IDENTIFICATION OF TEMPORAL TRENDS IN RAINFALL ANOMALIES OF DIFFERENT RAINFALL SEASONS IN SRI LANKA USING THE STANDARDIZED PRECIPITATION INDEX (SPI)

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Introduction

Sri Lanka is located in the tropical zone of the world between 5˚ 55' to 9˚51' of North Latitudes and 79˚42' to 81˚ 53' East longitudes and surrounded totally by the Indian Ocean. The Island received rainfall throughout the year in four rainfall seasons. There are two major rainfall seasons known as South-West (SW) Monsoon from May to September and North-East (NE) Monsoon from December to February. In between these monsoon seasons, two Inter-Monsoon periods are in existence, namely the First Inter-Monsoon (IM1) from March to April and Second Inter-Monsoon (IM2) from November to December. The SW Monsoon is the longest rainfall season of the Island which occurs for 5 months duration per year. Occurrence of rainfall anomalies (droughts and extreme rainfall events) in these rainfall seasons is not uncommon and vulnerability of different Agro-Ecological Regions for droughts has been identified [1]. Accordingly, almost all the regions of the island have a potential threat to droughts. A drought has been defined as a condition of moisture deficit sufficient to have an adverse effect on vegetation, animal and human beings [2].The indicator based identification, characterization and monitoring of droughts is a widely accepted and popular scientific approach rather than application of other complex methodologies. The standardized Precipitation Index (SPI) proposed by McKee and his co-workers [3] is found to be a versatile tool in drought alert, monitoring and analysis and it is the most widely acceptable index. This index is based on precipitation alone and makes the analysis relatively simple [4]. Secondly, the index makes it possible to describe the drought on monthly time scales. Further, SPI involves standardization which makes it particularly suited to compare drought conditions among different time periods and regions with different climatic conditions. In the context of climate change, there are many reports about the change in seasonal rainfall patterns, increasing trends of total rainfall and increased frequency in occurrence of rainfall events. This study was conducted to enhance the knowledge base on changes in seasonal rainfall patterns in Sri Lanka. This paper therefore attempts to identify any trends of seasonal rainfall anomalies with the aid of SPI values calculated for different time scales.

Materials and Methods

Selection of Locations

A total of 25 locations representing the Wet, Intermediate and Dry zones of Sri Lanka and having long term reliable rainfall records were selected for the study.

Table1. Locations selected for the study listed under respective Climatic Zone

Wet Zone	Intermediate Zone	Dry Zone
Agalawatte	Badulla	Jaffna
Galle	Kurunegala	Akkarayankulam
Kegalle	Matara	Iranamadu
Colombo	Hambantota	Vavuniya
Ratnapura	Moneragala	Anuradhapura
Katunayaka	Wellawaya	Ampara
Katugastota		Puttlam
Matale		Okkampitiya
Nuwara-Eliya		Batticaloa
		Trincomalee

Collection and Preparation of Rainfall Data

Rainfall data were collected from the Department of Meteorology, Sri Lanka as daily rainfall data. These daily rainfall data were then converted to monthly rainfall data. The time period covered was 1983 to 2015. Missing data were completed using Aphrodite climatic data which are available at https:// iridl.ldeo.columbia.edu/ SOURCES/.RIHN/.aphrodite/. Aphrodite data are gridded daily precipitation datasets collected by rain gauge observations through Asian precipitation activities [5].

Calculation of SPI

SPI values were calculated by fitting a probability density function to frequency distribution of precipitation summed over the desired time scale as described by T.B. McKee [3] based on the following equation.

$$\mathrm{SPI} = \frac{X_{ij-}X_{im}}{SD} \qquad (1)$$

Where, X_{ij} is the seasonal precipitation at the i^{th} location and j^{th} observation, X_{im} the long-term seasonal mean and SD is its standard deviation. The SPI series were then computed using the open source program available from National Drought Mitigation Center (http://drought.unl.edu/monitoringtools/ download able spi program.aspx). The classification of SPI values and categories of rainfall anomalies are given in Table 2.

Table2. Classification scales for SPI values [3]

Value	Category
More than 2.0	Extremely wet
1.50 to 1.99	Severely wet
1.00 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderate drought
-1.50 to -1.99	Severely drought
Less than -2.00	Extreme drought

In this study SPI values were calculated for different time scales; *viz.* two, three and five month's scales and relevant months related to the four rainfall seasons were extracted for further analysis.

Trend Analysis

Trend analysis was done by the non-parametric Mann- Kendall test to identify trends in rainfall anomalies determined by SPI values. This test was formulated as a non-parametric test [6] and later the distribution of test statistic was proposed [7] for testing non-linear trends. This test is widely used for the analysis of trends in climatology. The significance of trends was determined by the approximated Z value (Zs) of the Mann Kendall (MK) test statistic.

Results and Discussion

The results of the trend analysis for the 1st Inter monsoon period are given in Table 3. During this period; significant increasing trends for SPI were observed in the Wet Zone in 3 out of 9 locations; in Kegalle, Katugastota and Nuwara-Eliya. In the Intermediate Zone, no trends were observed except for Wellawaya, which exhibited a significant increasing trend signifying positive anomalies (wet conditions). Among the locations in the Dry Zone, Anuradhapura, Jaffna and Trincomalee reported significant increasing trends.

Table 3. Statistics of the locations which exhibited significant trends in rainfall anomalies (SPI values) in the First Inter Monsoon period

Location	Climatic Zone	AER	MK test statistic	Zs	Trend Type
Kegalle	Wet	WL2b	134	2.06	Increasing

Katugastota	Wet	WM2b	195	3.01	Increasing
Nuwara-Eliya	Wet	WU3	132	2.03	Increasing
Jaffna	Dry	DL3	177	2.73	Increasing
Anuradhapura	Dry	DL1b	184	2.84	Increasing
Wellawaya	Intermediate	IL1c	139	2.14	Increasing
Trincomalee	Dry	DL2b	134	2.06	Increasing

Zs = Z approximation, Zs>1.96= significant increase, Zs<1.96= Significant decrease AER = Agro Ecological Region

Nuwara-Eliya in the Wet Zone reported a significant decreasing trend in SPI for the SW period (Table 4). Although not significant, the Mann Kendall test statistic was negative in the other stations, except Kegalle and Colombo in the Wet Zone. As in the 1st inter monsoon period, only Wellawaya exhibited a significant increasing trend in the locations of intermediate zone.

Table 4. Statistics of the locations which exhibited significant trends in rainfall anomalies (SPI values) in the South West Monsoon period

Location	Climatic Zone	AER	MK test statistic	Zs	Trend Type
Nuwara-Eliya	Wet	WU3	-181	-2.79	decreasing
Jaffna	Dry	DL3	148	2.28	increasing
Ampara	Dry	DL2b	210	3.24	increasing
Sangaman Tank	Dry	DL2b	-133	-2.05	decreasing
Wellawaya	Intermediate	IL1c	151	2.32	increasing

Zs = Z approximation, Zs>1.96= significant increase, Zs<1.96= Significant decrease AER = Agro Ecological Region

As given in Table 4, only increasing trends were observed for the Second Inter Monsoon. Significant increasing trends were observed for Kegalle and Katugastota (Wet Zone), Matara and Wellawaya (Intermediate Zone) and Anuradhapura and Ampara (Dry Zone). Rainfall anomalies measured by SPI did not indicate any trend except for Matara in the Intermediate Zone (Table 5). A graphical representation of the results of trend analyses of rainfall anomalies in different locations is given in Figure 1.

Table 5. Statistics of the locations which exhibited significant trends in rainfall anomalies (SPI values) in the Second Inter Monsoon period

Location	Climatic Zone	AER	MK test statistic	Zs	Trend Type
Kegalle	Wet	WL2b	153	2.36	increasing
Katugastota	Wet	WM2b	141	2.17	increasing
Matara	Int.	IL1a	144	2.22	increasing
Anuradhapura	Dry	DL1b	151	2.32	increasing
Ampara	Dry	DL2b	132	2.03	increasing
Wellawaya	Intermediate	IL1c	147	2.26	increasing

Zs = Z approximation, Zs>1.96= significant increase, Zs<1.96= Significant decrease AER = Agro Ecological Region

Table 6. Statistics of the locations which exhibited significant trends in rainfall anomalies (SPI values) in the North East Monsoon period

Location	Climatic Zone	AER	MK test statistic	Zs	Trend Type
Matara	Intermediate	IL1a	149	2.40	increasing

Zs = Z approximation, Zs>1.96= significant increase, Zs<1.96= Significant decrease AER = Agro Ecological Region

Conclusions

Out of the total 25 locations studied, significant increasing trends in rainfall anomalies were observed in seven locations in the First Inter Monsoon season. In the SW monsoon season, significant increasing trends were observed in three locations and decreasing trends were observed in two locations. Only significant increasing trends were observed in the Second Inter Monsoon period. During the North East monsoon period, the only location exhibited a significant increasing trend, was Matara, which belongs to the Intermediate Zone. When considering all four monsoon seasons in all 26 locations, both the Inter Monsoon seasons and the South West Monsoon showed more significant trends. Seventeen out of 19 changing trends were increasing in the selected locations. Anomalies observed in the NE periods were comparatively low. This study provides valuable outputs for future predictions of rainfall anomalies and spatial mapping can be employed to represent past rainfall events and distribution of SPI values for better expression of results.

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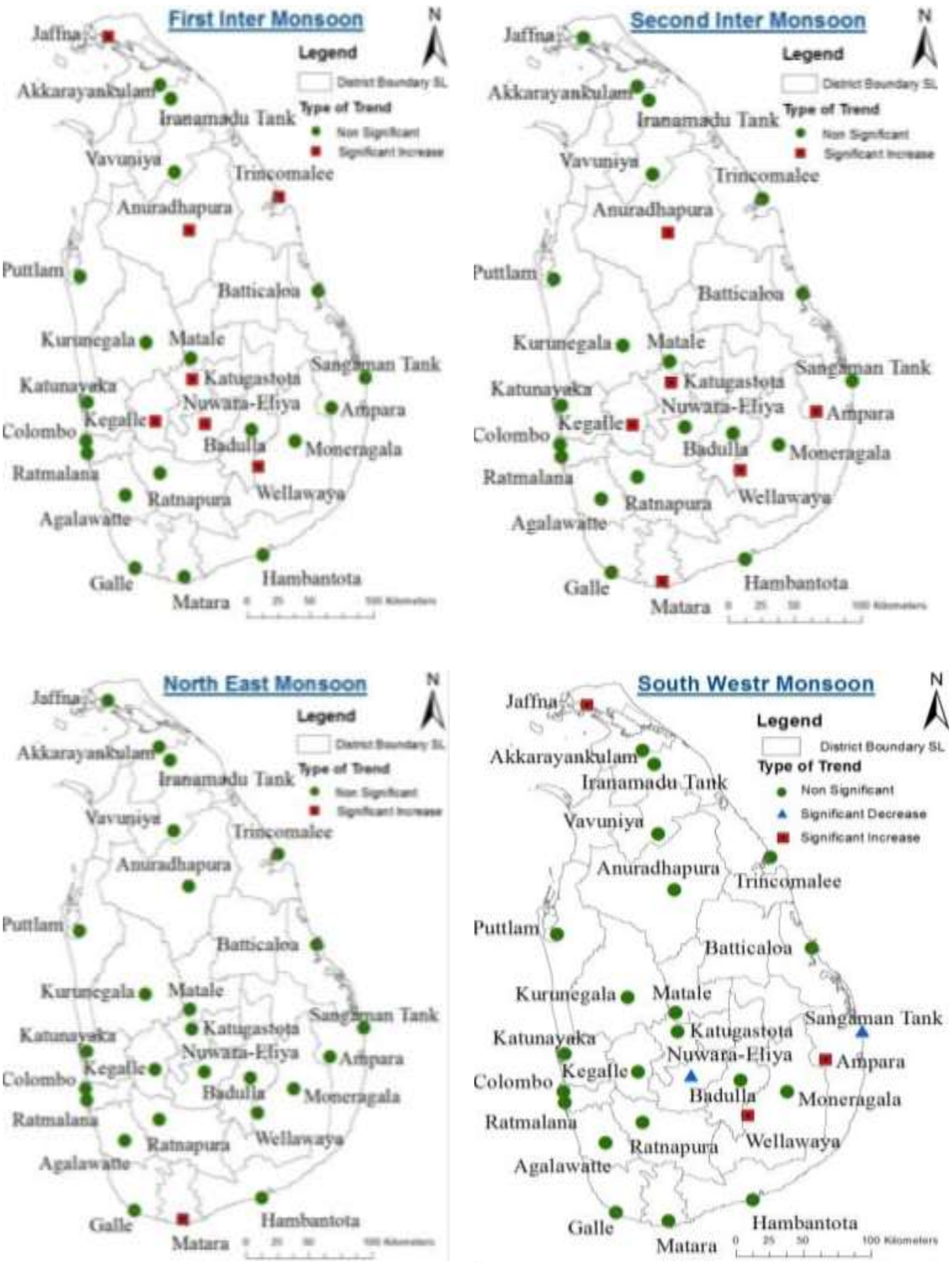

Figure1. Graphical Representation of types of trends in rainfall anomalies in different seasons

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