Implications of Seasonal Rainfall Trends for Agriculture in the Dry Zone of Sri Lanka

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Abstract: Sri Lanka is vulnerable to the changing climate because of the departures from the usual rainfall. This paper analyses the consistency in trends of rainfall in the dry zone of Sri Lanka with particular emphasis on the influence of four monsoon seasons on the regional agriculture. The data analyzed consists of the daily rainfall records (1996-2015) at 10 stations distributed throughout the dry zone of Sri Lanka. The non-parametric Mann-Kendall and Sen-Theil statistical methods were used for the investigation which is appropriate for the non-normal data with missing or censored records. To analyse the data with seasons, modified seasonal Mann-Kendall trend test was used. The pre-whitening method was applied to remove autocorrelation from the time series. Though the results show an increasing annual rainfall, a consistent reduction has been revealed in monthly rainfall during June and July. Nearly 30% of the stations demonstrated a statistically significant ($p<0.05$) increase in rainfall during the northeast monsoon season. However, statistically significant decline in monthly rainfall during June and July led the dry zone drier, which may have reduced the availability of the irrigable surface water during *Yala* (minor rainy) season. Findings of rainfall variation in dry zone help speculate water availability for crop requirement in the dry zone in Sri Lanka.

Keywords: Daily rainfall, Monsoon season, Non-parametric, Trend analysis

Introduction

Being an island and influenced by regional climate, the rainfall has changed in recent decades especially in the dry zone of Sri Lanka. Although it is highly influenced by the Indian Ocean and Indian Mainland which are responsible for the regional climate, there is a high chance for climatic drivers which makes vulnerable to the variable rainfall trends in Sri Lanka (Burt and Weerasinghe, 2014). Consisting two-thirds of the total land area of Sri Lanka, dry zone water availability is critical for the agriculture in Sri Lanka (Senaratne and Rodrigo, 2014).

The frequent rainfall events have intensified in recent years at least true in the countries of South Asian including

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Sri Lanka. The IPCC (Intergovernmental Panel for Climate Change) indicates that climate change takes place mainly by increasing intensity and frequency of the weather events although averages are not significant (IPCC, 2007). Such a gradual change in rainfall worsens the existing situation causing tremendous impacts; therefore, it is now essential to understand the country's vulnerability to the rainfall changes.

Most climate change investigations always proceeded with understanding historical trends (Irizarry-Ortiz *et al*., 2012). This paper uses linear climate metrics to study the trends of rainfall in the dry zone of Sri Lanka for the period of 1996-2015 using the 10 synoptic meteorological stations scattered throughout the dry zone.

Further, seasonal impacts of rainfall were also studied in the dry zone. Primarily, two monsoon winds highly influence the climate in Sri Lanka. The southwest monsoon (SWM) and northeast monsoon (NEM) reach Sri Lanka from May to September and December to February, respectively. During the SWM and NEM seasons, winds come from the northeast and southwest (Wickramagamage, 2010), respectively (Figure 1). The periods between these primary monsoons are referred to as inter-monsoonal seasons, which usually last for two months. They are called the first inter-monsoon (FIM) and second inter-monsoon (SIM) and occur during the periods of March-April and October-November, respectively. This portioning of seasons is widely used by many works of literature relevant to the climate in Sri Lanka (Malmgren *et al*., 2003; De Silva, 2006; Zubair *et al*., 2008; Nishadi and Smakhtin, 2009). The *Maha* season, which is the primary crop growing season in the dry zone of Sri Lanka, composed of SIM and NEM rainfall. The regional climatic patterns in Sri Lanka are primarily influenced by the El Nino-Southern Oscillation (ENSO) (Zubair *et al*., 2008). Due to its island geography, seasonal monsoons moderate the climate of Sri Lanka (National Atlas of Sri Lanka, 2007). Although non-parametric statistical techniques were previously used by Karunathilaka *et al*. (2017); Herath and Rathnayake (2005); Jayawardene *et al*. (2005), but seasonality components were not addressed appropriately for the detection of long-term trends. The primary objective of this paper is to assess the implications of rainfall trends in the dry zone of Sri Lanka using the daily rainfall records.

Methodology

Data

The data used for this study are precisely two decade or 20-year records of raw (or unadjusted) rainfall (mm) for the period of 1996-2015. Prior to 1996 at least five-year data are missing in the stations such as Jaffna, Pottuvil and Vavuniya. Daily rainfall records at 10 main meteorological stations scattered throughout the dry zone of Sri Lanka were selected for the analysis (Figure 1). These station records were gathered from the Meteorological Department of Sri Lanka. The rainfall data investigated is subject to consistency checks such as for station relocations,

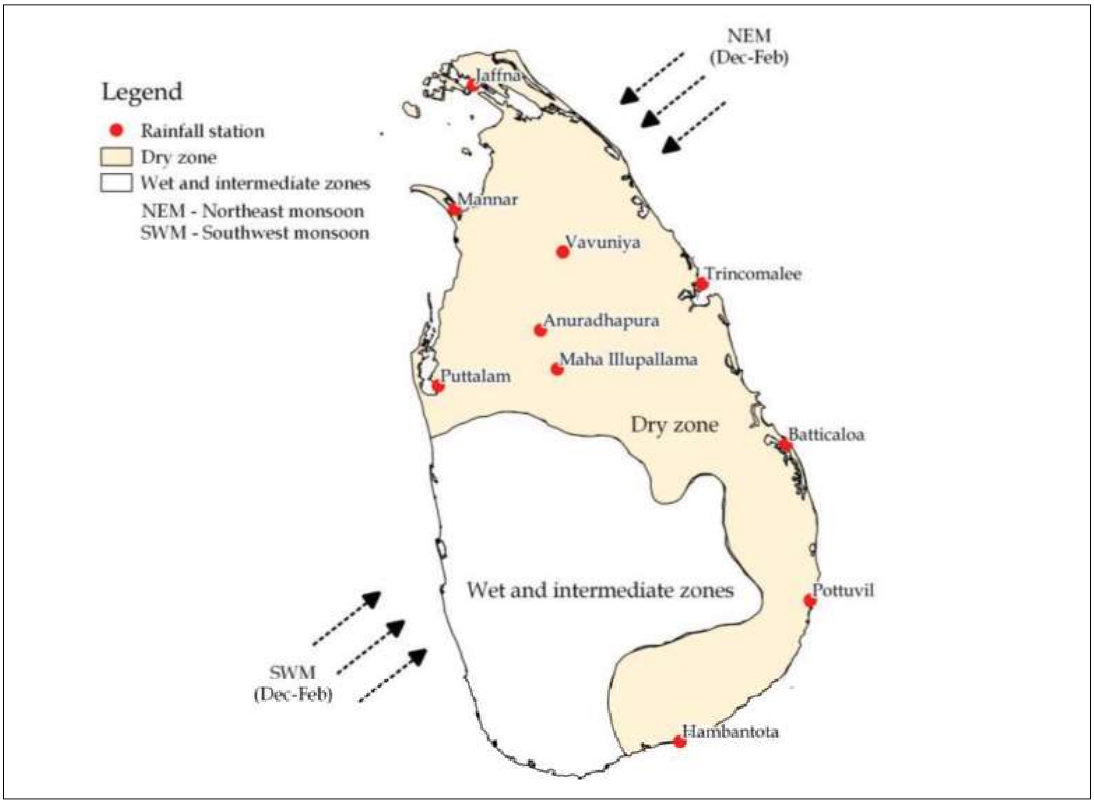


Figure 1: Rainfall stations in the dry zone of Sri Lanka.

instrumentation upgrade and changes in the surrounding ecosystem, which may introduce inhomogeneity, affecting the actual trend. Also, such inhomogeneity corrections may introduce false trends in the data (Pielke *et al*., 2007). Therefore, raw rainfall data was used to reveal the actual trends.

Analysis

Monthly, seasonal and annual trends were investigated for the statistically consistent trends. Although there is a possibility for a non-linear trend, this study seeks to reveal the presence or absence of a linear trend with a year as the explanatory variable. The standard methods are used to test the statistical significance of the slope parameter. For the majority of the trends in this study, the non-parametric Mann-Kendall trend test and Sen-Theil regression were utilized.

The Sen-Theil estimator was used to compute the trend slopes (Theil, 1950; Sen, 1968). The fitted regression line called a Sen-Theil trend line is a non-parametric, alternative to ordinary least square, can be used in conjunction with the Mann-Kendall test. The *p*- value of the estimated Theil-Sen slope is obtained using the Mann-Kendall test.

If there is a significant positive autocorrelation, the test tends to overestimate the significance, which leads to the rejection of the null hypothesis according to the selected level of significance. The opposite is also true where the test tends to underestimate the significance possibly when negative autocorrelation exists (Yue *et al*., 2002). Since the rainfall data of Sri Lanka showed significant autocorrelation, pre-whitening is applied to remove the positive autocorrelation.

In this investigation, the iterative pre-whitening method was performed as executed in the "*zyp*" package in R-programming environment (Zhang *et al*., 2000). Finally, the slopes of the Mann-Kendall test and Sen-Theil were computed for the pre-whitened data set. A modified Mann-Kendall trend test and Sen-Theil have been used to correct mild autocorrelation in between seasons, developed by Hirsch and Slack (1984).

The seasonal Sen-Theil slope estimator is computed by calculating pairwise slopes within each season and obtaining slopes from all seasons to compute a median slope for the entire period of record. In this approach, if there are opposing trends, then the power of the test is reduced because such trends may cancel each other out. Therefore, homogeneity between seasons was initially verified using the van Belle and Hughes trend test (van Belle and Hughes, 1984) prior to the application of seasonal Mann-Kendall and Sen-Theil tests. If the data were heterogeneous between seasons, then the original trend test was performed with pre-whitening.

The analysis was performed in the R-programming environment (R). R is an integrated, interactive environment for data manipulation and serves as a platform for high-level statistical data analysis (R-Core Team, 2016). Numerous statistical libraries available in R was used for the trend detection investigation. A default level of significance of 0.05 was used for all the statistical tests.

Results and discussion

Annual rainfall

Rainfall variability in the dry zone of Sri Lanka was observed to be high. However, average annual rainfall demonstrated linear increasing trend (Figure 2) of +15 mm/year, which agree with the recent rainfall trends reported for the dry zone (Abeysekera *et al*., 2015; Karunathilaka *et al*., 2017) and for Sri Lanka reported by various studies (Jayawardena *et al*., 2018; Naveendrakumar *et al*., 2018).

Notably, these annual average rainfall trends contradict with a decade old prediction by De Silva (2006), may be due to the usage of different baseline data (1961-1990).In general, annual average rainfall in the dry zone was scattered in between the range of 1100-1800 mm for the period of 1996-2015 with higher rainfall during the recent decade. The excess moisture condition (due to increased rainfall) in agriculture fields has severe implications on the crop management that may lead to a reduction in productivity (Herath and Thirumarpan, 2017; Senaratne and Rodrigo, 2014).

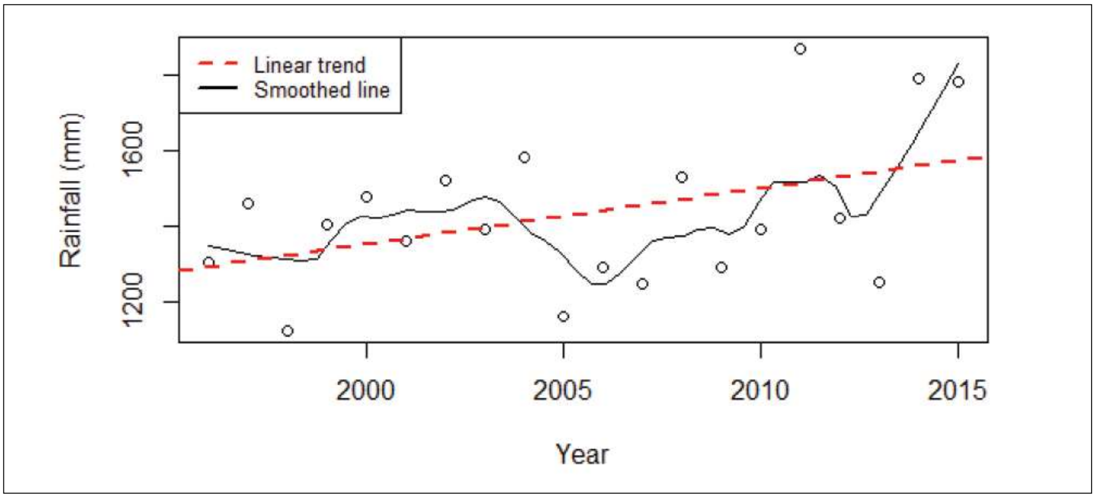


Figure 2: Average annual rainfall trend in the dry zone of Sri Lanka for the period of 1996-2015.

Monthly rainfall

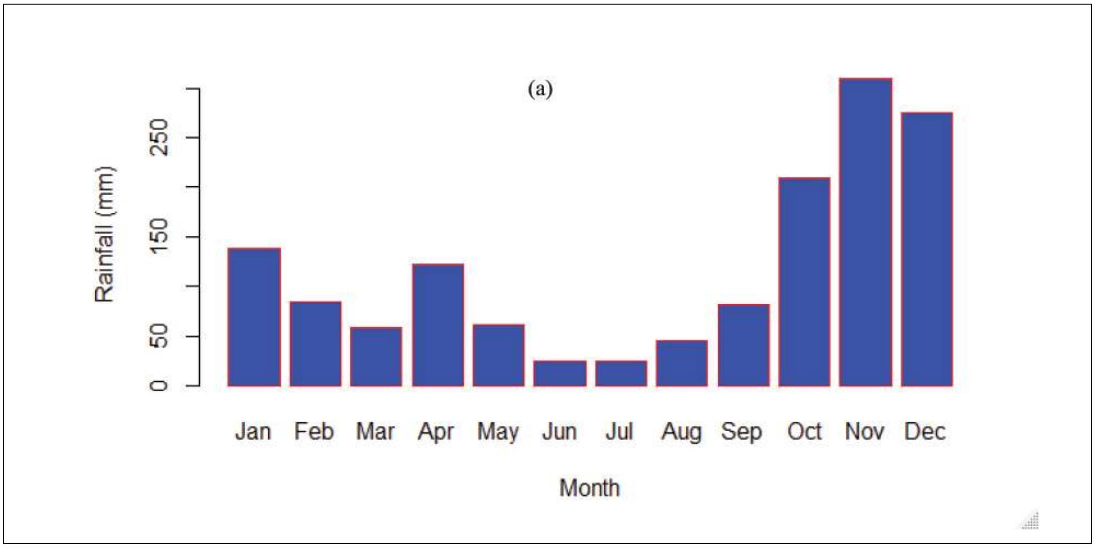
Table 1 presents the number of stations (out of 10) showed statistical trends (either positive or negative) in terms of monthly rainfall. It has been observed at least one station showed a statistically significant decrease in monthly total rainfall during June and July. Especially during June, 100% of the stations showed decreases only indicate a reduction in rainfall of dry zone of Sri Lanka during the middle phase of SWM. It also evidently indicates that dry months in dry zone underwent even drier due to consistently decreasing rainfall, although annual rainfall was

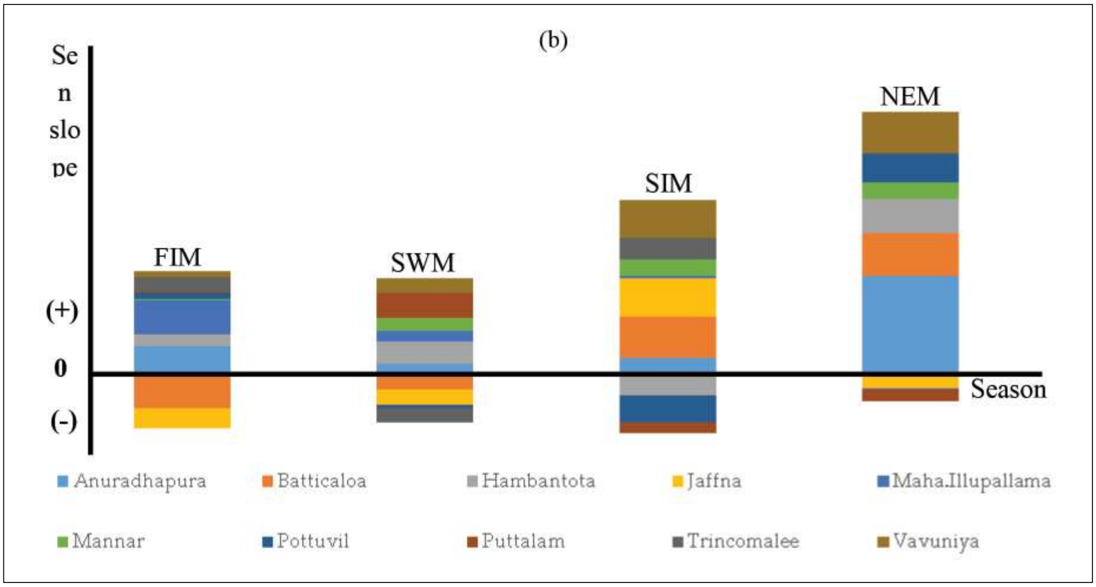
Table 1: Number of stations observed for decreases (-) and increases (+) in monthly total rainfall in stations of dry zone in Sri Lanka for the period of 1996-2015.

Month	Trend* -	Trend* +	Stations (statistically significant)
Jan	9 (0)	1 (0)	
Feb	5 (0)	5 (0)	
Mar	1 (0)	9 (3)	Hambantota, Pottuvil and Trincomalee
Apr	6 (0)	4 (0)	
May	6 (0)	4 (0)	
Jun	10 (1)	0 (0)	Maha Ilupallama
Jul	9 (2)	1 (0)	Jaffna and Mannar
Aug	1 (0)	9 (1)	Mannar
Sep	4 (0)	6 (0)	
Oct	1 (0)	9 (1)	Anuradhapura
Nov	3 (0)	7 (0)	
Dec	1 (0)	9 (0)	

**Stations showed a statistically significant trend (at the 5% level of alpha) are given in parenthesis* revealed an increase. The highest number of stations (30%) was observed during March (Hambantota, Pottuvil, and Trincomalee) followed by August (Mannar) and October (Anuradhapura) during the latter phase of the SWM and SIM. The surplus rainfall obtained during these months critical for the agricultural seed sowing in the dry zone of Sri Lanka.

The monthly rainfall ranged in between 30-300 mm in the dry zone of Sri Lanka. The highest rainfall has been obtained during November followed by December which is the latter phase of SIM and initial phase of NEM, respectively (Figure 3 (a)). It is clear that the dry zone is more influenced by the NEM comparing with the SWM in Sri Lanka. At least 70% of the rainfall stations with positive Sen slopes were observed mostly during the NEM and SIM when comparing with other rainfall seasons in dry zone (Figure 3 (b)).





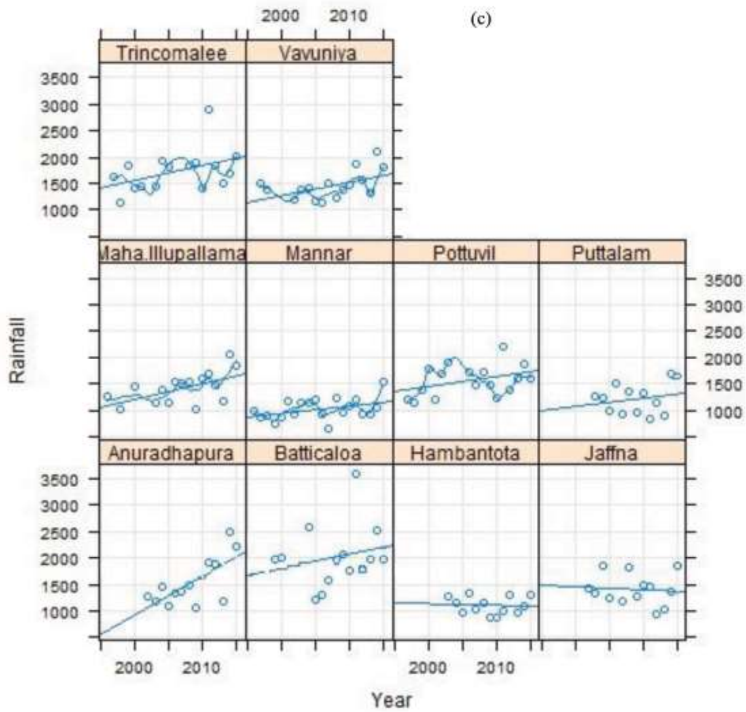


Figure 3: (a) Monthly rainfall, (b) Sen slopes of rainfall stations, and (c) Annual rainfall in the dry zone of Sri Lanka for the period of 1996-2015.

However, Jaffna, Maha Illupallama and Puttalam showed declining rainfall trend during the months of NEM season which agrees with the prediction by De Silva (2006). Figure 3(c) shows the annual average rainfall in the stations of dry zone of Sri Lanka for the period of 1996 to 2015.

Seasonal rainfall

Majority of the stations showed increases in rainfall during all four seasons. Almost 100% of the stations demonstrated a positive trend in which at least 10% of the stations showed a statistically significant increase in seasonal rainfall during the FIM, SWM and NEM seasons (Table 2). Especially during NEM season, 30% of the stations (Anuradhapura, Jaffna and Puttalam) showed a statistically significant increasing trend in seasonal rainfall over dry zone of Sri Lanka. Being an interior station, Anuradhapura demonstrated a statistically significant increase in seasonal rainfall during SWM, SIM and NEM seasons. The stations in coastal peripherals such as Hambantota and Jaffna showed statistically significant increase in rainfall during NEM and SIM seasons, respectively. Though statistically not significant, Jaffna was the only station revealed for the decrease in rainfall during SIM season. However, consistent surplus rainfall obtained in the proceeding NEM season may balance the deficit during SIM season, is an important source of water for agriculture in the dry zone (Senaratne and Rodrigo, 2014).

The increased rainfall during NEM season with high intensity may be the reason for the flood events reported in the past (Burt and Weerasinghe, 2014). Further, an increased rainfall during the *Maha* season and the prolonged dry spells during *Yala* season, may lead to the dry zone more vulnerable to groundwater exploitation due to unregulated water extraction for agricultural practices (Senaratne and Rodrigo, 2014).

Conclusion

Though annual rainfall in the dry zone has increased in the recent decade, consistent reduction during June and July makes the region drier in terms of water availability is evident. This increased rainfall during the *Maha* season and the prolonged dry spells during *Yala* season may lead to groundwater exploitation due to unregulated water extraction. Although it is difficult to reason out for such rainfall variation, the regional climatic driver may be the reason for such increasing rainfall trends in Sri Lanka. Findings of rainfall variation in dry zone are helpful in speculating water availability for crop cultivation especially during deciding on alternating tank-fed and rain-fed agricultural practices in the dry zone of Sri Lanka.

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