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ASSESSMENT OF THE PREDICTABILITY OF SEASONAL RAINFALL IN RATNAPURA USING THE SOUTHERN OSCILLATION AND ITS TWO EXTREMES

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Abstract: An attempt is made to assess the predictability of seasonal rainfall at Ratnapura, namely, first intermonsoonal convectional rains (FIM), second intermonsoonal convectional rains (SIM), south-west monsoon rains (SWM) and north-east monsoon rains (NEM) by using Southern Oscillation and occurrence of El Niño and La Niña events. Seasonal rainfall data of Ratnapura and three monthly averaged Southern Oscillation Index (SOI) values for 118 consecutive years were analysed for lag correlation coefficients (CCs). The link between seasonal rainfall with El Niño or La Niña events was evaluated using binomial analysis. The association between FIM rains and the SOI shows a weak positive relationship. All the other seasonal rains, SWM, SIM and NEM are negatively related to the SOI. However, these relationships are weak and therefore cannot be used for any predictive purposes without wide margins of errors. The link of FIM rains (March to April) either with El Niño or La Niña events was not clear. Nevertheless, it is apparent that there is a strong tendency for above normal SIM rainfall (October to November) during El Niño years. If an El Niño year is immediately followed by a La Niña year, both the FIM and SIM rains would produce above normal rains. It is interesting to note that the occurrence of "drought" conditions during the SWM season, May to September, is remote in a La Niña year. Significant associations between NEM rains (December to February) and El Niño or La Niña events were not observed.

Key words: Binomial analysis, El Niño, La Niña, rainfall, Ratnapura, Southern Oscillation.

INTRODUCTION

Ratnapura is an important area of the Wet zone of Sri Lanka where agricultural land use accounts for both field and plantation crops. Rainfall plays a vital role in maintaining these crops especially the plantation crops such as tea, rubber and coconut. The characteristic feature of the climate of Ratnapura is the year round rainfall. The annual rainfall ranges from 2800 mm to 5200 mm. It is a result of two intermonsoonal convectional rainy seasons; southwest monsoon rainy season and to a lesser extent the northeast monsoon rainy season. Being solely dependent on the rainfall, the agricultural production of the area is badly affected by

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abnormal weather conditions. The late onsets of the four different rainy seasons and the lack of anticipated amount of total rains from them cause widespread crop failures and poor yields. In addition, Ratnapura has gained much attention as one of the few areas of the country where floods are very common. Over the years, hundreds of lives have been lost through flooding and land slides. Rehabilitation and reconstruction has been expensive. Early prediction of rainfall can lead to precautionary actions to mitigate the possible catastrophic consequences.

There has been increasing recognition recently that the most important key to the earth's year to year climatic variability is the El Niño/Southern Oscillation phenomenon which is often referred to jointly as the ENSO phenomenon. The Southern Oscillation is the see-saw pressure pattern between the Indian-western Pacific (Indonesian low) and central-east Pacific oceans (south Pacific sub-tropical high). On average, pressure is low, relative to the zonal mean, over the Indian-western Pacific oceans and tends to be high over the central-east Pacific ocean. A simple index, the Southern Oscillation Index (SOI), is often used to study these pressure variations. This index is the difference between normalized monthly mean atmospheric pressures at Darwin (12°S, 131°E), normally low, and Tahiti (18°S, 150°W), normally high. Extreme anomalies in this pattern involve dislocations of the rainfall distribution in the tropics, bringing drought to some regions and torrential rains to others[1]. El Niño events occur during periods when sea surface temperatures (SSTs) are warmer and the trade winds are weaker than normal in the central and eastern Pacific, and SSTs are cooler than normal in the eastern Indian ocean and western Pacific oceans[2]. The opposite extreme, when the east Pacific is cool and pressure there is higher than the normal, is called anti-ENSO events or La Niña episodes. El Niño event usually starts early in the year and reaches its maximum intensity between the following November and January, returning to normal over the next few months[3]. The SOI is negative during the ENSO events and positive during the anti-ENSO events. ENSO phenomenon directly affect the climate of at least half of the planet and in many instances result in heavy loss of life and resources.

In previous studies[4-7], the association of the ENSO phenomenon and the spatial and temporal variability of rainfall of the major climatic zones of Sri Lanka have been reported. The strength of the relationship between SOI and rainfall varies depending on season and location. Therefore, the impact of ENSO phenomenon need to be assessed for individual locations[8]. However, an in depth investigation of the predictability of rainfall at Ratnapura using ENSO phenomenon has not been undertaken despite its usefulness in contingency planning. Hence, this paper investigates the association of seasonal rainfall at Ratnapura with the Southern Oscillation and the occurrence of El Niño and La Niña events in the Pacific region.

METHODS AND MATERIALS

Monthly rainfall data of Ratnapura for 118 consecutive years (1876-1993) were used for the analysis. These data were converted to four different rainfall seasons before being used in the study: first intermonsoonal convectional rainy season, FIM, (March-April), south-west monsoon rainy season, SWM, (May-September), second intermonsoon rainy season, SIM, (October-November) and north-east monsoon rainy season, NEM, (December-February). The status of each year, either El Niño or La Niña, during the period from 1876 to 1993 was identified using published information and was verified against the SOI data taken from the Bureau of Meteorology, Australia[9]. Although some of the relationships between the SOI and climatic fluctuations are not linear, it has been reported that the linearity assumption seems to work well for many areas in the world[10]. Assuming such a linear relationship, the association between the SOI and the normalized seasonal rainfall of Ratnapura was determined by lag-correlation analysis. The long term mean and the standard deviation used for normalization of the seasonal rainfall were calculated only using rainfall in normal years excluding the years with extreme phases of the SOI, i.e. El Niño and the La Niña years.

In analysis with the El Niño and the La Niña events, a year has been considered from March of the current year to February of the subsequent year. This period includes the peak months of the El Niño and La Niña events during October to December. Binomial probability analysis was used to determine whether the observed deviations of seasonal rainfall during El Niño and La Niña years are due to chance occurrence[11]. For each season, the number of above (below) normal years were counted in El Niño years. Let X_{obs} be the observed number of above (below) normal rainfall years among the N number of El Niño years. Then, $p = \Pr ob\ \{X \geq X_{obs}\}$, the probability of number of above (below) normal rainfall years, is at least as great as that observed during El Niño years. If this value is less than the signifieance level, it is unlikely that the observed event is a chance occurrence. A similar analysis was carried out for the La Niña years. A "Dry" season was defined when the normalised seasonal rainfall is less than -1 whereas seasons with +1 or greater normalised rainfall were considered as "Wet" seasons. In a data set, the interval from -1 to +1 standard deviation contains approximately 68 per cent of the data values. Therefore, data beyond ± 1 boundary can be safely interpreted as extreme cases of rainfall, droughts or floods.

RESULTS

Relationship between the Southern Oscillation and seasonal rainfall

The lag-correlations were computed to investigate whether the seasonal rainfall anomalies at Ratnapura would indicate a teleconnection to the SOI. Table 1 summarises the principal results of the lag-correlation analysis for four different

rainy seasons at Ratnapura. The three upper case letters that denote the three months period stand for the first letter of each month, i.e. JFM means average SOI of January through March. The three months periods are always from the current year unless specified otherwise. The mean SOI of NDJ and DJF periods were calculated using SOI of November and December of the preceding year along with the SOI of January and February in the current year.

In general, the correlation between first intermonsoon rains (FIM) and the mean SOI of preceding three months periods were positive and weak. The highest recorded correlation was 0.14 with the mean SOI of January through March. The lag-correlations of SOI with the south-west monsoon rains (SWM) was generally negative except with mean SOI of immediately preceding March to May period. The recorded highest correlation was -0.17 with the mean SOI of January to March. Unlike the relationships with the FIM and SWM rains, the association between the rainfall of the second intermonsoonal rains (SIM) and the mean SOI of the preceding months showed a relatively strong negative correlation (Table 1). The strongest link of SIM rains was associated to the mean SOI of May through July period. Approximately equal correlations of SIM rains were also recorded with the mean SOI of AMJ, JJA, JAS, ASO and SON time periods. The north-east monsoonal rains were negatively correlated with the mean SOI of the preceding months. The highest negative correlation of -0.18 was observed with the mean SOI of September through November period (SON).

Table 1 : Lag correlation coefficients between SOI and seasonal rainfall at Ratnapura (1876-1993).

SOI	FIM	SWM	SIM	NEM
JEM	0.14	-0.17	-0.02	-0.14
FMA	0.08	-0.10	-0.03	-0.09
MAM	0.01*	0.04	-0.12	-0.08
AMJ	0.04*	-0.07*	-0.25	-0.04
MJJ	-0.02*	-0.12*	-0.27	-0.04
JJA	-0.03*	-0.16*	-0.25	-0.05
JAS	-0.01*	-0.15*	-0.22	-0.11
ASO	0.02*	-0.15*	-0.24	-0.17
SON	0.05*	-0.13*	-0.25	-0.18
OND	0.04*	-0.11*	-0.09*	-0.15
NDJ	0.08	-0.12	-0.13	-0.09
DJF	0.05	-0.15	-0.09	-0.12

* mean SOI of the three months periods of the preceding year

The influence of the El Niño and La Niña episodes on seasonal rainfall

Table 2 shows the occurrence of above normal rainfall at four different rainy seasons during El Niño and La Niña years at Ratnapura. The two integers within the brackets denote the number of "Wet" and "Dry" rainy seasons, the extreme situations, occurred during El Niño and La Niña years. Out of 30 El Niño events during the study period, 14 events caused above normal FIM rains while 16 years resulted in below normal rainfall. There was a little contrast of rainfall anomalies in the FIM season with La Niña episodes. Out of 23 La Niña episodes during the study period, 15 episodes caused above normal rainfall while there were only 8 years with below normal rainfall. Both El Niño and La Niña events caused 14 years of above normal rainfall during the SWM season out of 30 and 23 such years, respectively (Table 2). These occurences were not significant at the 5% probability level.

There was a significant teleconnection between occurrence of El Niño events and the SIM rains at Ratnapura. Thirty El Niño events occurred during the last 118 years causing 22 years of above normal SIM rains at Ratnapura (Table 2). The binomial analysis showed that the occurrence of above normal rainfall during the SIM season is significant at the 5% probability level. Out of 22 years of above normal SIM rains, five occurences were "Wet" years. The influence of the La Niña events on the SIM rains was not significant. There were only 11 years with above normal SIM rains out of 23 La Niña events that occured during the last 118 years. Out of 12 below normal SIM rainy seasons during La Niña years, eight years were "Dry" years (Table 2).

Table 2: Number of occurrences of above normal rainfall during El Niño and La Niña years at Ratnapura (1876-1993).

Season	El Niño years	La Niña years
FIM	14 (3,4)	15 (6,2)
SWM	14 (6,5)	14 (12,2)
SIM	22* (5,0)	11 (6,8)
NEM	15 (7,6)	10 (3,3)

Total no. of El Niño years = 30 and total no. of La Niña years =23.
* significantly different at the 5% probability level. The two integers within the brackets denote the number of Wet and Dry rainy seasons, the extreme situations, occurred during El Niño and La Niña years.

The anomalies during the NEM do not show a clear pattern with either El Niño or La Niña episodes. Fifteen El Niño events were associated with above normal NEM rains resulting in the same number of years with below normal NEM rains. The influence of the La Niña episodes on the NEM rains was also not evident. Out of 23 La Niña episodes that occurred during the last 118 years, 10 years resulted in above normal NEM rains while 13 years caused below normal NEM rains at Ratnapura. None of these anomalies were significant at the 5% probability level. In addition, it is worth noting that the possibility of extreme NEM events of either drought or flood conditions, occurring during La Niña years is quite low (Table 2).

During the last 118 years, there have been 11 El Niño events immediately followed by La Niña events. Such ENSO events showed a reasonable forecasting possibility of FIM and SWM rains (Table 3). La Niña events preceded by El Niño events caused 8 years of above normal FIM rains, out of which three years were in the "Wet" extreme. However, this link was not significant at the 5% probability level. The effect of occurrence of El Niño and La Niña events in a row was more prominent with the SWM rains where 9 years produced above normal SWM rains. The binomial analysis showed that this occurrence is not due to chance. Out of these 9 years, 7 years were in the "Wet" extreme of SWM rains. Thus, if a La Niña event is immediately preceded by an El Niño event, it is more likely to receive above normal rainfall in both FIM and SWM seasons at Ratnapura. In the case of SWM rains, it would be more likely to experience flood conditions. However, this relationship was not clear with the SIM and NEM rains (Table 3).

Table 3 : Effect of occurrence of El Niño and La Niña events in a succession on seasonal rainfall at Ratnapura (1876-1993).

Season	No. of above normal years	No. of below normal years
FIM	8 (3)	3 (1)
SWM	9* (7)	2 (1)
SIM	5 (2)	6 (4)
NEM	5 (3)	6 (2)

total no. of years where an El Niño event is immediately followed by a La Niña event = 11
* significantly different at the 5% probability level. The integer within the bracket denotes the number of Wet (Dry) rainy seasons, the extreme situations.

DISCUSSION

In general, association between the SOI and the seasonal rainfall at Ratnapura was weak. All the correlation coefficients were below 0.27 indicating that only a very small portion (less than 7%) of the total variation of seasonal rainfall can be explained by the SOI. When the correlation coefficient of a relationship is less than 0.70, it has little or no predictive value being unable to explain at least 50% of the total variation of the system[12]. Thus, these findings suggest that the possibility of predicting the seasonal rainfall at Ratnapura by SOI alone has limited potential. The weak association between seasonal rains at Ratnapura and the SOI could be attributed to the micro scale convective activity which could mask the influences of large scale circulation changes on rainfall variations. Such small scale convection of the atmosphere is quite common in the Wet zone of Sri Lanka[6]. Nevertheless, it is noteworthy that most of the correlation values, obtained in this analysis, that are relatively high in magnitude were associated with the SIM rains.

The influence of the occurrence of El Niño or La Niña episodes on the first intermonsoon rains (FIM) at Ratnapura was not evident. The binomial analysis showed that there was no evidence to conclude that either El Niño or La Niña episodes cause above or below normal rains during the FIM season in Ratnapura and therefore, the observed rainfall anomalies are due to chance. The lack of any significant link between the occurrence of El Niño or La Niña events and the FIM rains could be attributed to the fact that both El Niño or La Niña events are at their early stages of development in the east and central Pacific oceans when the FIM season is effective over Sri Lanka. The magnitude of the increased (decreased) sea surface temperature over the Pacific ocean with a newly developed El Niño (La Niña) event is rather small. Such a small increase (decrease) of sea surface temperature would not be strong enough to influence the general circulation of the atmosphere and thereby the tropical rainfall.

The link between SWM rains and the occurrence of El Niño or La Niña events was also not distinct. It has been shown that the relationship between SWM rains and the occurrence of El Niño or La Niña events is weak in the Wet zone compared to the Dry zone[5]. However, it was interesting to note that likelihood of having "Wet" SWM rains at Ratnapura is higher if La Niña events cause above normal SWM rains (Table 2). Out of 14 La Niña years which resulted in above normal SWM rains, 12 years produced "Wet" SWM rains. Nine La Niña events which caused below normal rainfall resulted in only two years with "Dry" SWM rainy season. Thus, the possibility of drought conditions during May to September in La Niña years is rather low.

The significant relationship between El Niño events and SIM rains suggests that the increased SIM rains during El Niño years at Ratnapura are not due to chance and probably due to changes in the general circulation. It also points

towards a clear forecasting ability of five to six months in advance. There is more than 70% of chance of above normal SIM rains during an El Niño year. Although El Niño events have caused 8 below normal SIM rainy seasons during the last 118 years none of them were below -1 standard deviation (Table 2). Therefore, it is unlikely that El Niño would cause drought conditions during SIM seasons at Ratnapura. Generally, rainfall anomalies of SIM rains during El Niño years are positive over entire Sri Lanka and may range from +10 to + 30 per cent[5]. A possible explanation for such positive anomalies is that warm sea surface temperature anomalies during El Niño years may enhance the convection with cyclonic circulation near Sri Lanka[5].

Although the NEM season coincides with the peak period of El Niño and La Niña episodes, the rainfall anomalies do not show a clear contrast as in the case of the SIM season. This could be attributed to the fact that the NEM winds mainly bring rainfall to the windward side (eastern part) of the central highlands and little or no rains to the leeward side where Ratnapura is located.

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