Effect of El Niño Southern Oscillation (ENSO) on the number of "leaching rain" events in Florida and implications on nutrient management

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Summary and action items

The definition of leaching rains (3 inches in 3 days or 4 inches in 7 days) may need to be expanded to also include 1 inch in 1 day. Using three hypothetical tomato crops planted in Fall, Winter and Spring seasons in South Florida, the distribution of leaching rain events (based on all three criteria) was different based on ENSO. We therefore recommend that: (1) An in-depth study of leaching rainfall frequency be conducted for all major vegetable and horticultural commodity producing regions of Florida; (2) Adjustment factors to N fertilizer recommendations based on ENSO be developed and tested; and (3) The magnitude and frequency of leaching rainfalls based on ENSO phases should be used as input data in assessing watershed level nutrient loads in computer simulation models. A prerequisite for the availability of weather-based management decision is the availability of quality weather data. We recommend the FAWN network to be continuously supported, further integration of FAWN with the climate information and forecast system (AgCLimate.org), and the standardization of on-farm weather data recording for BMP documentation.

Typical rainfall patterns in Florida

Most of the state of Florida lies within the extreme southern portion of the Northern Hemisphere humid subtropical climate zone, noted for its long hot and humid summers and mild and wet winters. The southern most portion of the state is generally designated as belonging to the tropical savanna region. Sometimes also called the wet and dry tropics, tropical savanna precipitation is highly concentrated in the warmer months (Winsberg, 2003).

For field vegetables, growing seasons are defined when planting dates are between August 15 and October 15 for Fall, October16 and December 15 for Winter, and December 16 and February 15 for Spring. Fall is the most active growing season in South Florida, whereas Spring is the most active one in North Florida. Central Florida has virtually year-round production.

Florida is among the wettest states in the U.S. with most areas receiving at least 50 inches of rain annually (Black, 1993). The Panhandle and southeastern Florida are the two wettest parts of the state. The driest are the Florida Keys and the offshore bar of Cape Canaveral. The Panhandle receives so much rain because it has two wet seasons, one during the winter when

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fronts pass through bringing rain, the other in the summer, when convectional rain falls. Frontal precipitation plays an increasingly smaller role in annual precipitation the farther one goes down the peninsula. Although only half of the Panhandle precipitation occurs during the hot months between May and August, in Central Florida the share rises to between 60% and 65%. In the Keys and the extreme southwestern peninsula it rises to over 70%. Coastal locations, including the Keys, receive less rain than those nearby, but farther in the interior because they do not provide as good an environment for convectional heating. Figure1 shows the typical precipitation patterns for (a) Bay County located in the Florida Panhandle, and (b) Hendry County located in the southern half of the peninsula. It can be noticed that precipitation patterns in Bay County show two wettest periods, one centered around March and another one around July. In Hendry County, the wettest period is concentrated in the summer.

Fall in Florida is normally drier than summer, without the intense heating of the ground that occurs during summer, convectional rainstorms cease to be so frequent. Also the convergence of moist air masses from the Gulf of Mexico and the Atlantic Ocean over the interior of the peninsula are not as strong as during the summer. However, fall is the season when heavy rains may occur in association with tropical cyclones. According to Winsberg (2003), during the last 30 years, approximately 75% of all Florida weather stations reported at least one day in which eight inches of rain fell, and 12% experienced such torrential storms four or more times. Almost half of these heavy rains occurred in September and October and were associated with tropical depressions.

Spring in Florida is generally dry due to the weakness of two important mechanisms by which rainfall reaches the state. The polar jet stream rarely passes into the Deep South causing frontal rainfall to become less frequent than during the winter. The other reason is that the stable air flowing from high pressure systems over the Atlantic Ocean continues during the spring and reduces convectional and convergent rainfall, our main source of summer rainfall.

ENSO phases

El Niño–Southern Oscillation (ENSO) is a natural, coupled atmospheric–oceanic cycle that occurs in the tropical Pacific Ocean on an approximate timescale of 2–7 yr. The ENSO phenomenon is the strongest driver of inter-annual climate variability around the world and its impact on the climate of Florida is well documented (Fraisse et al., 2006). When sea surface temperature in the eastern equatorial Pacific Ocean is higher than normal the phenomenon is referred as El Niño. When the temperature is lower than normal the phenomenon is referred to as La Niña. When the temperature is normal, the event is referred to as neutral. El Niño normally brings 30% to 40% more rainfall and cooler temperatures during the winter and spring, while La Niña brings a warmer and drier than normal winter and spring. Florida also gets few Atlantic hurricane landfalls during El Niño years.

Previous studies have demonstrated that ENSO also affects crop production in Florida. Hansen et al. (1999) found that ENSO phase and season interacted to significantly influence quarterly yields, prices, and production of tomato, bell pepper, sweet corn and snap beans in Florida. Yields (tomato, bell pepper, sweet corn, and snap bean) were lower and prices (bell pepper and snap bean) were higher in El Niño than in neutral or La Niña winters. Production of tomatoes was higher in La Niña winters. They suggested that the yield response could be explained by increased rainfall, reduced daily maximum temperatures, and reduced solar radiation in El Niño winters. This suggests that in the context of BMPs, fertilizer recommendations could include an adjustment based on ENSO phases.

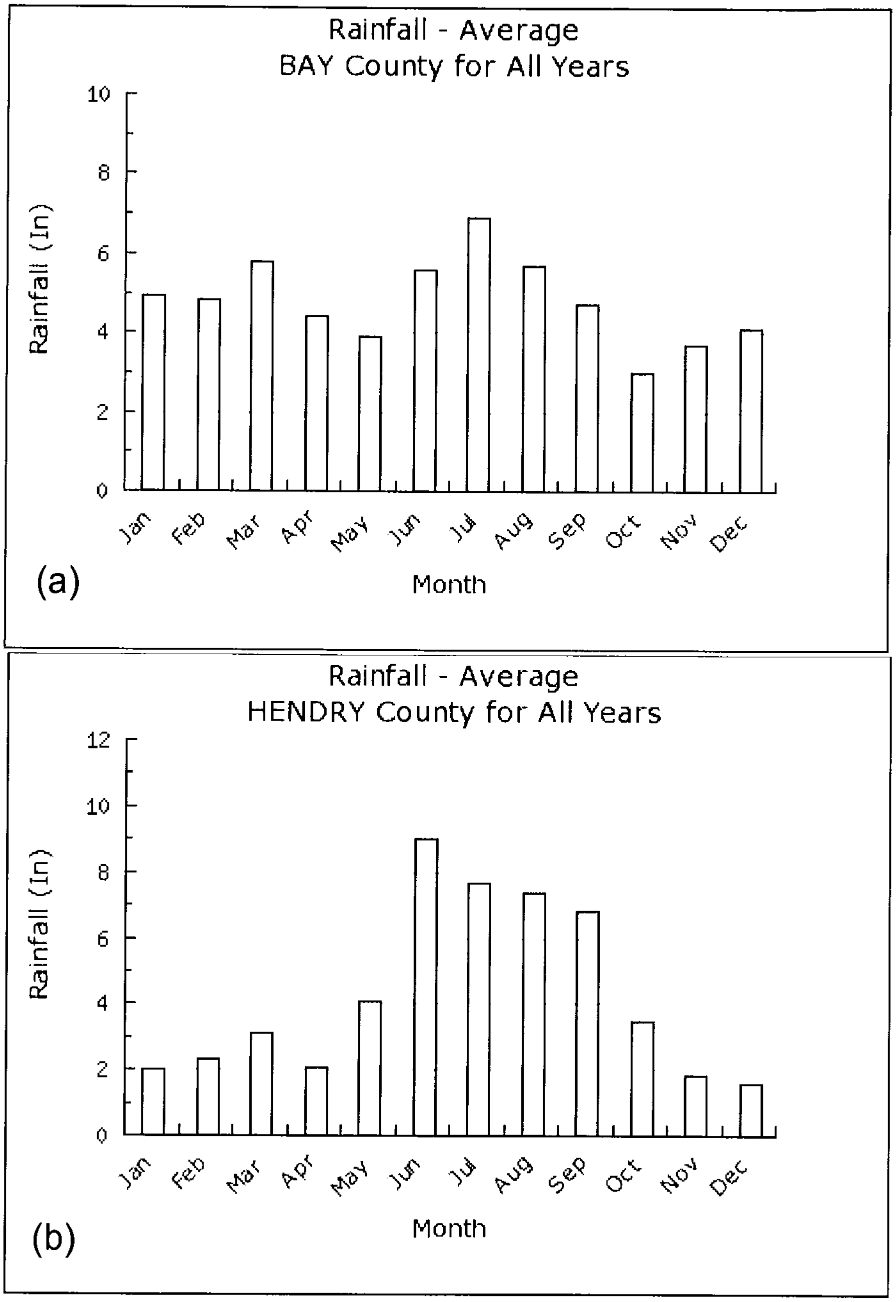

Figure 1. Typical precipitation patterns for Bay County, FL (a) and Hendry County, FL (b). Source: http://www.AgClimate.org

According to Hanley et al. (2003), the phase and strength of ENSO events are typically defined by an index; however, there are many such indices. There is no consensus within the scientific community as to which index best defines ENSO years or the strength, timing, and duration of events. Indices that are commonly used to classify ENSO events include regional sea surface temperature (SST) indices (e.g., Niño-1+2, Niño-3, Niño-4, Niño-3.4), the Japan Meteorological

Agency (JMA) index, and the surface atmospheric pressure–based Southern Oscillation index (SOI). The National Oceanic and Atmospheric Agency (NOAA) uses the Oceanic Niño Index (ONI), a 3 month running mean of SST anomalies in the Niño 3.4 region (5˚N-5˚S, 120˚-170˚W), to assign a phase to a given period of time. El Niño and La Ninã events are based on a threshold of +/- 0.5˚C SST anomalies in the Niño 3.4 region, based on the 1971-2000 reference period.

The ability to forecast ENSO phases provide a basis for developing strategies that can be implemented to customize fertilizer recommendations. Much of the skill in long-range seasonal forecasts over the United States and elsewhere derives from scientist's ability to predict the evolution of sea surface temperature (SST) anomalies in the equatorial Pacific up to one year in advance. There are two general types of prediction models that scientists currently use in order to predict SST's. A "dynamical model" consists of a series of mathematical expressions that represent the physical laws that govern the coupled ocean/atmosphere system. To make a forecast, dynamical models are given the current conditions in the ocean and atmosphere and then a computer "does the math" to determine what the future conditions (out to six months or more in advance) will be. The second type of model, a "statistical model", uses observations of the past to make predictions for the future. To make a forecast with a statistical model requires a long history of observations, generally of the same kind that would be used as input for dynamical models, but extending far back in time, by as much as 30 to 50 years (Tritel, 2005).

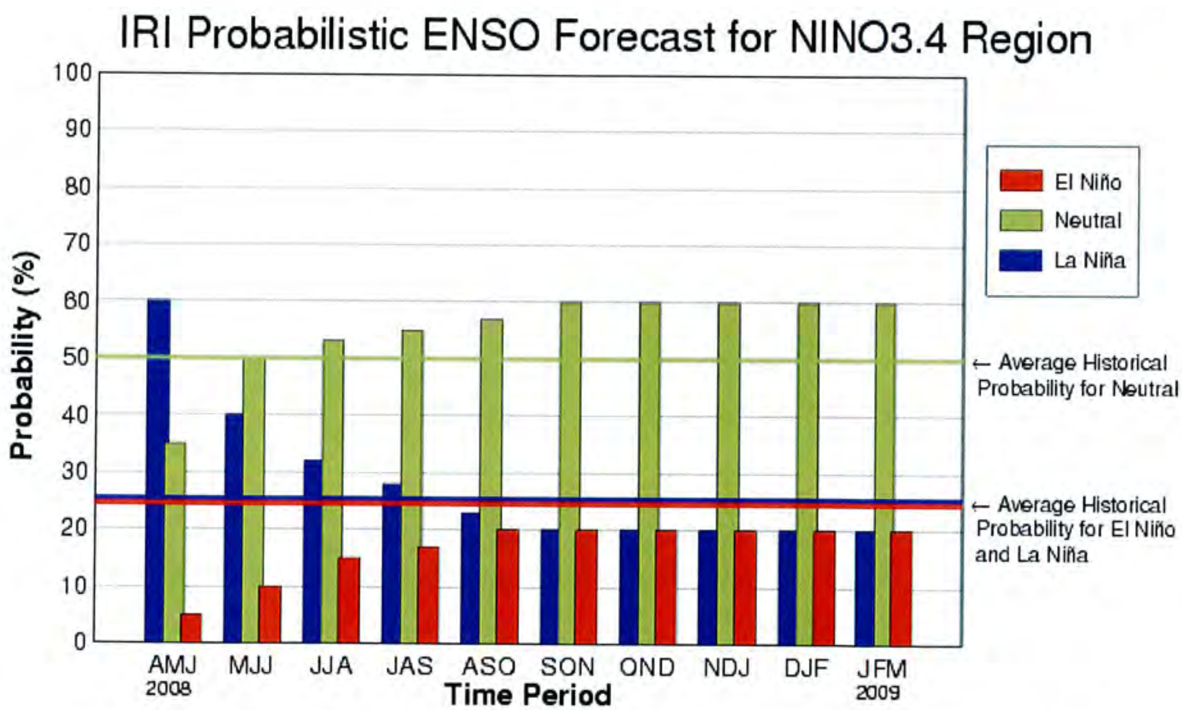

Figure 2. ENSO probabilistic forecast. Source: International Research Institute for Climate and Society (IRI).

Climate forecasts are generally presented in terms of probabilities since it is not possible yet to predict the exact amount of rainfall or the seasonal temperature range (Fraisse et ql., 2004). Figure 2 shows a probabilistic ENSO forecast for the Niño 3.4 region that is provided by the International Research Institute for Climate and Society (IRI). IRI probabilistic forecasts are based on combination of outputs from dynamical and statistical models for SST in the Nino 3.4 region for nine overlapping 3-month periods.

Leaching Rain Definition

Rainfall plays an important role in soluble nutrient (nitrogen) and sediment losses. Nitrogen (N) is leached from the rooting zone to deeper soil layers during periods with either a precipitation or irrigation surplus. In this way N is transported down the soil profile out of reach of plant roots, and so is lost from the plant-soil system.

The UF-IFAS (Simonne and Hochmuth, 2006) and BMP (FDACS, 2005) definition of a leaching rain is 3 inches in 3 days or 4 inches in 7 days. While consensus exists that such rains are likely to be leaching, smaller rainfall amounts may also leach nutrients. Research on water table response to rainfall for Immokalee fine sand has shown that 1 inch of rainfall results in raising the water table by 16 inches (Jaber and Shukla, 2006). Consequently a 1-inch rainfall event in one day may result into nutrient leaching at the beginning of the season when the water table is kept near the 14-inch depth high due to limited rooting depth, and most the fertilizer is still present in the bed. The UF-IFAS Vegetable Fertilizer Task force recommended that the definition of rainfall be expanded (Cantliffe et al., 2006).

Hypothesis, Goal and Objectives of Project

The main hypothesis of our study is that the probability of leaching rains occurrence in Florida during fall, winter, and spring cropping seasons is affected by ENSO. The main question to be answered is if we can use ENSO forecast to adapt fertilization recommendations and reduce potential nutrient losses in Florida. If this hypothesis is true, the goal of this project would be to (1) assess the effect of ENSO phases on horticultural crop production, (2) identify a method for predicting ENSO before each growing season, and (3) develop adjustments to fertilizer recommendations based on ENSO. This article presents a preliminary analysis of historical rainfall frequencies and discusses implications to tomato fertility management. This article also recommends a more in-depth analysis for other horticultural commodities and different planting dates.

Methods

The approach used in this study was to analyze long term precipitation records of weather stations located in production areas across southern Florida. Weather observations were compiled from the National Weather Service's Cooperative Observer network (NCDC TD 3200), which contains daily values for maximum temperature, minimum temperature, and precipitation for a period of record of at least 50 years extending through December of 2006. Four stations were selected based on (1) length of record, (2) data completeness, (3) homogeneity, and (4) representativeness of agricultural production areas (Table 1).

Table 1. Weather stations selected for the analysis of leaching rain frequency.

Station ID	Station Name	County	Latitude (°N)	Longitu de (°W)	Start Year	End Year
84662	La Belle	Hendry	26.75	-81.4333	1932	2004
86880	Parrish	Manatee	27.6167	-82.35	1948	2006
87205	Plant City	Hillsborough	28.0167	-82.15	1895	2006
88780	Tamiami Trail	Dade	25.7667	-80.8167	1940	2003

The historical occurrences of leaching rain events defined as 1 inch in one day, 3 inches in 3 days, and 4 inches in 7 days were analyzed for each station during three typical tomato growing seasons:

1. Fall, planting date on August 15 and crop grown for 15 weeks;
2. Winter, planting date on October 15 and crop grown for 20 weeks;
3. Spring, planting date on December 15 and crop grown for 17 weeks.

Frequency and exceedance probabilities were calculated for each planting season, leaching rain category, and ENSO phase. The ENSO index developed by the Japan meteorological Agency (JMA), which is based on regional sea surface temperature (SST), was used in this study to classify growing seasons. The JMA index is a temperature-based index and uses mean SSTs within the equatorial Pacific region that extends from 4°N-4°S to 150°-90°W. The JAM definition of a warm (cold) ENSO requires the SST in this region to be greater than 0.5°C (less than -0.5°C) for six consecutive months and the months must include October, November, and December (Hanley et al., 2003).

Results and Discussion

Figures 3 through 5 show the total precipitation amounts observed at selected stations during the fall, winter, and spring growing seasons. Long term trends and El Niño and La Niña growing seasons are also shown in the graphs. In general it can be observed that during the spring and winter growing seasons (Figs. 4 and 5), high precipitation amounts occur mostly during El Niño years, sometimes during neutral years, and rarely during La Niña years. During the fall growing season we can observe the occurrence of high precipitation amounts during La Niña years as shown in the case of Hillsborough and Dade counties. We can speculate that this is due to the fact that there is a higher chance for hurricanes and tropical storms to land in the U.S. during La Niña years than during El Niño years. Long term trends do not show major shifts, perhaps a slight downward trend for the total precipitation observed during the fall growing season in the two southern most counties (Dade and Hendry counties). The station with the longest record (Plant City, Hillsborough County) shows good variability from year to year but no significant long term trend.

Table 2 shows the basic statistics for the total observed rainfall during the three growing seasons in each of the weather stations selected for the study. Average precipitation ranged from 4.8 inches during La Niña spring seasons in Dade County to 19.6 inches during neutral fall seasons, also in Dade County. Average precipitation amounts are higher during the fall growing season than during the winter or spring seasons. Results in the table confirm that precipitation amounts during La Niña years are generally lower than during neutral and El Niño years, but primarily during the winter and spring seasons and not so much during the fall growing season.

The number of leaching rainfall events were analyzed in terms of probability of exceedance. We are interested in answering questions: what is the probability that the number of 3 inches in 3 days events will exceed a certain threshold during the fall growing season in a particular place? The answer to this question will help establish acceptable "risk levels" to allow higher N applications. Probability of exceedance tables are included in Appendix A. In the case of 1 inch in 1 day events, probabilities for at least one event to ten events to occur during the growing season were calculated. In the case of 3 inches in 3 days and 4 inches in 7 days, probabilities for at least one to five events to occur during the growing season were calculated. Several conclusions can be drawn from the results, the probability of at least five or more 1 inch in 1 day events to occur (Tables A1-4) is fairly low in most cases, with the exception of El Niño growing seasons when the probability of having at least five events can be as high as 75% in Manatee County, during the spring growing season. Further south in the peninsula the calculated probability decreases significantly and it is only of 8% in the case of spring growing seasons in Dade County. If we consider the probability of having at least three 1 inch in 1 day events as a threshold for estimating leaching potential, it could be concluded that the chances are fairly high during the fall growing season, independent of ENSO phases, but only significant during the winter and spring growing seasons in the case of El Niño years.

In the case of 3 inches in 3 days or 4 inches in 7 days events (Tables A5-A8), the probability of having at least three events is low, independent of the season and location. The probability of having at least two events is only significant (once every two years) during the fall growing season, when it can be as high as 50% during El Niño and neutral years (Table A6). Results for one single event of either 3 inches in 3 days or 4 inches in 7 days, indicate that differences among ENSO phases may only be relevant during the winter and spring growing seasons. These observations support another conclusion of the Vegetable Fertilizer Task Force that fertilizer recommendations based on a single number are unlikely to well represent the diversity of growing conditions in Florida.

Spatial variability in rainfall and how well long-term weather stations represent nearby farms must also be evaluated. Baigorria et al. (2007) analyzed the spatial variability of rainfall in the southeastern U.S.A. using both daily and monthly rainfall data. They concluded that two well defined rainfall spatial correlation patterns were found corresponding to the frontal and the convective rainy seasons. Spatial correlations during the frontal rainy season were characterized by a widely spread pattern in a northeast-southwest direction around weather stations, which is perpendicular to the usual weather front paths. During the convective rainy season, correlations were characterized by small concentric patterns in which correlations decreased rapidly over short distances from each weather station. However, larger areas of higher correlations were found using monthly rainfall amounts than when using daily rainfall amounts.

Conclusions

Long term precipitation records observed at four weather stations were analyzed during this study to evaluate the potential effect of ENSO phases on the number of leaching rain events during the fall, winter, and spring growing seasons in Florida. Preliminary results indicate that ENSO phase forecast could be used to anticipate nitrogen leaching potential in tomato fields during the growing season in South Florida, especially during winter (planting dates between Oct. 16-Dec.15) and spring (planting dates between Dec. 16 and Feb. 15) growing seasons, when La Niña years tend to be drier than neutral and El Niño years. During the fall growing season the difference in probabilities may not be significant, depending on the number of events being considered. The same conclusion can be reached for the total precipitation received during the growing season. This may be due to the fact that during El Niño years there is a lower chance for hurricanes and tropical storms. Further research is required before the use of ENSO forecasts to adjust amounts of nitrogen applied to tomato production. The methodology used in this study can be applied to create maps of "leaching risk" probabilities that could eventually be used for adjusting nitrogen fertilizer recommendations.

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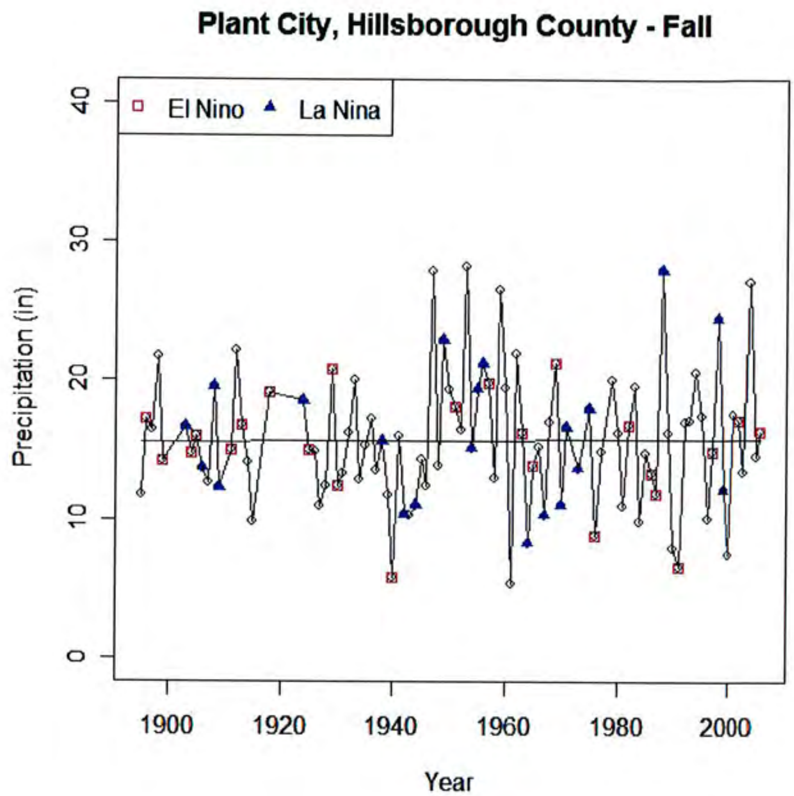


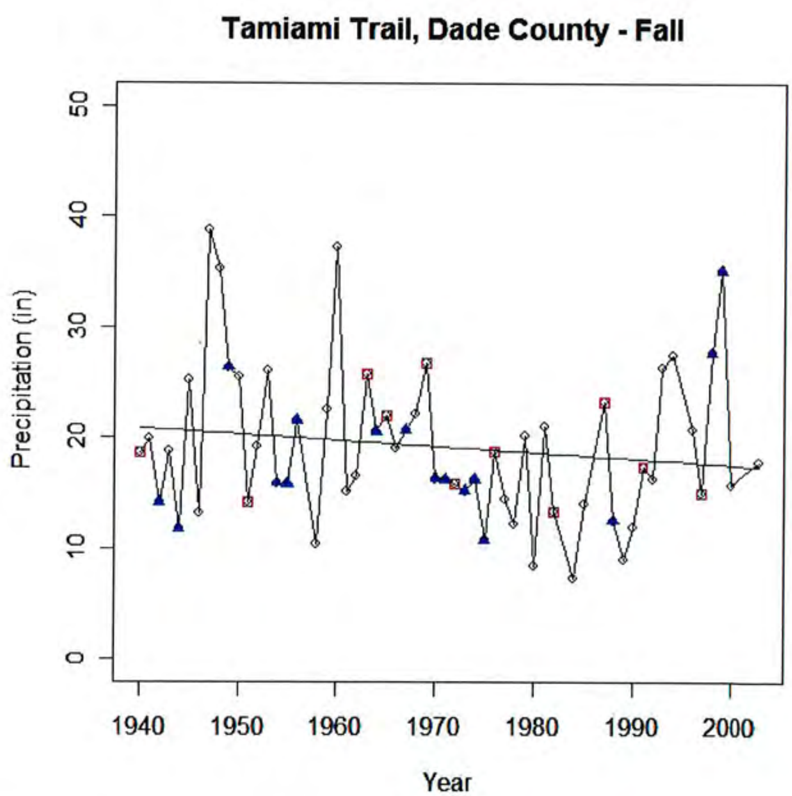
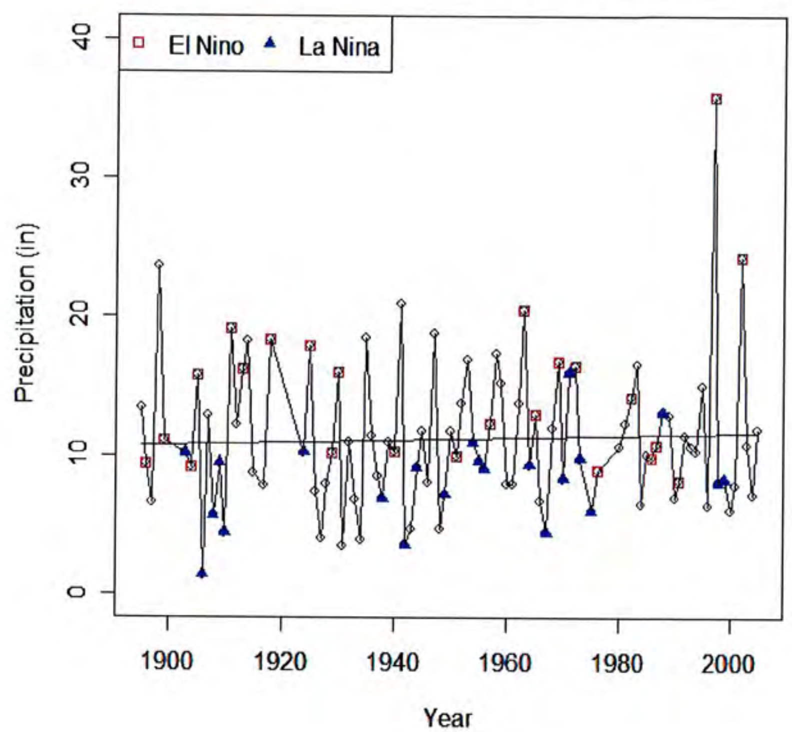


Figure 3. Total precipitation observed during the fall growing season at the Plant City (top) and Tamiami trail (bottom) weather stations. Open squares indicate El Niño growing seasons and solid triangles indicate La Niña seasons.

Plant City, Hillsborough County - Winter



Tamiami Trail, Dade County - Winter

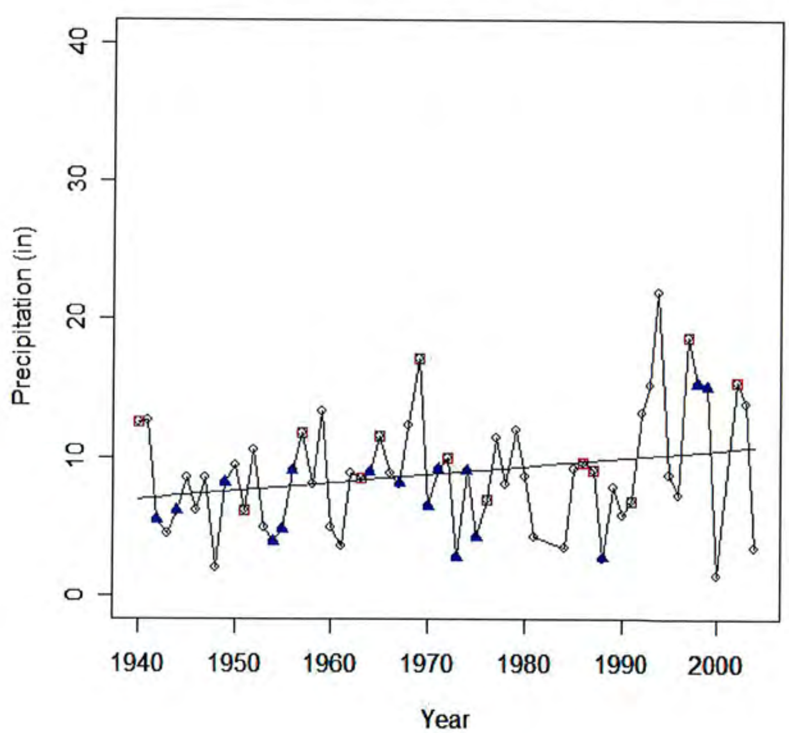
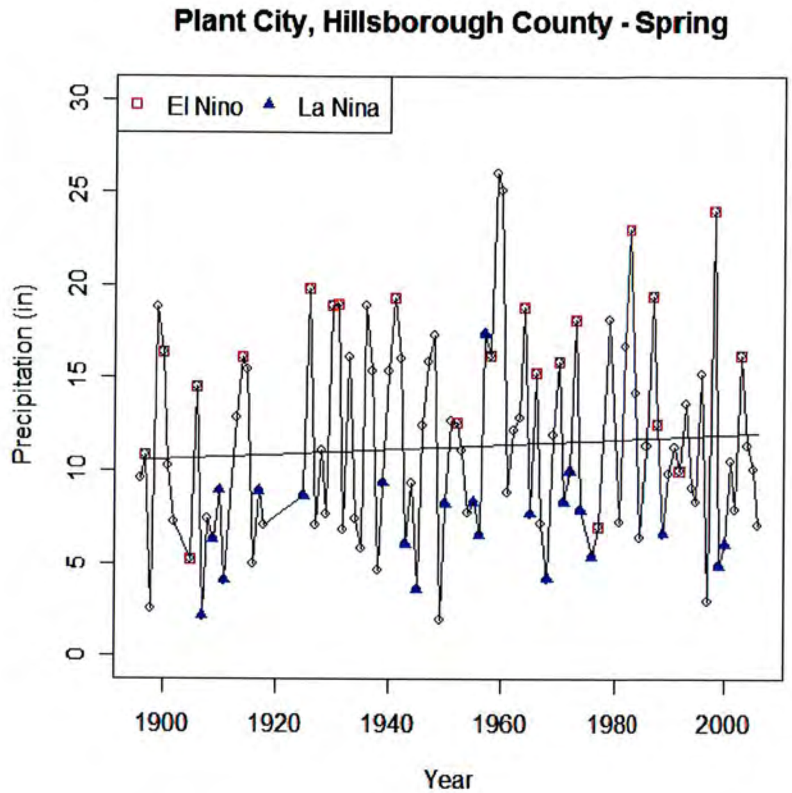


Figure 4. Total precipitation observed during the winter growing season at the Plant City (top) and Tamiami trail (bottom) weather stations. Open squares indicate El Niño growing seasons and solid triangles indicate La Niña seasons.



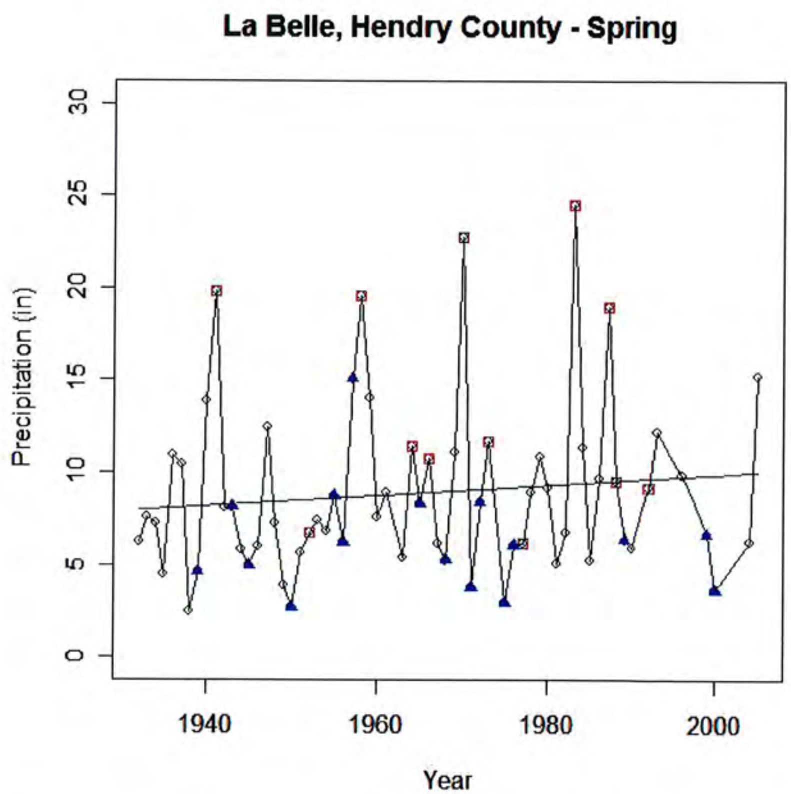


Figure 5. Total precipitation observed during the spring growing season at the Plant City (top) and La Belle (bottom) weather stations. Open squares indicate El Niño growing seasons and solid triangles indicate La Niña seasons.

Table 2. Basic statistics for total precipitation during the fall, winter, and spring growing seasons.

Weather Station	ENSO Phase	Fall Season				Winter Season				Spring Season			
		Min.	Mean	Max	STD	Min	Mean	Max	STD	Min	Mean	Max	STD
84662 La Belle Hendry Co.	Neutral	8.3	16.7	29.3	5.4	2.9	9.1	13.8	2.8	2.5	8.2	15.2	3.1
	El Niño	11.4	17.0	25.2	4.5	7.5	12.6	17.4	3.0	6.1	14.3	24.5	6.4
	La Niña	5.9	12.8	16.2	2.8	2.9	7.1	13.3	3.0	2.7	6.4	15.1	3.0
86880 Parrish Manatee Co.	Neutral	10.0	18.4	28.2	5.5	1.8	11.0	18.5	4.3	2.8	10.7	20.5	3.7
	El Niño	7.6	18.2	25.3	5.4	8.8	17.0	37.4	8.5	6.1	16.4	27.1	5.9
	La Niña	6.8	15.1	28.1	6.2	3.7	8.2	14.2	3.7	2.9	6.4	13.2	3.1
87205 Plant City Hillsborough Co.	Neutral	5.4	15.8	28.2	5.0	3.5	10.9	23.6	4.6	1.9	11.1	26.0	5.1
	El Niño	5.9	15.1	21.3	3.9	8.2	14.8	35.8	6.2	5.2	15.9	24.0	4.7
	La Niña	8.3	16.2	27.9	5.2	1.4	8.3	16.0	3.2	2.2	7.2	17.4	3.1
88780 Tamiami Trail Dade Co.	Neutral	7.4	19.6	38.8	8.0	1.5	8.6	22.0	4.3	2.6	6.8	12.2	2.6
	El Niño	13.4	19.2	26.8	4.7	6.2	11.1	18.7	4.0	5.9	10.7	19.5	4.6
	La Niña	10.8	18.6	35.1	6.5	2.8	7.5	15.4	3.8	1.4	4.8	9.2	2.1

Table A1. Probability of exceedance (%), La Belle weather station (Coop-ID 84662), Hendry County – 1 inch in 1 day events.

Weather Station	SEASON	ENSO Phase	No. of Events 1	2	3	4	5	6	7	8	9	10
	Fall	Neutral	100	96.7	83.3	56.7	50.0	40.0	23.3	20.0	16.7	6.7
		El Niño	100	100	100	80.0	60.0	60.0	40.0	20.0	0	0
		La Niña	100	84.6	69.2	38.5	15.4	15.4	15.4	0	0	0
		All Years	100	94.6	82.1	57.1	44.6	39.3	25.0	16.1	8.9	3.6
84662 La Belle	Winter	Neutral	93.9	69.7	36.4	24.2	6.1	3.0	0	0	0	0
Hendry Co.		El Niño	100	100	91.7	50.0	50.0	33.3	8.3	0	0	0
		La Niña	75.0	43.8	31.2	18.8	0	0	0	0	0	0
		All Years	90.2	68.9	45.9	27.9	13.1	8.2	1.6	0	0	0
	Spring	Neutral	91.7	69.4	41.7	27.8	8.3	5.6	5.6	0	0	0
		El Niño	100	91.7	83.3	50.0	41.7	41.7	33.3	25.0	8.3	8.3
		La Niña	81.2	37.5	6.2	6.2	6.2	6.2	0	0	0	0
		All Years	90.6	65.6	40.6	26.6	14.1	12.5	9.4	4.7	1.6	1.6

Table A2. Probability of exceedance (%), Parish weather station (Coop-ID 86880), Manatee County – 1 inch in 1 day events.

Weather Station	SEASON	ENSO Phase	No. of Events 1	2	3	4	5	6	7	8	9	10
	Fall	Neutral	100	100	96.2	88.5	57.7	46.2	38.5	26.9	11.5	3.8
		El Niño	100	100	90.0	90.0	70.0	40.0	30.0	20.0	10.0	10.0
		La Niña	100	77.8	77.8	66.7	55.6	44.4	11.1	11.1	11.1	11.1
		All Years	100	95.8	89.6	83.3	58.3	43.8	31.2	22.9	12.5	6.2
86880 Parrish	Winter	Neutral	89.7	86.2	72.4	51.7	27.6	10.3	6.9	3.4	3.4	0
Manatee Co.		El Niño	100	100	80.0	70.0	60.0	50.0	10.0	10.0	10.0	10.0
		La Niña	90.0	70.0	50.0	30.0	10.0	10.0	0	0	0	0
		All Years	91.8	85.7	69.4	51.0	30.6	18.4	6.1	4.1	4.1	2.0
	Spring	Neutral	93.1	82.8	62.1	44.8	34.5	13.8	6.9	6.9	3.4	0
		El Niño	100	91.7	91.7	75.0	75.0	58.3	33.3	25.0	16.7	16.7
		La Niña	70.0	50.0	40.0	10.0	0	0	0	0	0	0
		All Years	90.2	78.4	64.7	45.1	37.3	21.6	11.8	9.8	5.9	3.9

Table A3. Probability of exceedance (%), Plant City weather station (Coop-ID 87205), Hillsborough County – 1 inch in 1 day events.

Weather Station	SEASON	ENSO	No. of Events									
		Phase	1	2	3	4	5	6	7	8	9	10
87205 Plant City Hillsborough Co.	Fall	Neutral	100	94.2	88.5	69.2	50.0	28.8	17.3	5.8	0	0
		El Niño	100	95.7	82.6	78.3	56.5	34.8	17.4	8.7	0	0
		La Niña	100	95.0	80.0	65.0	55.0	30.0	20.0	0	0	0
		All Years	100	94.9	85.7	71.4	52.0	29.6	17.3	5.1	0	0
	Winter	Neutral	98.1	73.1	53.8	34.6	23.1	13.5	3.8	1.9	1.9	0
		El Niño	100	91.7	75.0	62.5	37.5	20.8	12.5	12.5	12.5	4.2
		La Niña	90.9	63.6	45.5	22.7	4.5	0	0	0	0	0
		All Years	96.9	75.5	57.1	38.8	22.4	12.2	5.1	4.1	4.1	1.0
	Spring	Neutral	94.5	74.5	50.9	36.4	23.6	16.4	12.7	5.5	1.8	1.8
		El Niño	100	95.5	81.8	81.8	68.2	54.5	31.8	18.2	9.1	4.5
		La Niña	90.9	63.6	22.7	13.6	4.5	4.5	0	0	0	0
		All Years	94.9	76.8	51.5	41.4	29.3	22.2	14.1	7.1	3.0	2.0

Table A4. Probability of exceedance (%), Tamiami trail weather station (Coop-ID 88780), Dade County – 1 inch in 1 day events.

Weather Station	SEASON	ENSO	No. of Events									
		Phase	1	2	3	4	5	6	7	8	9	10
88780 Tamiami trail Dade Co.	Fall	Neutral	96.7	86.7	76.7	73.3	70.0	56.7	43.3	26.7	16.7	10.0
		El Niño	100	100	100	90.0	70.0	70.0	30.0	30.0	20.0	0
		La Niña	100	100	93.3	66.7	46.7	33.3	26.7	20.0	13.3	6.7
		All Years	98.3	93.1	86.2	75.9	63.8	53.4	37.9	27.6	17.2	8.6
	Winter	Neutral	81.8	57.6	39.4	18.2	12.1	9.1	0	0	0	0
		El Niño	92.3	76.9	38.5	30.8	23.1	15.4	7.7	0	0	0
		La Niña	81.2	62.5	31.2	6.2	0	0	0	0	0	0
		All Years	83.9	62.9	37.1	17.7	11.3	8.1	1.6	0	0	0
	Spring	Neutral	71.0	38.7	22.6	12.9	3.2	0	0	0	0	0
		El Niño	100	58.3	33.3	33.3	8.3	8.3	8.3	8.3	0	0
		La Niña	62.5	31.2	12.5	0	0	0	0	0	0	0
		All Years	74.6	40.7	22.0	13.6	3.4	1.7	1.7	1.7	0	0

Table A5. Probability of exceedance (%), La Belle weather station (Coop-ID 84662), Hendry County – 3 inches in 3 days and 4 inches in 7 days events.

Weather Station	SEASON	ENSO Phase	No. of Events									
			3 inches in 3 days					4 inches in 7 days				
			1	2	3	4	5	1	2	3	4	5
	Fall	Neutral	63.3	26.7	13.3	0	0	63.3	26.7	13.3	3.3	0
		El Niño	80.0	10.0	10.0	10.0	0	50.0	20.0	10.0	10.0	0
		La Niña	46.2	7.7	0	0	0	53.8	15.4	0	0	0
		All Years	64.3	21.4	10.7	3.6	0	64.3	19.6	8.9	1.8	0
84662 La Belle Hendry Co.	Winter	Neutral	24.2	0	0	0	0	21.2	0	0	0	0
		El Niño	66.7	16.7	0	0	0	33.3	0	0	0	0
		La Niña	31.2	0	0	0	0	18.8	6.2	0	0	0
		All Years	32.8	4.9	0	0	0	21.3	4.9	0	0	0
	Spring	Neutral	16.7	2.8	0	0	0	16.7	2.8	0	0	0
		El Niño	58.3	25.0	8.3	0	0	41.7	8.3	0	0	0
		La Niña	18.8	0	0	0	0	0	0	0	0	0
		All Years	25.0	6.2	1.6	0	0	17.2	3.1	0	0	0

Table A6. Probability of exceedance (%), Parrish weather station (Coop-ID 86880), Manatee County – 3 inches in 3 days and 4 inches in 7 days events.

Weather Station	SEASON	ENSO Phase	No. of Events									
			3 inches in 3 days					4 inches in 7 days				
			1	2	3	4	5	1	2	3	4	5
86880 Parrish Manatee Co.	Fall	Neutral	73.1	50.0	26.9	7.7	0	73.1	46.2	23.1	3.8	0
		El Niño	60.0	50.0	30.0	10.0	0	70.0	40.0	0	0	0
		La Niña	66.7	22.2	11.1	11.1	11.1	66.7	22.2	11.1	0	0
		All Years	70.8	41.7	22.9	8.3	2.1	77.1	39.6	12.5	2.1	0
	Winter	Neutral	48.3	6.9	0	0	0	20.7	3.4	3.4	0	0
		El Niño	70.0	40.0	10.0	10.0	10.0	70.0	20.0	10.0	10.0	0
		La Niña	40.0	0	0	0	0	30.0	0	0	0	0
		All Years	51.0	12.2	2.0	2.0	2.0	32.7	6.1	4.1	2.0	0
	Spring	Neutral	48.3	13.8	0	0	0	31.0	0	0	0	0
		El Niño	58.3	25.0	8.3	8.3	0	50.0	8.3	8.3	0	0
		La Niña	30.0	0	0	0	0	30.0	0	0	0	0
		All Years	47.1	13.7	2.0	2.0	0	35.3	2.0	2.0	0	0

Table A7. Probability of exceedance (%), Plant City weather station (Coop-ID 87205), Hillsborough County – 3 inches in 3 days and 4 inches in 7 days events.

Weather Station	SEASON	ENSO Phase	No. of Events									
			3 inches in 3 days					4 inches in 7 days				
			1	2	3	4	5	1	2	3	4	5
87205 Plant City Hillsborough Co.	Fall	Neutral	65.4	23.1	9.6	3.8	0	65.4	25.0	5.8	0	0
		El Niño	60.9	30.4	0	0	0	73.9	26.1	0	0	0
		La Niña	65.0	25.0	10.0	5.0	0	65.0	20.0	15.0	0	0
		All Years	64.3	24.5	7.1	3.1	0	67.3	23.5	6.1	0	0
	Winter	Neutral	26.9	0	0	0	0	32.7	3.8	0	0	0
		El Niño	41.7	20.8	4.2	4.2	0	37.5	16.7	4.2	4.2	4.2
		La Niña	31.8	4.5	0	0	0	18.2	0	0	0	0
		All Years	31.6	6.1	1.0	1.0	0	30.6	6.1	1.0	1.0	1.0
	Spring	Neutral	36.4	7.3	3.6	1.8	0	30.9	7.3	0	0	0
		El Niño	54.5	22.7	0	0	0	59.1	9.1	4.5	0	0
		La Niña	31.8	0	0	0	0	18.2	0	0	0	0
		All Years	39.4	9.1	2.0	1.0	0	34.3	6.1	1.0	0	0

Table A8. Probability of exceedance (%), Tamiami trail (Coop-ID 88780), Dade County – 3 inches in 3 days and 4 inches in 7 days events.

Weather Station	SEASON	ENSO Phase	No. of Events									
			3 inches in 3 days					4 inches in 7 days				
			1	2	3	4	5	1	2	3	4	5
88780 Tamiami trail Dade Co.	Fall	Neutral	63.3	43.3	20.0	13.3	10.0	60.0	36.7	26.7	6.7	0
		El Niño	70.0	30.0	10.0	10.0	0	90.0	50.0	10.0	0	0
		La Niña	86.7	33.3	6.7	6.7	0	86.7	33.3	13.3	6.7	0
		All Years	72.4	37.9	15.5	12.1	5.2	74.1	37.9	20.7	6.9	0
	Winter	Neutral	21.2	6.1	3.0	0	0	15.2	6.1	3.0	0	0
		El Niño	30.8	7.7	0	0	0	30.8	7.7	0	0	0
		La Niña	31.2	6.2	0	0	0	18.8	6.2	0	0	0
		All Years	25.8	6.5	1.6	0	0	16.1	6.5	1.6	0	0
	Spring	Neutral	12.9	3.2	0	0	0	3.2	0	0	0	0
		El Niño	33.3	8.3	8.3	0	0	33.3	0	0	0	0
		La Niña	0	0	0	0	0	0	0	0	0	0
		All Years	13.6	3.4	1.7	0	0	8.5	0	0	0	0