Rainfall Pattern Changes in Sugarcane Plantation in Sevanagala, Sri Lanka

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ABSTRACT

The present study was carried out to identify temporal changes in rainfall patterns in the Sevanagala sugarcane project area in Sri Lanka. Rainfall data collected from the agro-meteorological station of the Sevanagala sugarcane project from 1984 to 2018 were taken for analysis. Dates of rainfall onset and date of terminations, and length of rainfall seasons were assessed. The single mass curve method was used to confirm the consistency of the data set. The Mann-Kandal test was conducted to identify of statistical significance of changes in rainfall onset date, date of termination, and length of rainfall season. The time series trend of the rainfall onset date, date of termination, and length of rainfall season were quantified using Sen's slope estimation method. The results revealed that bi-modal rainfall distribution is prominent in the Sevanagala sugarcane project area. On average, the first rainfall season is distributed from March to July, and the second rainfall season is from October to February. Analogically, the rainfall season onset date for the first and second rainfall seasons was the twenty-eighth of March and the fourteenth of October, respectively. Termination dates of the first and second rainfall seasons were the twenty-ninth of May and the twenty-ninth of December, respectively. Based on the Mann-Kandal test, it was revealed that the rainfall season onset date in the first rainfall season was significantly delayed at a rate of 2.6 days per decade during the 1984 to 2018 period. The termination date of the first rainfall season did not exhibit any significant change over time during the study period. The rainfall onset date of the second rainfall season was also shown a significant delaying trend by 2.7 days per decade during the respective 35-year period. The length of the first rainfall season has not shown a significant change over time. The length of the second rainfall season has shown a significant change by shortening its length at a rate of 7.6 days per decade. Hydro-climatological challenges incurred due to these changes in rainfall season onset date and season length can have a negative effect on the soil water balance of the sugarcane plantations. Thus, precautions must be taken to mitigate this issue at the farmer's field scale as well as the water-basing scale. Most adverse hydro-climatological conditions can often be eliminated by completing land preparation activities in advance and planting operations immediately after starting of rainfall.

Key word: Climate change, Rainfall pattern, Sri Lanka, Sugarcane

INTRODUCTION

Changing rainfall pattern has been identified as a major climatic issue in crop production in Sri Lanka (Esham and Garforth, 2012; Panabokke and Punyawardena, 2010). This effect is more significant in crop cultivations that follows rainfall pattern for their planting and harvesting operations (Zhao and Li, 2016). Rain-fed sugarcane, which has an annual crop cycle, is one such crop cultivated in the dry zone of Sri Lanka (Shanmuganathan, 1990). Most field operations, including land preparation, planting, and other agronomic practices, are seasonal practices in rain-fed sugarcane cultivations (Kumarasingheand Wijayawardhana, 2011). Two planting seasons, from March to April (first planting season) and from October to November (second planting season), and the short harvesting season from January to March and the main harvesting season from May to October, are usually practiced (Shanmuganathan, 1990).

Sugarcane planting at inappropriate times due to erratic or delayed rainfall seasons has caused germination failures, uncontrollable weed growth, and suppression of tillering (Wyseure *et al.*, 1994). Also, late planting directly causes great economic losses at seed cane nurseries as over-matured nurseries often have to be harvested for crushing cane. Rainfall established in advance is another negative impact of rainfall variations, as it interrupts the land preparation activities and increases the risk of uncontrollable soil erosions in newly tilled sugarcane lands. Not only the onset date, date of termination, and length of rainfall period are also to be considered as delaying of date of termination of rainfall season directly influences the starting date of harvesting season of sugarcane plantations. At least one month of dry weather conditions is needed for the accumulation of sugar in sugarcane stalks (Mettananda, 1990; Wyseure et al., 1994). Nevertheless, dry weather is needed for safer transport of sugarcane harvest (Shanmuganathan, 1990), as most of the furrow lines within the sugarcane field are subjected to destruction during transport operations of cane harvest under moist weather conditions. Thus, planning the planting and harvesting schedules based on scientific judgments on rainfall season onset date, date of termination, length of the rainfall season, and their changes over time is a fundamental need to ensure the sustainable management of sugarcane plantations in Sri Lanka. Therefore, the current analysis was carried out to find out the onset date, date of termination, and length of rainfall season and quantify their changes in the Sevanagala sugarcane plantation site based on the daily rainfall data over the past three decades.

MATERIALS AND METHOD

Study area

The study was conducted in the Sevanagala sugarcane project in Sri Lanka (latitude from 6°26'36.53"N to 6°20'4.35"N and longitude from 80°50'31.94"E to 80°58'10.23"E). The area locates on the western boundary of Moneragala district, 150 km away from the capital Colombo. It is located in the low country dry zone (DL_{1b}) as per the agroecological zone classification (Punyawardhana, 2008). Usually, two rainfall seasons per year are prominent. The mean annual temperature is about 28.6 ^{0}C, and the average humidity is 72.6%. Average pan evaporation is about 4.5 mm/day (Wijayawardhana *et al*., 2013).

Data

Daily rainfall data recorded in the agro-met station of the Sevanagala sugarcane project, Sri Lanka (Latitude: 6°23'46.93"N; Longitude: 80°54'45.54"E) for 35 years from 1984 to 2018 were used for the analysis. Two rainfall seasons (in local name, *YALA* season and *MAHA* season rainfall) were analyzed separately. Day number was given from 1 to 184 for the first rainfall season, starting from the 1st of March till the 31st of August, and from 1 to 182 for the second rainfall season, starting from the first of September to the 28th or 29th of February, respectively. The consistency of the data set was tested with the single mass curve method(Kazembe, 2014).

The long-term average rainfall

The long-term average was evaluated based on the mean monthly and 75 probability rainfall method. 75 probability rainfall was calculated as per the ranking method (Ritzema, 1994) using equation 01.

$F(x>x_r) = 1-[r/(n+1)]$--------------.Equation 01

Where, $F(x \geq x_r)$ = 0.75, r = rank number, n = number of years in the dataset

Rainfall seasons onset and date of termination

Several methods have been used to define rainfall onset date of a rainy period (Matthew *et al*., 2017; Odekunle, 2006), *i.e*., point of the maximum curvature of cumulative rainfall curves (Sonnadara, 2015) or point at the 7-8 % cumulative percentage (Amekudzi *et al*., 2015; Matthew *et al*., 2017; Odekunle, 2004) or probability or dependable rainfall method (Weerasinghe, 1989) or water balance method (Kazembe, 2014). In the current paper, the date at the 10 % of cumulative rainfall was taken as the rainfall onset date of the season, and similarly, the date at 90% of accumulated rainfall was selected as the date of termination. Rainfall onset and date of termination in the first rainfall season in 1995 are depicted in Figure 1 to demonstrate the methodology followed in selecting the onset and date of termination.

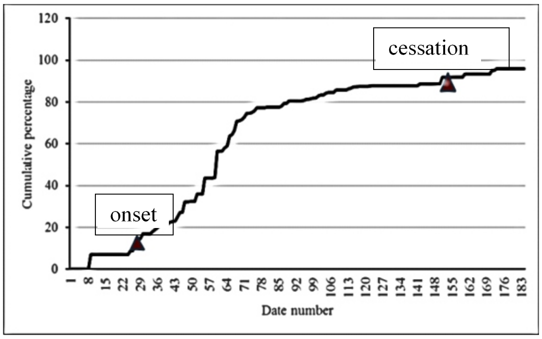


Figure 1: Rainfall onset date (27= 27th march) and date of termination (151 = 29th July) in first rainfall season, 1995

Rainfall seasons length

The length of the rainfall season was obtained using the following equation.

L= (dt-do)+1 --------Equation 02

Where, L = Rainfall season length (number of days), dt = date of termination, do = onset date

Statistical analysis

Statistical analysis was carried out with MAKESENS software developed by Finnish Meteorological Institute (2002). The significance of increasing or decreasing trend for the rainfall season's onset date, date of termination, and rainfall season length was tested with the Man-Kandal procedure (Ojo and Ilunga, 2018) and was evaluated using Z distribution at alpha values of 0.05, 0.1, and 0.2. A positive Z value indicates an upward trend, and similarly negative values for downward (Salmi *et al*., 2002). The adopted model is given in Equation 3.

$x_i = f(t_i) + \varepsilon_i$ ------- Equation 03 (Salmi *et al*., 2002)

Where f*(t)* = increasing or decreasing function of parameter *x* (x= onset date or date of termination or length of the rainfall season), ε_i = residual component.

The slope of the linear trend (as change per year) was estimated with the Sen's method (Ojo and Ilunga, 2018). In Sen's method, the slope of all data pairs of the time series data set is calculated individually (Equation 04), and then the parameter *Qi* is ranked according to the ascending order. The median value of the ranked data set was taken as the final value of the slope of the trend line (Salmi *et al*., 2002).

Where, Q_i = slope between desired data pair, (x_j - x_k) =desired data pair, (*j-k)* = interval between x_j and x_k (number of days)

$$Q_i = \frac{(x_j - x_k)}{(j-k)} \quad \text{--------Equation 04}$$

RESULTS

The long-term average rainfall

The distribution of mean monthly rainfall and 75 probability rainfall is given in the Figure 2. According to the mean monthly and 75 probability rainfall data, a bi-

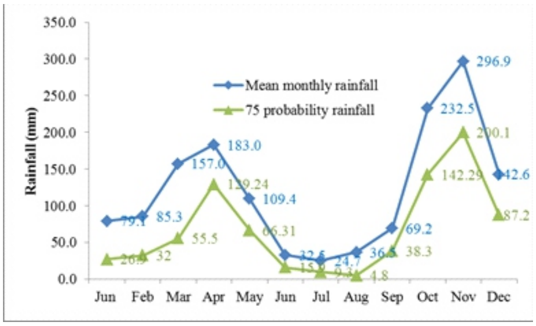


Figure 2: Distribution of mean monthly rainfall and 75 probability rainfall in Sevanagala (data 1984-2018)

modal rainfall pattern with two peaks in April and November was prominent in the Sevanagala sugarcane plantation site.

The mean monthly rainfall of April and November are 183.0 mm ± 14.4 mm and 296.9 mm ± 20.7 mm, respectively. July

was the driest month, having the lowest mean monthly rainfall of 24.7 mm ± 4.1 mm. Annual average rainfall from 1984 to 2018 was 1448.6 mm ± 49.4 mm.

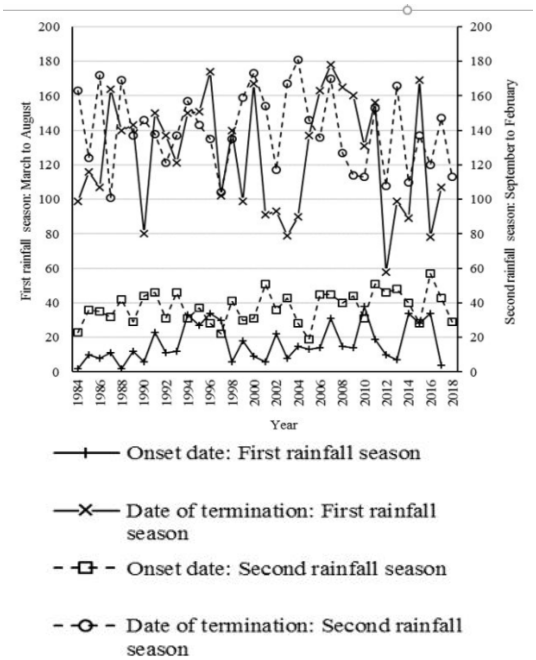


Figure 3: Distribution of onset date and date of termination of two rainfall seasons (data from 1984-2018)

Onset date, date of termination, and length of rainfall seasons

The distribution of onset date, date of termination, and length of rainfall seasons from 1984 to 2018 are given in Figure 3.

First rainfall season

The first rainfall season starts by the twenty-eigh[th] of March and continues till the twenty-nin[th] of May at a probability ≥ 0.75 level. As such, there is a 25% chance to extend the first rainfall season after the thirtieth of May. These findings are highly compatible with the previous studies (Ariyawansha and Keerthipala, 2010).

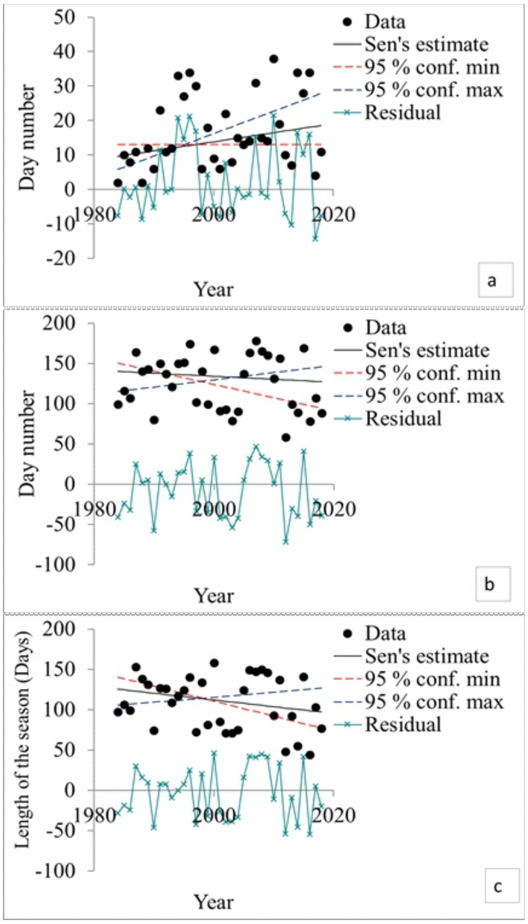


Figure 4: Temporal changers of onset date (a), date of termination (b) and length (c) of the first rainfall season

However, on average, the first rainfall season receives 543.0 mm ± 22.1 mm rainfall which constitutes 37.5 % of the annual average rainfall. Temporal variations of the onset date, date of termination, and length of rainfall seasons (duration) of the first rainfall season are shown in Figure 4.

Constructed trend lines (Sen's estimate) confirm that the onset date of the first rainfall season is an in-delaying trend (significant at 0.1 alpha level). Parameters for the trend lines of the first rainfall season are given in Table 2.

Table 2: Trend lines statistics for first rainfall season

Parameter	Calculated Z value	Regression line gradient (Sen's slope estimate)	Relative change per decade (days)
Onset date	1.71**	0.263	2.63
ceeasation date	-0.70	-0.056	0.56
Rainfall season length	-0.98	-0.094	0.94

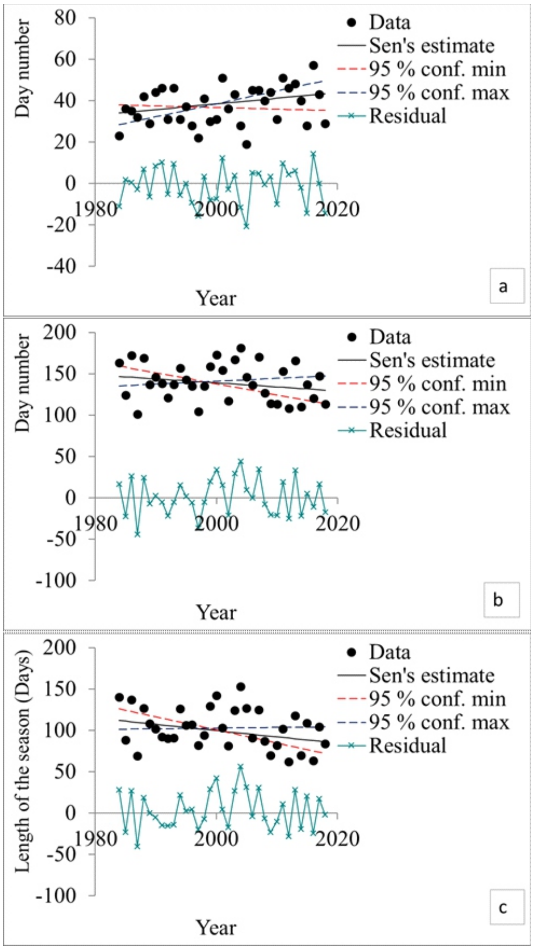
****Significant at $\alpha = 0.05$, ** Significant at $\alpha = 0.1$, * Significant at $\alpha = 0.2$*

It is evident that (Table 2) the onset date of the first rainfall season has been delayed at a rate of 2.63 days per decade. However, the date of termination and length of the first rainfall season has not exhibited a significant change during the study period due to a high standard error at ± 6 on the temporal scale.

Second rainfall season

According to the analysis, the second rainfall season starts on the fourteenth of October and continues till the twenty-ninth of December (probability ≥ 0.75). On average, 905.7 mm ± 36.0 mm of rainfall is received during the second rainfall season, and it constituted 66.7% which is higher than that of the rainfall in the first rainfall season. The second rainfall season receives 62.5% of the annual average rainfall. Temporal changes of onset, date of termination, and length of season (duration) of the second rainfall season are shown in Figure 5.

It is evident that the onset date of the second rainfall season is in a delaying



Figuer 5: Temporal changers of onset date (a), date of termination (b) and length (c) of the second rainfall season

was observed to be decreasing trend at alpha=1.0 significant level. Parameters for the trend lines of the second rainfall season are given in Table 3.

Table 3: Trend lines statistics for the second rainfall season

Parameter	Calculated Z value	Regression line gradient (Sen's splope estimate)	Relative change per decade (days)
Onset date	1.41*	0.273	2.73
Ceeasation date	-1.19	-0.485	4.85
Rainfall season length	-1.72**	-0.759	7.59

****Significant at $\alpha = 0.05$, ** Significant at $\alpha = 0.1$, * Significant at $\alpha = 0.2$*

Accordingly, the onset date of the second rainfall season has been significantly delayed at a rate of 2.73 days per decade. Also, it was worth noting that the length of the rainfall season has diminishing trend at a rate of 7.59 days per decade for the period of 1984 to 2018. However, the trend of the date of termination of the second rainfall season was not significant.

DISCUSSION

The narrowing of the rainy season due to delayed starting and the early termination of the rainy season can adversely affect the sugarcane replanting calendar currently being implemented in Sevanagala. It has also been observed that the shortening of the rainy season leads to an increase in the length of the dry period. This phenomenon can be identified as an emerging threat to young cane plants. In addition, shortening the duration of the rainy season puts additional pressure on subsequent field operations, such as land preparation and timely supplying of plant material from the nurseries, as most of these operations may be completed during the shortened rainy season. Moreover, operations linked to water management and soil conservation can be hampered due to the intensification of field operations, which ultimately leads to serious damage to soil resources in long term.

Therefore, short-term and long-term strategies must be adapted to address the above-mentioned hydro-climatological challenges associated with changes in rainfall onset dates and length of the rain season. Completing land preparation activities in advance and planting operations immediately after the commencement of the rainy season are possible strategies that can easily be adopted at the farmer's fields scale to meet these hydro-climatological issues. Providing adequate machinery facilities, including high-powered tractors for land preparation during the dry season, may be an additional solution to improve land preparation before the onset of rainfall because it allows to take full advantage of the rainfall in terms of germination tillering and growth of the sugarcane. It enables to utilize complete rainfall season for crop establishment and growth.

CONCLUSION

The daily rainfall data analysis of the Sevanagala sugarcane plantation site for 1984–2018 demonstrated a characteristic bimodal rainfall pattern. Dates of the onset of the rainfall season are observed to be delayed by 2.6 and 2.7 days per decade during the first and second rainfall seasons, respectively. However, the date of termination of both rainfall seasons remained the same.

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