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Impact of El Niño Southern Oscillation on Dry-Season Rainfall in Trinidad

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The impact of the El Niño Southern Oscillation (ENSO) on dry-season rainfall in Trinidad was investigated using data from four stations on the island for the period 1946-1996. Two statistical procedures were employed, namely, the parametric one-way analysis of variance (ANOVA) and its non-parametric counterpart, the Kruskal-Wallis (K-W) test. At all stations, the order of increasing rainfall (means and medians) was warm phase (El Niño), neutral phase ("Normal") and cold phase (La Niña). However, at three of the stations (two in north and one in central Trinidad), the differences were not statistically significant ($\alpha = 0.05$). A statistically significant result was obtained only at the southern station. At this station, the ANOVA indicated that mean El Niño rainfall and mean La Niña rainfall were significantly different from each other but were not significantly different from mean "Normal" rainfall ($\alpha = 0.05$). The K-W test, on the other hand, indicated that median La Niña rainfall was significantly different from both median El Niño rainfall and median "Normal" rainfall but the latter two medians were not significantly different from each other ($\alpha = 0.05$). These results therefore demonstrate that El Niño's tendency to decrease dry-season rainfall in Trinidad is weak or negligible, and La Niña's tendency to increase dry-season rainfall in north and central Trinidad is weak or negligible but may be significant in the southern part of the island. Consequently, ENSO forecasts are of little or no practical utility to planners and decision-makers in the weather-dependent sectors of the economy for the dry seasons that coincide with the forecasted ENSO events.

1. Introduction

El Niño Southern Oscillation (ENSO) is a complex anomalous quasi-periodic ocean-atmosphere phenomenon occurring every three to seven years in the equatorial Pacific Ocean [1]. It is essentially a cycle that encompasses changes in ocean surface temperatures, atmospheric winds and air pressures. A typical ENSO cycle comprises three phases, namely, the extreme warm phase (El Niño), the extreme cold phase (La Niña) and a "Normal" range of sea-surface temperatures in the central and/or eastern equatorial Pacific Ocean [2].

ENSO events are thought to be associated with anomalous precipitation patterns spanning most of the globe leading to floods, forest fires, droughts and diseases in several countries [2]. This pervasive impact on precipitation patterns has been the subject of numerous studies published in the literature, e.g., [3-8]. These studies have identified and quantified precipitation anomalies associated with the warm and/or cold phase of ENSO at many locations on the earth.

In Trinidad, however, very little work has been done to assess the impact of ENSO on rainfall in general, and more specifically, during the critical dry-

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season period (January - April). **Rogers** [5] using data (1935-1981) from one site in north Trinidad (St. Clair, Port of Spain) reported that for the period January - March, rainfall is significantly lower during El Niño than during La Niña. On the other hand, no significant difference was found between rainfall during El Niño and La Niña for the April - June period. A major deficiency of this study, however, was the failure to compare El Niño rainfall and La Niña rainfall with "Normal" rainfall. It is therefore not known whether the rainfall during the two extreme phases of ENSO were significantly different from "Normal" rainfall.

Shrivastava [9] using limited data (1979-1996) from one site on the North Coast of Trinidad (La Filette) plotted dry-season rainfall amount versus the corresponding year. By visual examination of the graph on which El Niño years were identified, the author concluded that it might be possible to discern a link between El Niño and the occurrence of drought in Trinidad during the dry-season period. No statistical analyses were carried out to substantiate the apparent link. **Shrivastava** [10] subsequently emphasised the need for further research in this area as one of the important issues necessary for integrated water resources management. Moreover, it is important to note that rainfall amounts during the dry season in Trinidad may also have a significant influence on several other sectors of the economy such as construction, agriculture, tourism and sports.

Intense monitoring of the equatorial Pacific Ocean, coupled with improved models of the ENSO phenomenon, now enables the detection of a new ENSO event several months in advance [11-12]. If the nature of ENSO's influence on rainfall amounts could be established, this advanced warning would provide planners and decision-makers with enough lead-time to develop appropriate response strategies to mitigate the adverse effects and/or take advantage of the benefits.

The objective of this study, therefore, was to analyse dry-season rainfall data in Trinidad to determine whether or not ENSO events have a statistically significant impact on the dry-season rainfall of Trinidad.

2. Data and Methods

2.1 Rainfall Data

The data used in the analysis were obtained from the Piarco Meteorological Office and the Water Resources Agency. Only stations with continuous monthly rainfall data for the period 1946-1996 were considered for analysis. The only stations that fulfilled this criterion were Piarco (Meteorological Office), Port of Spain (Botanical Gardens, St. Clair), Couva (Exchange) and Cedros (Perseverance Estate) (See **Figure 1**). The dry season was taken as the period January - April. The dry-season rainfall amounts were obtained by summing up the individual monthly rainfall for these four months.

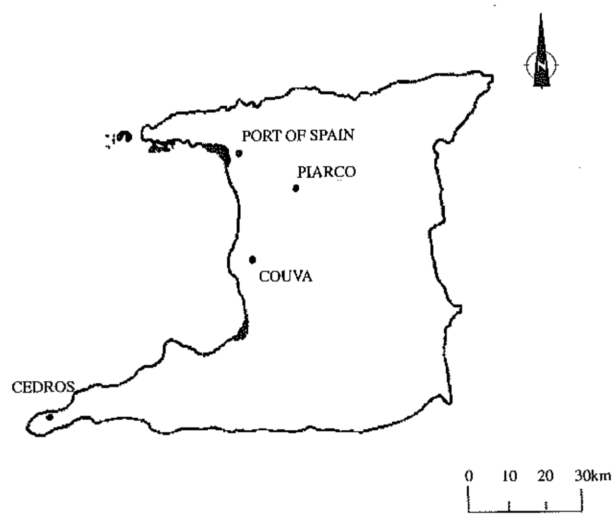

FIGURE 1: *Geographical Location of the Four Stations*

2.2 Dry Season Classification

The first step in the procedure was to identify the prevailing conditions for each dry season during the period 1946-1996. This was necessary so that each season could be placed in one of three categories, namely, El Niño, La Niña or "Normal". However, there is no single universal quantitative definition of what constitutes an ENSO cycle, and several are in current use by ENSO researchers. In this study, the working definition used by the Japan Meteorological Agency (JPA) was selected. It is an objective procedure and the ENSO phases identified are quite consistent with the consensus of the ENSO research community [2]. In this procedure, monthly sea surface temperatures (SSTs) are monitored in 2° x 2° grids in the equatorial Pacific Ocean and averaged for a specific area, namely 4°N – 4°S and 90°W – 150°W. There are therefore 120 (4 x 30 boxes) monthly mean SST normals and SST values. The JPA index is the 5-month running mean of the spatially averaged SST anomalies with the base period of 1961-1990. Periods with index values +0.5°C or greater are classified as El Niño and those with index values -0.5°C or less are classified as La Niña. All other periods are classified as "Normal". Using this procedure, the years in which the dry season experienced El Niño conditions were 1958, 1969, 1973, 1983, 1987 and 1992. The years in which the dry season experienced La Niña conditions were 1946, 1950, 1955, 1956, 1968, 1971, 1974, 1976, 1985 and 1989. All other years were classified as "Normal".

2.3 Statistical Tests

The data categorised using the above classification procedure were thereby transformed to the typical k independent samples problem, with k equal to three. The three treatments in this case were El Niño, La Niña and "Normal", with dry-season rainfall amount as the random variable. The data for each of the four locations were then analysed using the parametric one-way analysis of variance (ANOVA) and its non-parametric counterpart, the Kruskal-Wallis (K-W) test [13].

With the ANOVA, the null hypothesis is that the means of the three treatments are equal while the alternative hypothesis is that at least two of the means are not equal. The populations are assumed to be normally distributed. Since serious departures from normality and heterogeneity of variances can distort ANOVA results, particularly if standard deviations are correlated with means among ENSO phases, the non-parametric Kruskal-Wallis test was included.

With the K-W test, the assumption of normality is relaxed, and the null hypothesis tested is that the three populations are identical, that is to say, they have the same probability distributions. The alternative hypothesis is that at least two populations are different from each other. In simpler terms, the null hypothesis is that the medians of the three treatments are equal while the alternative hypothesis is that at least two medians are not equal. It is worth noting that non-parametric tests are more robust and have more power than their parametric counterparts when the assumption of normality is not satisfied [14-16].

3. Results and Discussion

Figures 2, 3, 4 and **5** show the scatter plots of the dry-season rainfall data at the four stations for the period under consideration while **Table 1** provides the corresponding summaries of the basic statistical parameters. A salient feature of the data is the high variability of rainfall at each station. This is evident from the high standard deviations (SD) and coefficients of variation (CV), and the large differences between maximum (MAX) and minimum (MIN) values, i.e., the large ranges. Another significant feature of the data is the notable differences between the mean and median rainfall values. The mean rainfall is greater than the median at all four locations indicating that the underlying population distributions may be positively skewed and therefore non-normal.

A summary of the results of the one-way analysis of variance is presented in **Table 2.** These results indicate that mean El Niño rainfall and mean La Niña rainfall were respectively less than and greater than mean "Normal" rainfall at all four stations. However, only at Cedros is the observed F value (5.65) greater than the test F value (3.19) and therefore indicative of a statistically significant result ($\alpha = 0.05$). This implies that neither El Niño nor La Niña exhibit any statistically significant influence on the dry-season rainfall at Piarco, Port of Spain or Couva ($\alpha = 0.05$).

At Cedros, however, the statistically significant result suggests that at least two means are not equal. A simple way to identify specific differences is by examining the confidence intervals of the means for the three phases. The 95% confidence intervals (CIs) for mean "Normal", mean El Niño and mean La Niña rainfalls are 208.0–291.0, 36.2–238.2 and 270.0–426.4 respectively.

The CIs for mean El Niño and mean La Niña rainfalls do not overlap which indicates a statistically significant difference between the two means ($\alpha = 0.05$). This implies that rainfall during El Niño

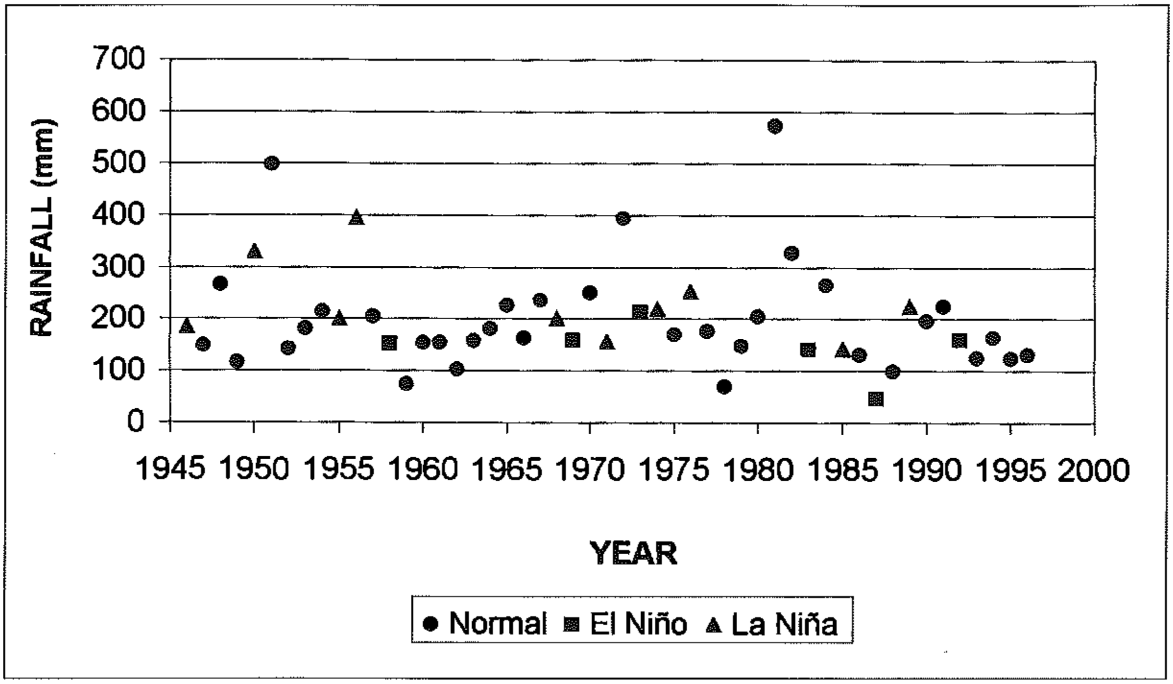

FIGURE 2: *Dry-Season Rainfall at Piarco*

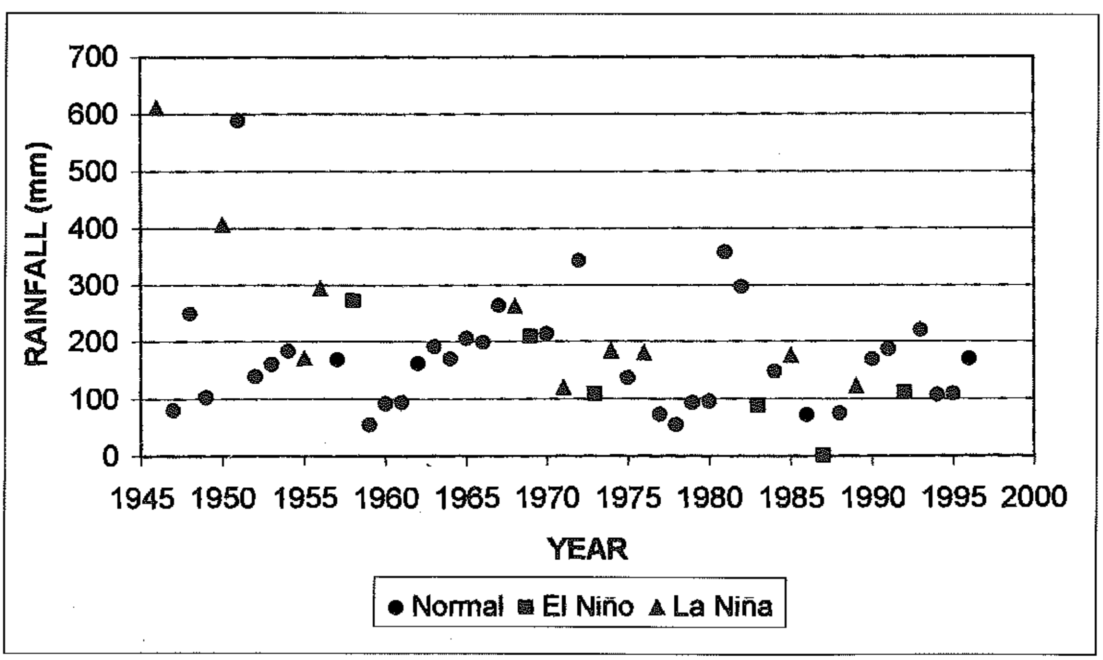

FIGURE 3: *Dry-Season Rainfall at Port of Spain*

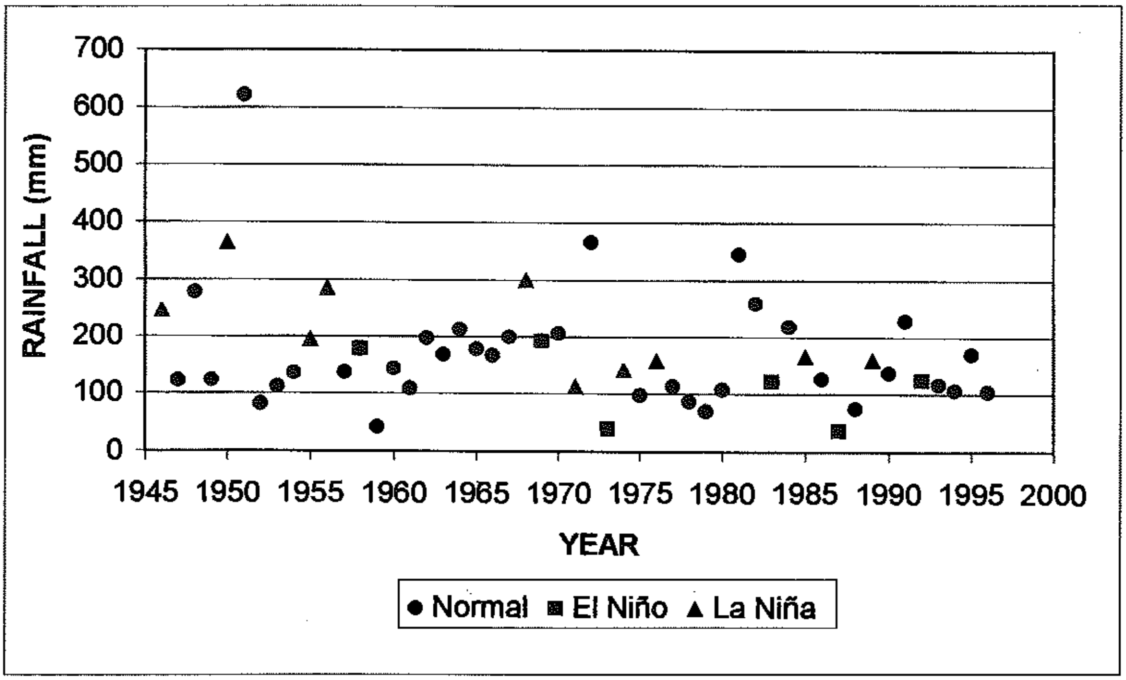

FIGURE 4: *Dry-Season Rainfall at Couva*

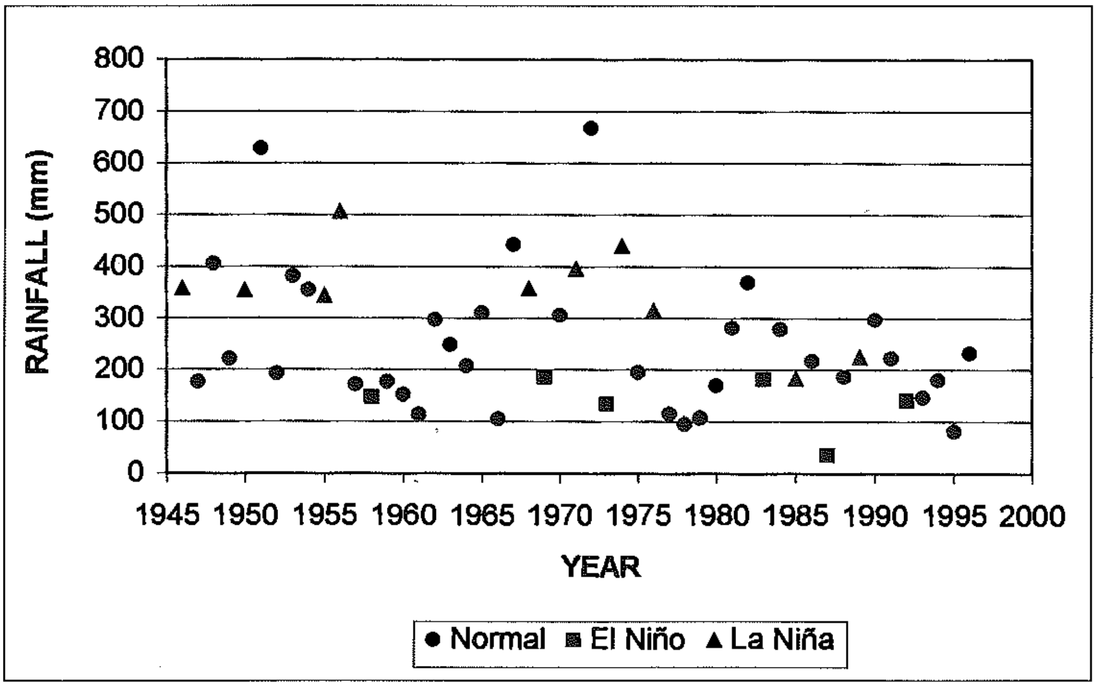

FIGURE 5: *Dry-Season Rainfall at Cedros*

TABLE 1: *Dry-Season Rainfall (mm) Characteristics at the Four Stations for the Period 1946–1996*

Station	Mean	Median	SD	CV (%)	MIN	MAX
Piarco	199.6	176.3	99.7	49.9	47.3	573.9
Port of Spain	183.4	169.3	119.0	64.9	1.5	611.7
Couva	172.6	144.0	101.3	58.7	36.5	621.7
Cedros	255.9	221.5	134.0	52.4	35.3	668.0

TABLE 2: *Results of One-Way Analysis of Variance showing Mean Rainfall (mm) ±95% Confidence Limits and the Corresponding Observed F Values*

Station	Normal	El Niño	La Niña	F
Piarco	199.9±33.6	146.0±81.2	230.8±62.9	1.38
Port of Spain	172.4±39.2	132.3±94.8	253.0±73.4	2.56
Couva	170.8±33.9	116.0±81.8	213.0±63.4	1.80
Cedros	249.8±41.8	137.2±101.0	348.2±78.2	5.65

The F test statistic at the $\alpha = 0.05$ level, $F_{2,48} = 3.19$

TABLE 3: *Results of the Kruskal-Wallis Test showing Median Rainfall (mm)/Rank for the Three Phases at the Four Stations and the Corresponding H Values*

Station	Normal	El Niño	La Niña	H
Piarco	169.7/25.1	156.1/18.2	210.1/33.7	4.47
Port of Spain	161.2/24.4	111.0/20.7	182.2/34.7	4.59
Couva	136.9/24.9	123.9/18.2	181.0/34.4	5.04
Cedros	217.0/25.0	144.1/11.2	356.8/38.5	13.27

The overall average rank is 26. The chi-squared test statistic at $\alpha = 0.05$ with 2 degrees of freedom, $\chi^2_{0.05}$, is 5.99

is significantly different from rainfall during La Niña ($\alpha = 0.05$). On the other hand, the CIs of mean El Niño and mean La Niña rainfalls both overlap with the CI of mean "Normal" rainfall indicating that rainfall during El Niño and La Niña are both not significantly different from "Normal" rainfall ($\alpha = 0.05$).

Table 3 shows a summary of the results of the K-W test. At all four stations, the median rainfalls for El Niño and La Niña dry seasons were respectively less than and greater than the corresponding medians for "Normal" dry seasons. However, a statistically significant result was obtained only at Cedros where the observed H (13.27) was greater than the test statistic (5.99). This implies that neither El Niño nor La Niña has a statistically significant effect on the dry-season rainfall at Piarco, Port of Spain and Couva ($\alpha = 0.05$).

At Cedros, however, the statistically significant result indicates that at least two medians are not equal. To identify differences between any two of the three ENSO phases, the method of multiple comparisons was used [17]. In this method, the magnitude of the difference in average ranks is computed and compared with its corresponding test value at a particular significance level. At the $\alpha = 0.05$

level, the test values for "Normal"-El Niño, La Niña - "Normal" and La Niña -El Niño are 15.8, 12.8 and 18.4 respectively. From **Table 3**, the corresponding actual differences in average ranks are 13.8, 13.5 and 27.3 respectively. This indicates that median El Niño rainfall is not significantly different from median "Normal" rainfall (since 13.8 < 15.8) but median La Niña rainfall is significantly different ($\alpha = 0.05$) from both median El Niño rainfall (since 27.3 > 18.4) and median "Normal" rainfall (since 13.5 > 12.8).

It is therefore evident from the above results that there is generally a decrease in dry-season rainfall during El Niño but the decrease is not statistically significant ($\alpha = 0.05$). El Niño's effect in decreasing dry-season rainfall is thus weak or negligible.

On the other hand, there is generally an increase in dry-season rainfall during La Niña but the increase is statistically significant only at Cedros ($\alpha = 0.05$). The influence of La Niña in increasing dry-season rainfall is thus weak or negligible in north and central Trinidad but may be significant in the southern part of the island. Consequently, ENSO forecasts are of little or no practical utility to planners and decision-makers in the weather-dependent sectors of the economy for the dry seasons that coincide with the forecasted ENSO events.

4. Conclusions

The following are the major conclusions that can be drawn from this study with respect to ENSO and dry-season rainfall in Trinidad:

1. The influence of El Niño in decreasing dry-season rainfall is weak or negligible.

2. The influence of La Niña in increasing dry-season rainfall is weak or negligible in north and central Trinidad but may be significant in the southern part of the island.

3. The advanced knowledge of an impending ENSO event is of little or no practical utility to planners and decision-makers in the weather-dependent sectors of the economy for the dry seasons that coincide with the anticipated ENSO event.

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