing, and construction industries, as well as on national and global commodity prices. Moreover, due to linkages of the Southern Oscillation with other climatic oscillations around the world, El Niño effects reach far beyond the realm of the Pacific Ocean region.

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