Impact of El Niño Southern Oscillation and Indian Ocean Dipole Index on growing seasonal characteristics: A case study in Batalagoda, Sri Lanka

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Abstract: **Ocean atmospheric phenomenon such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (DMI) have an impact on global level climatic patterns and agriculture. The climate and agricultural activities of Sri Lanka, which is a tropical island in the Indian Ocean, mainly depends on the amount and the distribution of rainfall. The objective of this study was to assess the impact of ENSO and DMI on growing seasonal characteristics of Batalagoda, Sri Lanka. The growing seasonal characteristics such as the onset, retreat, length of the season, seasonal rainfall and rainy days were initially assessed using Instat Statistical Programme. Pearson correlation analysis was then performed to check their relationship with oceanic indices. The Multivariate ENSO Index and DMI did not show a significant correlation ($p > 0.05$) between onset, retreat and length of the season. However, the retreat of the season showed a significant ($p < 0.05$) relationship with Southern Oscillation Index (SOI). Both SOI and MEI showed significant ($p < 0.05$) correlation with the growing seasonal rainfall. Due to some signals of the impact of oceanic indices on the growing seasonal characteristics of Batalagoda, further studies are needed to be carried out throughout the county using the similar approach.**

Key words*: ENSO, MEI, SOI, *Yala*, *Maha

I. INTRODUCTION

Agriculture is one of the main income sources of Sri Lanka which contributes more than 7% to the national economy. Food production in many part of the world highly dependent on climate inputs such as growing season temperatures and rainfall (Abbas and Mayo, 2021). Being a tropical country, marked seasonal temperature variation cannot be observed, hence rainfall pattern plays a major role to determine climatic characteristics in Sri Lanka (Kurukulasuriya and Ajwad, 2007; Esham and Garforth, 2013). Three types of rainfalls namely, monsoonal, conventional and cyclonic are identified in Sri Lanka, in which monsoons are the dominant. Four monsoon seasons can be observed in Sri Lanka as; South West monsoon (SWM) from June to September, North East Monsoon (NEM) from December to February, First Inter-Monsoon (FIM) from March to May and Second Inter-Monsoon (SIM) from October to November (Suppiah, 1996). A bi-modal rainfall distribution is observed in the country which leads to two growing seasons; *Yala* (minor) and *Maha* (major) seasons.

There are enough evidence to suggest that agriculture is largely affected by different oceanic activities that includes El Niño Southern Oscillation (ENSO) and Dipole Mode Index (DMI) (Li and Zhao, 2019; Wand et al., 2020). The ENSO is one of the most important ocean atmospheric phenomenon that is responsible for global climate variability. Several studies has been conducted to identify the relationship between ENSO and Sri Lankan rainfall (Suppiah, 1997; Zubair, 2002; Malmgren et al., 2003; Zubair and Ropelewski, 2006). It directly affects the agriculture in Sri Lanka. Zubair (2002) found that rice production in Maha increased and Yala decreased with El Niño whereas contrast condition during La Niña phases. However, impact of ENSO on growing seasonal characteristics has not received much research attention.

Being a country with agricultural based economy and lifestyle, information on the relationship between oceanic indices and growing seasonal characteristics provide vital information on agricultural decision making and policy formulation. Therefore, this study was conducted to identify the impact of El Niño Southern Oscillation and Dipole Mode Index on growing seasonal characteristics of Sri Lanka using one of the representative locations in the country. In order to study the relationship between oceanic indices, the growing seasonal characteristics of the selected location was assessed initially.

II. MATERIALS AND METHODS

Study area

Batalagoda (7.51 ºN, 80.45 ºE) was selected as a representative location in this study. Batalagoda belongs to Low country Intermediate zone region 1a (IL1a) agroecological zone and receive more than 1400 mm of rainfall annually (Punyawardene 2008). The major land use type in the area is rice cultivation.

Data

Observed daily rainfall data of Batalagoda during 1981-2019 period were collected from the Department of Meteorology, Sri Lanka.

Three oceanic indices namely, Southern Oscillation Index (SOI), Multivariate ENSO Index (MEI) and Dipole Mode Index (DMI) were used in this study. The Southern Oscillation Index (SOI) is a standardised index established on the observed sea level pressure differences between Tahiti and

Darwin, Australia. It measures the large scale fluctuations in air pressure during El Niño and La Niña events and widely used in ENSO calculations. Wolter and Timlin, (1993) developed the Multivariate ENSO Index (MEI) using six variables to monitor ENSO namely sea level pressure, zonal and meridional components of surface wind, sea surface temperature, surface air temperature and cloudiness. It represents the ENSO phenomenon more comprehensively (Singh, 2001). The DMI represents the sea surface temperature gradient between the western equatorial Indian Ocean (50E-70E and 10S-10N) and the south eastern equatorial Indian Ocean (90E-110E and 10S-0N).

SOI and MEI values were obtained from National Oceanic and Atmospheric Administration (NOAA), USA (https://www.ncdc.noaa.gov/teleconnections/enso/indicators/soi/ and https://cmr.earthdata.nasa.gov/search/ concepts/ C1214428208-SCIOPS, respectively). The Dipole Mode Index dataset of NOAA ESRL Physical Sciences Laboratory (https://psl.noaa.gov/gcos_wgsp/Timeseries/ DMI/) were used. Years with extreme onset of the growing seasons were categorised in to El Niño, Neutral and La Niña following the definition of Centre for Ocean-Atmospheric Prediction Studies, The Florida State University (https://coaps.fsu.edu/jma).

Onset, retreat and length of the season

The onset and retreat of the season were determined using Instat Statistical Programme (Version 3.036) (Stern et al. 2003). The amount of rainfall to define a rainy day were initially set as 0.85 mm (Wimalasiri et al., 2017). The onset of the season was defined as “the first occasion with more than 20 mm rainfall in a 1 or 2 days period after 1st September and no dry spell of 10 days or more within the following 30 days period”. The retreat of the season was set as the first occurrence of a dry spell of three consecutive weeks after November 1st, with less than 20 mm of rainfall. The duration between retreat and the onset were calculated as the length of the season.

Statistical analysis

The relationship between ocean indices of previous 6 months period (March – August) before the onset of the season according to the definition of the onset (September) and growing seasonal characteristics were analysed following the method used by Zubair et al. (2002). Similarly, ocean indices of previous 3 months period (June – August) before the onset were obtained and used in correlation analysis. The Pearson correlation was used to study the relationship between parameters.

III. RESULTS AND DISCUSSION

Onset, retreat and length of the season

The variation of onset and retreat dates are shown in figure 1. The average onset and retreat dates of the rainy season were 26th September and 29th December, respectively. When compared with the onset, retreat of the season showed higher variability (coefficient of variation - CV 0.074). Out of 39 retreat events during 1981-2019 period, 14 of them (35.9%) were observed in the following year. The most delayed onset (2008) and retreat (2000) were observed in La Niña years. The earliest onset (year 2017) and retreat (year 1986) were generally neutral years.

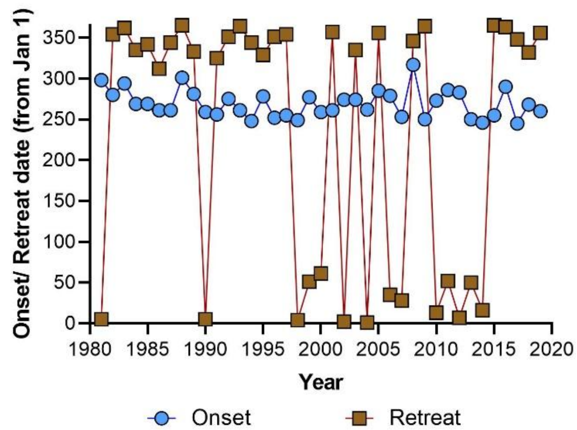

Fig. 1 Variation of onset and retreat dates of the growing season during 1981-2019 period.

With parallel to the onset and retreat, the length of the season also varied throughout the study period (CV 0.34) (Figure 2). The mean length of the season was 94 days, which is around 3 months period. However, the length of the season ranged from 29 (in 2008) to 168 (in 2000) days. Interestingly, both years were categorized as La Niña years.

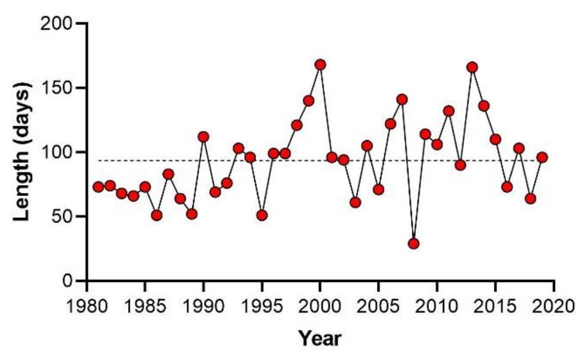

Fig. 2 Variation of length of the growing season during 1981-2019 period. The length of the season is marked using the dashed line.

Seasonal rainfall amount and number of rainy days

Both seasonal rainfall amount and rainy days showed a high variation (Figure 3). The highest seasonal rainfall of 1616 mm was in year 1997 which was categorized as a La Nina year. The lowest seasonal rainfall (342 mm) was reported from a neutral year (2003). The highest seasonal rainy days (82 days) was observed from year 2014 which is a neutral year. However, the lowest number of rainy days (17 days) were reported from year 2008 (La Niña).

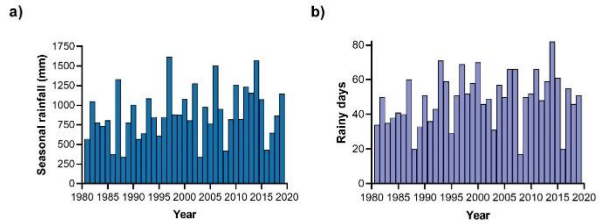

Fig. 3 Variation (a) growing seasonal rainfall and (b) number of rainy days of the growing season during 1981-2019 period.

Growing seasonal characteristics and ENSO and other variables

Out of the five growing seasonal characteristics studied (onset, retreat, length, rainfall amount and rainy days), a significant ($p < 0.05$) correlation was observed between SOI (March – August period) and the retreat of the season only. None of the growing seasonal characteristics showed a significant ($p < 0.05$) correlation with MEI or DMI during March – August period. When compare with the oceanic indices during previous 3 months (June – August period), seasonal rainfall showed significant ($p < 0.05$) correlation with both SOI and MEI. None of the parameters showed significant correlation ($p > 0.05$) with DMI (June – August period).

Suppiah, (1997) studied the relationship between extremes of ENSO and Sri Lankan rainfall using more than 100 years of data and found that no clear effect on rainfall amount during FIM due to ENSO phenomenon. In contrast, El Niño produced below normal rainfall during SWM, while La Niña resulted above normal rainfall. Further, wet conditions of Sri Lanka during SWM period were coupled with negative sea surface temperature (SST) anomalies of central and eastern Pacific and west Indian Oceans and positive SST anomalies of east Indian and western Pacific Oceans (Suppiah, 1997). In contrast, drier conditions were associated with reverse SST anomalies.

El Niño contributed to drier conditions in Sri Lanka during January to March and July to August and rainfall during these time of the year were statistically significant to ENSO indices (Suppiah, 1997). Zubair (2002) studied the effect of ENSO on rice cultivation in Sri Lanka and found that rice production in Yala decreased with El Niño and increased with La Niña phases and the relationship was higher than that with rainfall. Even though a strong relationship between El Niño southern Oscillation with rainfall patterns and crop yield were observed in Sri Lanka, the relationship with the onset, retreat, length of the season, seasonal rainfall and number of rainy days were week in the studied location. However, due to some promising characteristics such as retreat and seasonal rainfall, this could be further studied throughout the country for different timescales.

IV. CONCLUSION

Growing seasonal characteristics that includes the date of onset, retreat, length of the season, seasonal rainfall amount and rainy days were derived for Batalagoda Sri Lanka using a novel approach. The relationship between onset of the growing season and Southern Oscillation Index, Multivariate ENSO Index and Dipole Mode Index showed that there is no significant relationship ($p > 0.05$) between them. However, some of the ocean indices can be used to predict the retreat of the season and seasonal rainfall amount. Further studies are needed throughout the country using the approach described in the paper to get an overall picture.

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