

**An investigation into the impact of *El Niño* Southern Oscillation events on rainfall and sugarcane production in Guyana**

**By**

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**ABSTRACT**

This study investigated the impact of one of the most influential global climatic phenomena, the El Niño Southern Oscillation event, on rainfall and sugar cane production in Guyana, and the possibility of including climate information into the agricultural decision making calendar for sugar cane.

Investigations on the influence of ENSO (SST and SOI) on local rainfall revealed statistically weak but significant ( $P < 0.05$ ) positive relationships for individual estates. Combination of estates of similar geographic characteristics resulted in the strengthening of the relationship between ENSO and rainfall but there was also a subsequent decline in the frequency of occurring significant cases, with only SOI showing significance.

Evaluation of the influence of rainfall/ENSO on yields also showed statistically weak positive but significant relationships. Analyses of the impact of ENSO influenced rainfall on critical crop growing periods and subsequent yield revealed relatively stronger relationships and more consistency in the levels of significance realized.

**The findings of the study were: a relationship does exist between ENSO indices and rainfall for the Guyana sugar cane industry. Statistically weak, yet significant relationships exist between ENSO influenced rainfall and sugarcane yields.**

## INTRODUCTION

The Caribbean region experiences significant inter-annual variations in rainfall associated with *El Niño* Southern Oscillation, the North Atlantic Oscillation, tropical waves and longer- term climate variations. Of these, ENSO has been established as being the most influential.

The Guyana sugar industry is of significant socio-economic benefit to Guyana and the Caribbean region. It is against this background that the overall objective of this study was to assess the impact of El Niño Southern Oscillation on the sugar industry in Guyana. To this end the specific objectives of the study were:

1. To use local historical data of local rainfall and sea surface temperature (SST) and Southern Oscillation Index (SOI) data to investigate possible links between Guyana's rainfall variations and *El Niño* events.
2. To use local rainfall, SST, SOI and past yield statistic data to analyze the impacts of *El Niño* on sugar cane yields.
3. To identify possible entry points for inclusion of climate information into the agricultural decision calendar for utilization in the management and production of sugar cane.

Yield analysis done in this study only considered gross cane yields i.e. tonnes of sugar cane harvested per hectare (tc/ha), to eliminate errors associated with computing tonnes sugar per hectare ts/ha to reduce the extent of subjective and management influences that can contribute to determinations of sugar cane yields.

## MATERIALS AND METHODS

Six estates were selected as study sites, these were, Skeldon, Albion, Blairmont, Enmore, La Bonne Intention and Wales Estates. The selected locations are having climate data covering a period of approximately 50 years, and provide a good representation of the corporation's total area in cane production.

Each site selected represented a particular "sample point" that was established by the central meteorological station, from which rainfall data have been historically collected. Rainfall measured in millimeters was taken from the monthly meteorological data submitted by individual estates. The Guyana Sugar Corporation's records provided detailed data on tonnes of sugar cane harvested from the six estates, for each crop for the years 1956 to 2006.

The Sea Surface Temperature and Southern Oscillation Index data were collected from the National Oceanic and Atmospheric Administration (NOAA). Sea Surface Temperature indices were collected from Niño Region 3.4 (5° N- 5° S, 120° - 170° W) base period. The data period covered 1950 to the first half of 2006 (monthly data).

Southern Oscillation Index (SOI) was based on means and standard deviation calculations over the period 1933 to 1992 inclusive. The monthly data was for the period 1876 to the first half of 2006. The SOI is one measure of the large-scale fluctuations in air pressure occurring between the western and eastern tropical Pacific. It is calculated based on the difference in air pressure anomaly between Tahiti and Darwin, Australia. The negative phase of the SOI represents below-normal air pressure at Tahiti and above-normal air pressure at Darwin (<http://www.pmel.noaa.gov/TaO/elNina-Story.html>)

The time series of the SOI and SST in the eastern equatorial pacific indicates that ENSO has an average return period of about four years (<http://www.pmel.noaa.gov/TaO/elNina-Story.html>).

Other data included published and unpublished records and reports on pest outbreaks, annual reports of the Guyana sugar industry and a moisture deficit template, developed to moisture stress period and as an aid to decision making for supplemental irrigation (Davis-communication). In addition, there were discussions and information provided by local management representatives and researchers, which provided additional, relevant information.

Simple cross-correlation and multiple regression analysis were among the statistical tools used to analyze the data collected. Multiple regression analysis was done using the PROC REG procedure in SAS. The quality of data was examined by influence statistics using the influence option in the model statement of the PROC REG procedure. In a few instances, influential data were omitted from the regression analysis. The probability level of testing the significance contribution of parameters (independent variables) towards the model was determined by model  $R^2$  and CV- values. When  $R^2$  values were low, the probability level used for testing model parameters was raised to as high as 15%. At a given probability level, whenever the contribution of a parameter was marginal, it was omitted from the regression model. Several data sets were empirically generated in order to break down the analysis to reflect any geographical pattern due to estate location on the regressor variables.

## RESULTS AND DISCUSSION

### Relationship between ENSO and Rainfall in the sugar industry

Various estates were evaluated individually and as groups with grouping being done based on similar geography and climate regimes (**Table 1**). Multiple regression analyses conducted using rainfall data (by crop) as the dependent variable and various ENSO indices as independent variables for the industry as a whole revealed weak relationship (**Table 2** and **Appendix 1** for meaning of acronyms).

Similarly, individual estates evaluated against the same year's indices reflected relatively weak relationships, with the tendency to fluctuate between locations. In some cases relationships were similar, stronger or weaker, when compared to results derived from analysis of the industry as a whole (**Table 3**).

These findings suggest that temporal and spatial variation of rainfall in Guyana associated with ENSO may influence sugar cane production trends. This also supports the findings of Pulwarty (2001), who studied the impact of *El Niño* events on rainfall and the sugar industry in Trinidad and Tobago.

Combined estate locations reflected an overall improvement in the strength of the relationships between rainfall and ENSO indices for the different combinations. However generally, there was a subsequent decline in the level of confidence in the relationships attained. Only the SOI index showed significant levels during the second crop period (**Table 4**).

### Influence of ENSO induced rainfall on Cane Yields

Analysis carried out to determine the influence of ENSO influenced rainfall (same and previous year) on yields (first and second crop) for the provinces of Demerara and Berbice and combinations of the Berbice and Demerara locations reflected statistically positive, weak relationships. With significance levels being recorded for the first crop same year for Berbice for FCRFT and FCRFA. ENSO indices SST and SOI also recorded weak relationships, with only SST recording significant level at the Demerara combination for the SCYLD (**Table 5**).

Evaluation of yield with both rainfall and ENSO indices simultaneously using the SAS multiple regression model for individual estate locations showed statistically weak relationships. However, both SWR and BCF yields were impacted on by ENSO and yield parameters for the first crop. This level of significance was however not realized at the GV location, indicating that the rainfall experienced had less influence on yields at this location (**Table 6**).

The same trend held for yield responses when rainfall and ENSO indices were tested with the same or following years yield.

Coefficients of determination ranged widely, with cases reflecting both minimal and substantial contributions to yield fluctuations.

In order to determine the degree of predictability and consistency of the climatic response of the different selected combinations and individual locations, those showing significance in the multiple regression models were subjected to simple linear regression analysis. This initiative was taken to determine their individual impact on yield. Each

location/combination was regressed in terms of the crop yield for which they showed significance in the model versus the related rainfall parameter or ENSO index to which they reflected significant relationships.

Generally, the relationships reflected were positive but statistically weak, however significance ( $P < 0.05$ ) was maintained in most cases. There were a few cases where combinations and individual locations no longer showed significant relationships when first crop yields were regressed with ENSO indices at Skeldon and East Demerara. (**Table 7**).

These findings are in no way unique to the Guyanese experience, but are quite similar to results of research carried out in Trinidad, in which case, it was concluded that ENSO is not the only mediating factor on sugar production in Trinidad but that variability of agricultural yield also depends on the climate parameters at the location (Pulwarty, 2001).

The identification and prediction of the influences of seasonal to- inter- annual –climate phenomena, like the El Niño Southern Oscillation (ENSO), has brought attention to possible short-term impacts of changes in climate (Chen et al, 2001). Other contributing factors other than climate influence include the adoption of high yielding varieties of cane, uniform planting practices, soil characteristics, the prevalence of pests and disease outbreaks, industrial unrest and timeliness of field operations.

Still unresolved is the issue of the sensitivity of agricultural yield variability to climate change. The ultimate answer depends upon future technological progress, crop climatic adaptation, and carbon dioxide fertilization effects (with regard to C3 and C4 plants), among many other factors. But a current statistical answer can be obtained from historical records relating crop yield variability to climate (Chen et al, 2001). One recommended approach is that of using pooled time series cross-sectional data to measure yield variability impacts of shifts in climate (Chen et al, 2001). This paper attempts to provide some of the preliminary work required to apply such a methodology with the ultimate goal being the realization of an appropriate, predictive- agro-climate model for the sugar industry.

Analysis of the effects of ENSO influenced rainfall (same and previous year) on yields for Blairmont estate, yielded more consistent results. These results were considered to be significant because it is felt that because of its geographic location and responsiveness to prudent agronomic management practices, the yields at this location would be less influenced by factors other than climate. There was a general improvement in the strengths of the relationships realized when compared to results for all significant combinations/locations (**Table 8**). However, although the relationship was weak it was nevertheless statistically significant for the first and second crops except SCYLD vs. SCRFT where critical rainfall was tested against yields for the same and following years.

This analysis was done for two periods, February to December and August to June hence the results will be impacted on by ENSO. Enfield and Mayer in Pulwarty et al (2001) have shown the mediating factors to be (1) an atmospheric adjustment over the southern Caribbean and (2) a delayed response of about 4-6 months in the tropical North Atlantic SSTs.

This is supported by the finding that statistically, ENSO related Atlantic fluctuations lag behind the Pacific component by four to five months. This relationship is weakest during October, November and December and builds to its most intense state by April to July of the following year (Pulwarty, 2001)

This lagged warming of the tropical Atlantic is known to result in increased rainfall during the dry and early rainy seasons in Trinidad. This has subsequently led to yield fluctuations depending on the range of the prevailing soil water depth (Pulwarty, 2001).

**Entry points for the inclusion of climate information into the agricultural decision making calendar.**

Excessive rainfall during early plant growth is known to promote adverse soil conditions such as high water tables, improper soil aeration and increased erosion in the uplands. On the other hand, a suppressed soil water level allows for improved root growth and minimizes the direct impacts of rain on young plants (Pulwarty, 2001). The impact of wet season water table depth on sugar cane yield was quantified in Pulwarty (2001) and a strong positive correlation was found to exist.

There are two cropping seasons each year for sugar cultivation in Guyana (the ‘first’ and ‘second’ crops). Since historically the ENSO peak period coincides with planting, germination and elongation all of which influence yields, this presents the first “entry point” (or opportunity) for the application of climate information. (See Figure 1).

During the second crop period two sets of activities and plant growth stages can be impacted on by peak ENSO periods. First, the periods of maturation and harvest can be influenced by extreme ENSO- influenced conditions, thus a possible entry point for predictive climate ‘intervention” at the end of the second crop calendar period. Secondly, although not to the same extent as in the first crop, the planting period in the second crop can be exposed to climate extremes. This period provides a brief opportunity for the inclusion of climate into the decision- making calendar (**Fig. 2**).

**Table 1: The various estate locations examined in the study**

<b>Rainfall Parameter</b>	<b>Variable Identifier</b>	<b>Coefficient of Determination</b>	<b>Coefficient of Variation</b>
FCRFT	FCSST* FCSOI*	0.134	30
SCRFT	SCSST* SCSOI	0.126	28
FCRFA	FCSST* FCSOI*	0.178	26
SCRFA	SCSST* SCSOI*	0.161	26

**Table 2: Rainfall versus ENSO indices (Industry)**

<b>Individually</b>	<b>Group</b>
Skeldon (SWR)	SWR-AN-BCF (Berbice)
Albion (AN)	EHP-LBI-GV (Demerara)
Blairmont (BCF)	SWR-AN
Enmore (EHP)	EHP-LBI –BCF (EDB) information
La Bonne Intention (LBI)	EHP-LBI (EDE)
Wales (GV)	

**Table 3: Rainfall versus ENSO indices (Skeldon, Albion and Enmore)**

<b>Estate Location</b>	<b>Rainfall Parameter</b>	<b>Variable Identifier</b>	<b>Coefficient of Determination</b>	<b>Coefficient of Variation</b>
<b>Skeldon</b>	FCRFT	FCSST* FCSOI	0.102	27
	SCRFT	SCSST SCSOI	0.063	25
		FCRFA	FCSST* FCSOI*	0.12
	SCRFA	SCSST SCSOI*	0.13	22
<b>Albion</b>	FCRFT	FCSST* FCSOI*	0.169	25
	SCRFT	SCSST* SCSOI*	0.22	24
		FCRFA	FCSST* FCSOI*	0.193
	SCRFA	SCSST* SCSOI*	0.312	20
<b>Enmore</b>	FCRFT	FCSST* FCSOI*	0.184	33
	SCRFT	SCSST* SCSOI*	0.145	32
		FCRFA	FCSST* FCSOI*	0.2
	SCRFA	SCSST* SCSOI*	0.18	30

**Table 4: Rainfall versus ENSO indices (EHP-LBI-BCF)**

<b>Rainfall Parameter</b>	<b>Variable Identifier</b>	<b>Coefficient of Determination</b>	<b>Coefficient of Variation</b>
FCRFT	FCSST FCSOI SCSST SCSOI*	0.28	27
SCRFT	FCSST FCSOI SCSST SCSOI*	0.21	27
FCRFA	FCSST FCSOI SCSST SCSOI*	0.30	25
SCRFA	FCSST FCSOI SCSST SCSOI*	0.24	25

**Table 5: Yield versus same year ENSO indices and rainfall (Berbice and Demerara)**

<b>Estate Location</b>	<b>Rainfall Parameter</b>	<b>Variable Identifier</b>	<b>Coefficient of Determination</b>	<b>Coefficient of Variation %</b>
Berbice	FCYLD	FCRFT* FCRFA* FCSST FCSOI	0.14	15.4
	SCYLD	SCRFT SCRFA SCSST SCSOI	0.03	16.2
Demerara	FCYLD	FCRFT FCRFA FCSST FCSOI	0.009	19
	SCYLD	SCRFT SCRFA SCSST* SCSOI	0.048	20

**Table 6: Yield versus previous year ENSO and rainfall indices (Skeldon and Wales)**

<b>Estate Location</b>	<b>Yield Parameter</b>	<b>Variable Identifier</b>	<b>Coefficient of Determination</b>	<b>Coefficient of Variation %</b>
Skeldon	FCYLD	FCRFT FCRFA FCSST* FCSOI*	0.06	16
	SCYLD	SCRFT SCRFA SCSST SCSOI	0.001	18
Wales	FCYLD	FCRFT FCRFA FCSST FCSOI	0.11	18
	SCYLD	SCRFT SCRFA SCSST SCSOI	0.09	19

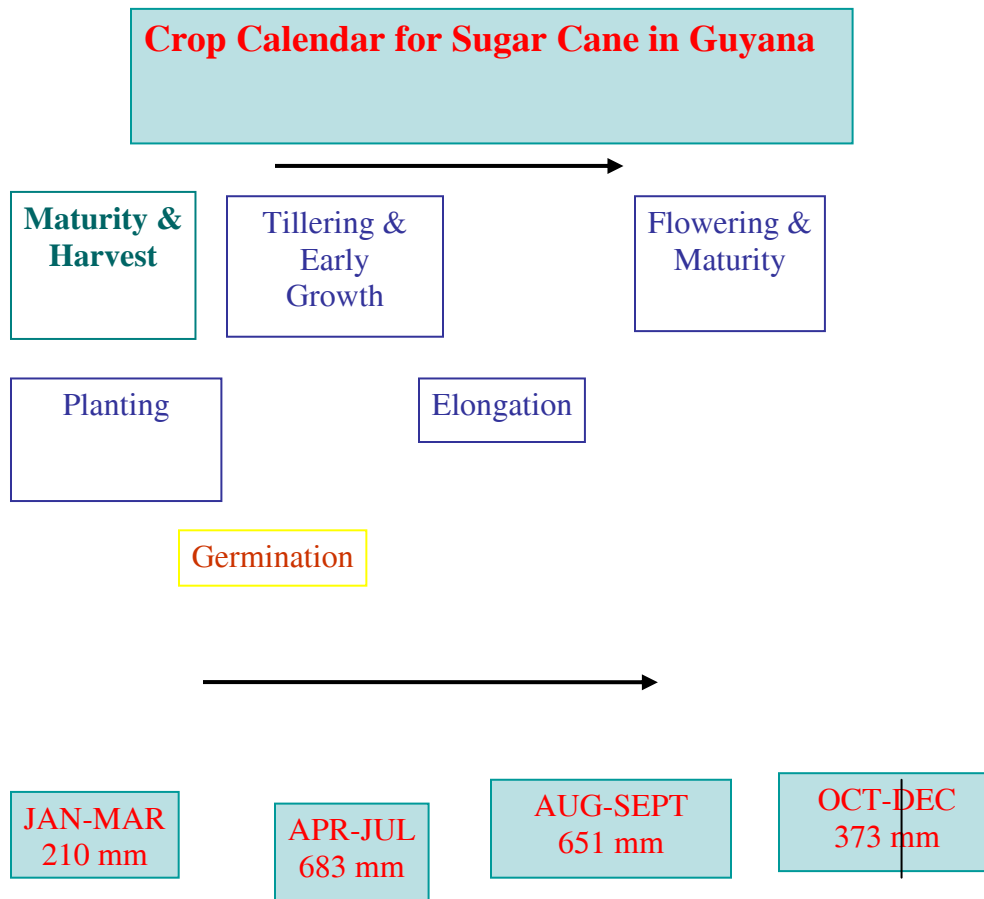
**Table 7 Yield vs. ENSO indices and RF parameters for indiv and combined sites**

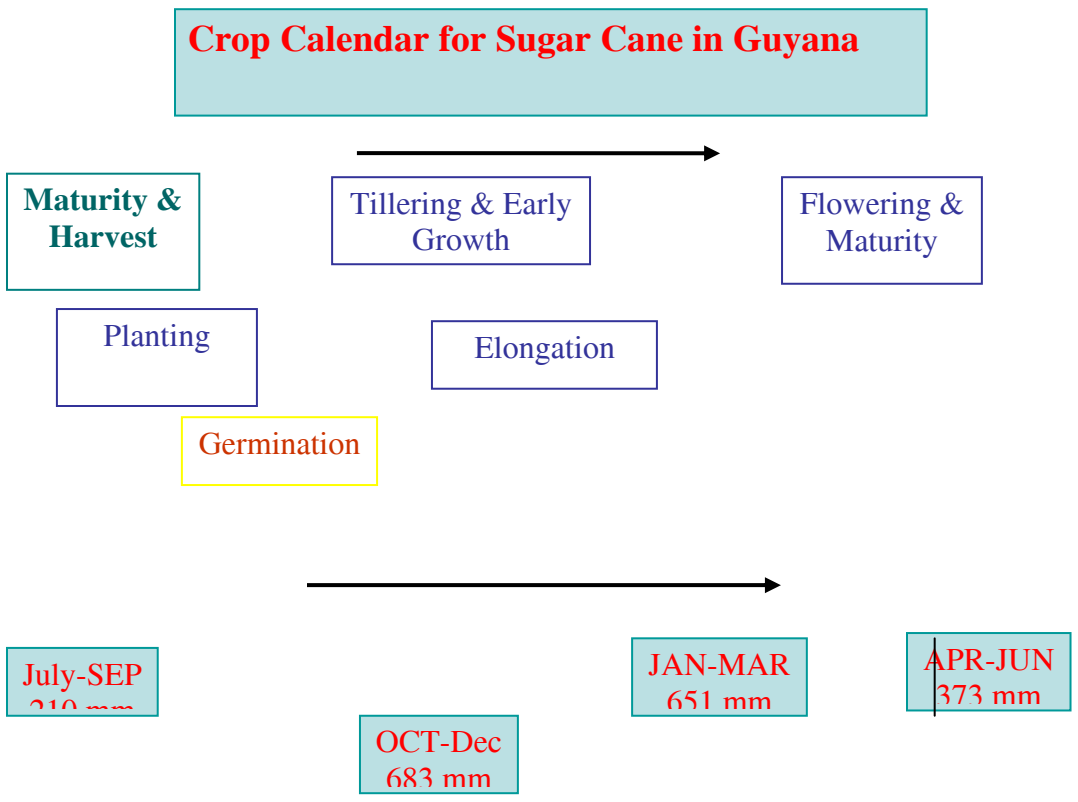
LOCATION	CROP YIELD	RAINFALL/ ENSO INDICIES	DETERMINATION COEFFICIENT	EQUATION
BLAIRMONT	FCYLD	FCRFT* FCRFT*	$R^2 = 0.043$ $R^2 = 0.096$	$y = 0.0044x + 71.379$ $y = 0.0086x + 63.183$
BLAIRMONT	FCYLD	SCRFT* SCRFT*	$R^2 = 0.0334$ $R^2 = 0.0155$	$y = 0.0043x + 71.536$ $y = 0.0038x + 71.051$
BLAIRMONT	SCYLD	FCRFT* FCRFT *	$R^2 = 0.1693$ $R^2 = 0.087$	$y = 0.0105x + 64.843$ $y = 0.0076x + 69.713$
BLAIRMONT	SCYLD	SCRFT* SCRFT	$R^2 = 0.1$ $R^2 = 0.0075$	$y = 0.0126x + 61.311$ $y = 0.0025x + 78.203$

**Table: 8 Yield versus ENSO influenced rainfall for critical growing periods at Blairmont**

LOCATION	CROP YIELD	RAINFALL/ ENSO INDICIES	COEFFICIENT OF DETERMINATION	EQUATION
BERBICE	FCYLD	FCRFT* FCRFA	$R^2 = 0.0218$ $R^2 = 0.006$	$y = 0.005x + 64.731$ $y = 0.0022x + 72.285$
SKELDON	FCYLD	FCSST FCSOI	$R^2 = 0.002$ $R^2 = 0.0004$	$y = -1.1083x + 74.878$ $y = 0.4728x + 74.883$
BLAIRMONT	FCYLD	FCRFT* FCRFA*	$R^2 = 0.0925$ $R^2 = 0.0645$	$y = 0.0069x + 67.261$ $y = 0.0703x + 68.831$
SKELDON/ ALBION	FCYLD	FCRFT*	$R^2 = 0.011$	$y = 0.0041x + 63.204$
SKELDON/ ALBION	FCYLD	FCSST* FCSOI*	$R^2 = 0.011$ $R^2 = 0.004$	$y = 3.2837x + 68.922$ $y = 3.7209x + 68.891$
EAST DEMERARA/ BLAIRMONT	FCYLD	FCRFT* FCRFA*	$R^2 = 0.048$ $R^2 = 0.0311$	$y = 0.0071x + 52.542$ $y = 0.0707x + 54.519$
EAST- DEMERARA	FCYLD	FCSOI	$R^2 = 0.0004$	$y = -0.6525x + 58.086$

Figure 1.0: Agricultural calendar for the first crop (GuySuCo)





*Figure 2.0: Agricultural calendar for the second crop (GuySuCo)*

## REFERENCES

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What is El Niño?

<http://www.pmel.noaa.gov/TaO/elnina-Story.html> (accessed August 3, 2006)

**Appendix 1**

Table showing acronyms of parameters measured in Analysis

<b>ACRONYMS</b>	<b>MEANINGS</b>
<b>FCRFT</b>	First Crop Rainfall Total
<b>FCRFA</b>	First Crop Rainfall Average
<b>SCRFT</b>	Second Crop Rainfall Total
<b>SCRFA</b>	Second Crop Rainfall Average
<b>FCSST</b>	First Crop Sea Surface Temperature
<b>SCSST</b>	Second Crop Surface Temperature
<b>FCSOI</b>	First Crop Southern Oscillation Index
<b>SCSOI</b>	Second Crop Southern Oscillation Index
<b>FCYLD</b>	First Crop Yield Data
<b>SCYLD</b>	Second Crop Yield Data