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RESEARCH ARTICLE

Identification of changes in rainfall pattern in paddy growing areas in Sri Lanka: A case study in Anuradhapura district

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ABSTRACT

It is now widely accepted that the global climate is changing with increasing greenhouse gas concentration in the atmosphere due to human activities. There is enough evidence for more negative impacts of climate change on world agricultural sector. As an agricultural country, Sri Lanka is also experiencing some inevitable consequences due to changing rainfall onset, distribution and the amount. Standardized Precipitation Index (SPI) is a drought monitoring index which is developed for identifying rainfall anomalies with respect to the past data in the same location for specific time scales. The aim of this study was to identify the changes in rainfall patterns using SPI in Anuradhapura district which is one of the major paddy growing areas in Sri Lanka. Monthly rainfall data were collected from four Meteorological Stations viz, Anuradhapura, Maha Iluppallama, Maradankadawala and Kebithigollewa for the period of 1980-2018. Five months SPI values were computed to represent Yala & Maha cultivation seasons and 12 months SPI values were computed to represent the annual rainfall anomalies. Mann Kendal Test was used to identify the trends in selected SPI time series. The results of the study revealed that, there are significant increasing trends in total annual rainfall in Anuradhapura district indicating low risk of having drought years in future. The significant increasing trend in SPI values in Yala & Maha seasons in both Anuradhapura and Maha Iluppallama stations imply that there is a high chance of receiving enough water for cultivation in both seasons in near future. Further, a significant decrease could be observed in total annual and Yala season's SPI values in Maradankadawala indicating a high potential of having droughts. However, Kebithigollewa does not show any significant change in total annual, Yala or Maha seasons rainfall patterns. Finally, it can be concluded that, as Anuradhapura, Maha Iluppallama and Kebithigollewa areas are getting slightly wetter, the paddy cultivation in the Western and Southwestern areas of Anuradhapura district would not be severely affected due to changing rainfall patterns. However, as Maradankadawala area is getting slightly dryer with the changing rainfall patterns, strengthening water conservation techniques would be better for paddy cultivation in the Southeastern area of Anuradhapura district in order to adapt to the incoming dry periods.

Keywords: *Changing rainfall patterns, paddy cultivation, Standardized Precipitation Index (SPI), wet and dry occurrences, Yala and Maha cultivation seasons*

INTRODUCTION

Long term change in the expected patterns of average weather of a region over a significant period of time can be defined as the climate change (Mahato, 2014).

Anthropogenic reasons and natural phenomenon are the main causes of climate change according to IPCC (2014). When human activities like industrialization, urbanization, etc. and deforestation influence on the climate change, it is called as anthropogenic climate change. Further, urbanization is combined with consumption of energy and GHG emission (IPCC, 2014). Anthropogenic climate change has increased drastically during the last few decades and has become a major concern for the world as a whole (Tomby and Zhang, 2019). The El Nino - Southern Oscillation (ENSO) phenomenon and changes in local sea surface temperatures have also been shown to have strong influence on global and regional weather patterns (Stenseth *et al.,* 2003).

The main consequences of climate change are increasing temperature and changes in precipitation. The contribution of agriculture sector to climate change and the negative impacts of climate change on agriculture have been projected as significant. According to Mahato (2014), increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce the yield. Further, IPCC (2014) states that climate change adversely influences on rainfall intensity as well as on the rainfall distribution pattern. Therefore, the impacts of climate change on sustainable food production and food security are unescapable. The economy of countries, having a large agricultural share, faces a larger exposure to climate change than the countries with a lower share, these shares vary widely.

Further, as revealed by Eckstein *et al.* (2018), Sri Lanka is in the 4th place in climate change vulnerability rankings. Temperature is expected to rise from 1.1–2.4 °C by 2100, depending on the emission scenario. Rainfall is projected to increase by 48% for the Southwest Monsoon by 2050 which affects the wetter Southern part of the country, while the Northeast Monsoon, which occurs in the drier northern region, is predicted to decrease by 27–29%. Therefore, the Wet Zone is expected to become wetter and the Dry Zone to become drier with climate change (Eckstein *et al.,* 2018).

Paddy is one of the major cultivated crops in Sri Lanka and paddy cultivation is really important as rice is the main meal in Sri Lanka. Rice cultivation occupies 34% of total cultivated land area in Sri Lanka and as an average 560,000 ha are cultivated during *Maha* (October to February) and 310,000 ha during *Yala* (March to August) making the average annual extent sown with rice to about 870,000 ha (Department of Agriculture Sri Lanka, 2016). Mostly, rain-fed paddy cultivation is done in Dry Zone of Sri Lanka during *Maha* season. Anuradhapura district in Dry Zone has the highest potential ability to cultivate rice rather than the other areas with available fertile lands (Paddy Statistics-Department of Census and Statistics, 2016).

Even though Sri Lanka has a high average rainfall due to its tropical and monsoonal climate, highly seasonal and spatial variability of rainfall creates periodic shortages of water for both agricultural and domestic use.

As revealed by Jayawardane *et al.* (2005), a detailed knowledge of variations in rainfall is essential for proper water management practices. Ekanayake and Perera (2014) have carried out a research to find the drought severity in Anuradhapura district considering three months SPI using only monthly rainfall data of three rain-gauge stations in Anuradhapura for the period of 1951 to 2007.

Gunawardhana and Dharmasiri (2015) have done a research to find drought hazard and managing its impacts through the disaster management approach in Anuradhapura district only considering the changes in annual rainfall. However, it can be seen that more comprehensive scientific literature is less available on the identification of changing rainfall patterns in Anuradhapura district of Sri Lanka. Therefore, this study was carried out to identify the changes in rainfall patterns and to assess the potential of receiving enough rainfalls to Anuradhapura district using widely accepted drought monitoring index, Standardized Precipitation Index (SPI).

MATERIALS AND METHODS

Anuradhapura, Maha Illuppallama, Kebithigollawa and Maradankadawala weather stations were selected for the study considering data availability and their geographical location in Anuradhapura district. Daily rainfall data at Anuradhapura & Maha Illuppallama stations and monthly rainfall data at Kebithigollawa & Maradankadawala stations were collected from Department of Meteorology of Sri Lanka for the period of 1980–2018. Figure 1 shows the areal coverage of each rain-gauge station in Anuradhapura district obtained using Thiessen - Polygon Method (Rachel and Peter, 2017) under GIS environment.

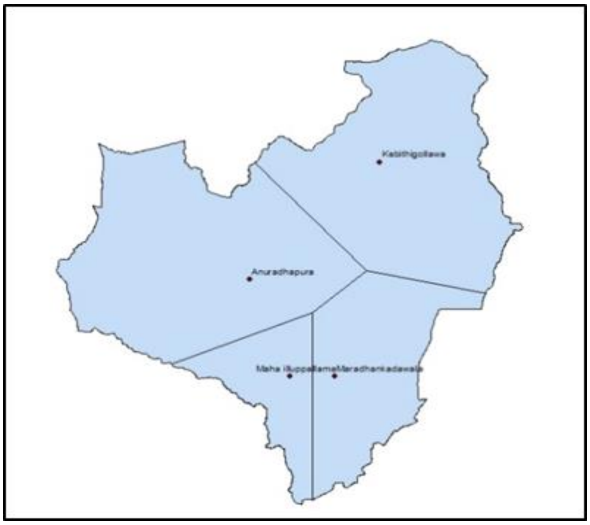

Figure 1: Areal share of four rain-gauge stations in Anuradhapura district.

The SPI was used to identify rainfall anomalies and the SPI time series were computed using the open source program available in National Drought Mitigation Centre (http://drought.uni. Edu/monitor/spi/program/spi_program.htm). According to McKee *et al.* (1993), SPI is a powerful and flexible index which demands only precipitation data. In addition, it is effective in analyzing wet periods/cycles and dry periods/cycles. The SPI was designed to quantify the precipitation deficit for multiple timescales such as 3, 6, 12 and 24 months. These timescales reflect the impact of drought on the availability of different water resources. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards *et al.*, 1997). Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. As the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. Table 1 shows the McKee *et al.* (1993) classification system used to define drought intensities resulting from the SPI.

Table 1: Classification of SPI values.

Class	Description	SPI
1	Extreme drought	-2.00 and less
2	Severe drought	-1.50 to -1.99
3	Moderate drought	-1.00 to -1.49
4	Near normal	-0.99 to 0.99
5	Moderately wet	1.00 to 1.49
6	Severely wet	1.50 to 1.99
7	Extremely wet	2.00 or more

Further, the Mann-Kendall test was used at 0.05 and 0.1 level of significance to determine whether the SPI time series have a monotonic upward or downward trend.

RESULTS AND DISCUSSION

Changes in annual rainfall pattern

Anuradhapura District shows comparatively dry condition with annual rainfall of 892–1159 mm at the beginning (1985–1989) and there is a gradual increment of rainfall during 1990–2014 period as evident by Figure 2. However, a considerable area of whole Anuradhapura district is dry during 2005–2009. During 2010–2014 year time period, almost Anuradhapura district gets more rain and whole District is comparatively wet. From 2015–2017, it has become comparatively dry again. It is also clear that, the Western part of Anuradhapura district has become wetter than the other parts.

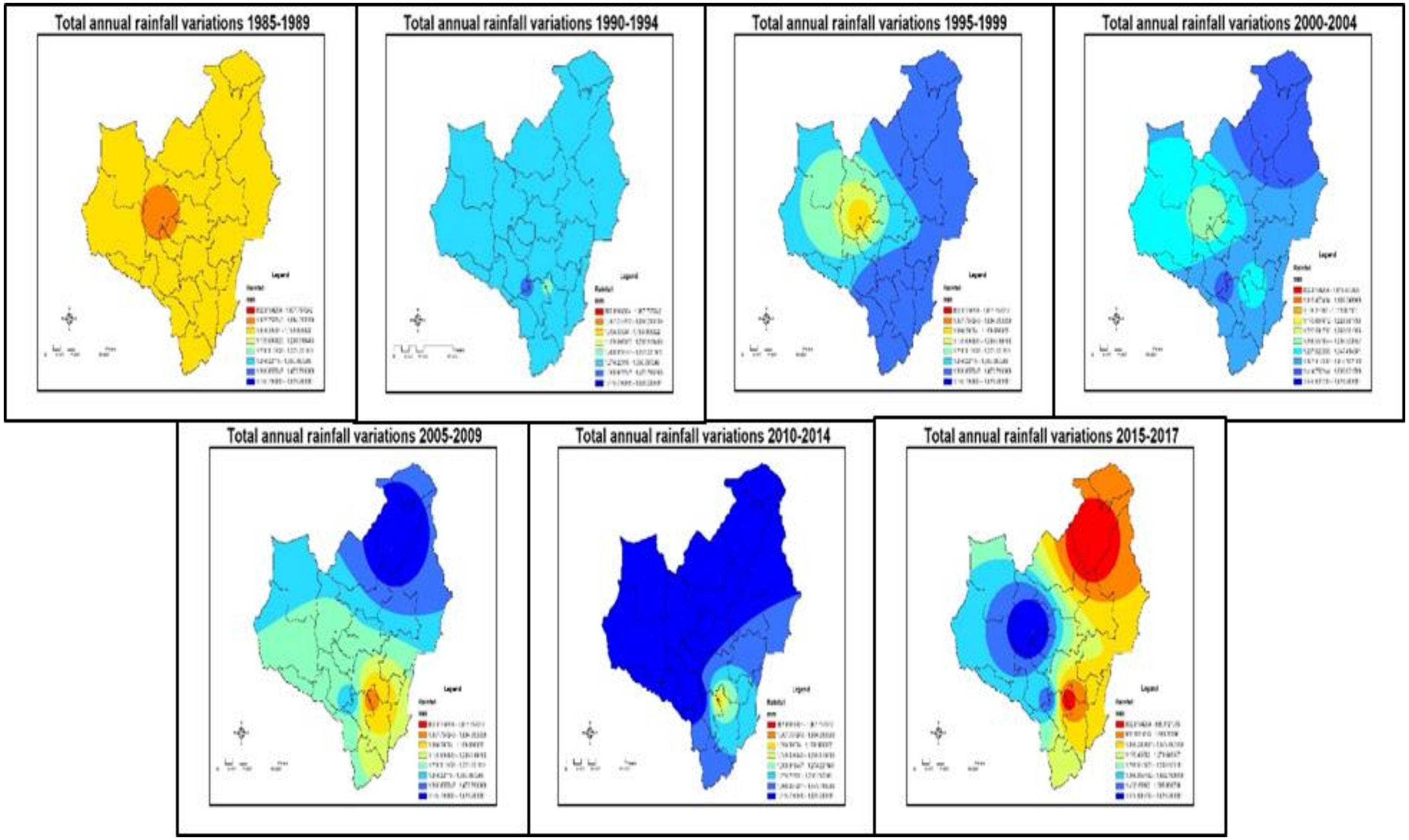

Figure 2: Variations of average annual rainfall during five year time interval.

The average annual rainfall of Anuradhapura district varies from 892–1628 mm for the period of 1985–2015. According to the Sri Lankan Agro-ecological Region map of 2003, Anuradhapura district belongs to three Agro-ecological Regions; DL1b, DL1e and DL1f. Higher amount of rainfall receives to DL1b among these three Agro-ecological Regions and it has recorded as more than 900 mm per year (Punyawardana, 2002). As revealed by Figure 3 and Table 2, Anuradhapura and Maha Illuppallama rain-gauge stations have increasing trends in total annual rainfall while Maradankadawala and Kebithigollewa show decreasing trends during last 30 years

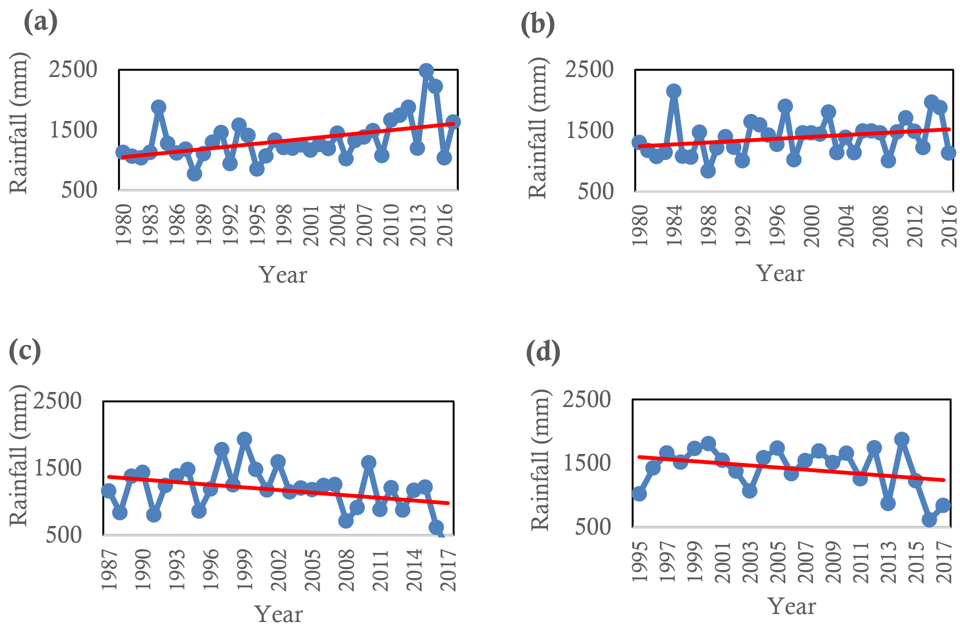

Figure 3: Temporal variations of total annual rainfall at (a) Anuradhapura (b) Maha Illuppallama (c) Maradankawala (d) Kebithigollawa.

Table 2: Results of Mann-Kendall test for annual rainfall.

Rain-gauge station	Significance level	***P***-value	Interpretation
Anuradhapura	0.05	0.005	Increasing trend
Maha Illuppallama	0.05	0.048	Increasing trend
Maradankadawala	0.1	0.075	Decreasing trend
Kebithigollewa	0.1	0.145	No trend

The increasing trends of both Anuradhapura and Maha Illuppallama rain-gauge stations are significant ($P<0.05$). The decreasing trend in Maradankadawal shows a significant trend at 10% level of significance though Kebithigollewa rain-gauge station has no significant trends at both 5 and 10% significance levels.

Changes in rainfall pattern in *Maha* season

According to Figure 4 and Table 3, there are increasing trends in SPI values in Anuradhapura and Maha Illuppallama rain-gauge stations while there are decreasing trends in Maradankadawala and Kebithigollewa rain-gauge stations for *Maha* season. Among these four rain-gauge stations, only Anuradhapura has a significantly increasing trend at 5% significance level.

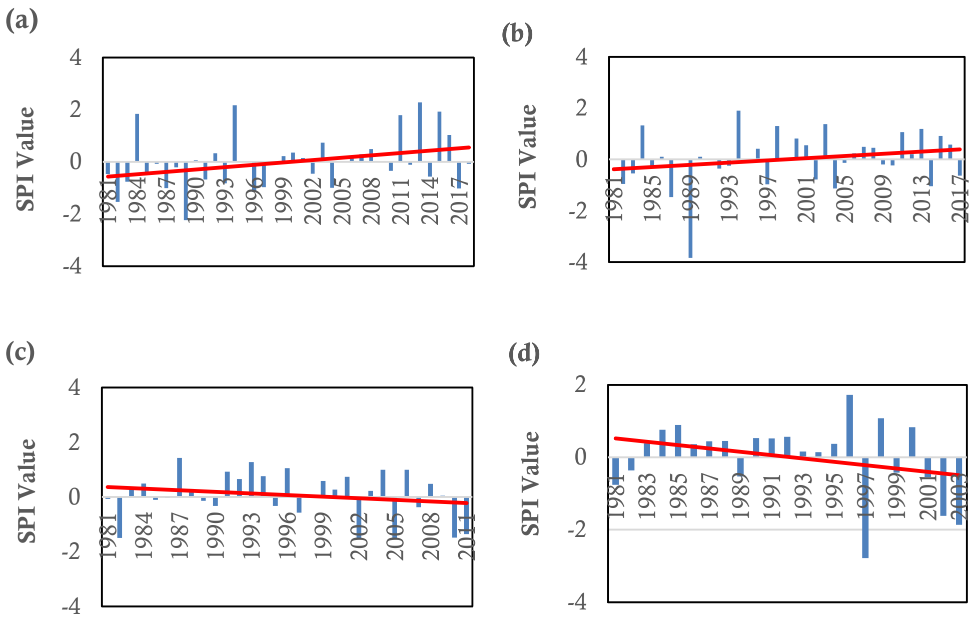

Figure 4: Temporal variation of 5-month SPI for *Maha* season at (a) Anuradhapura (b) Maha Illuppallama (c) Maradankawala (d) Kebithigollewa.

Table 3: Results of Mann-Kendall test for *Maha* season.

Rain-gauge station	Significance level`	***P***-value	Interpretation
Anuradhapura	0.05	0.047	Increasing trend
Maha Illuppallama	0.05	0.165	No trend
Maradankadawala	0.1	0.353	No trend
Kebithigollewa	0.1	0.198	No trend

Though Maha IIluppallama, Maradankadawala and Kebithigollewa rain-gauge stations have increasing and decreasing trends, they are not significant at either 5 or 10% significance levels based on the Mann-Kendall test. When considering SPI values of these four rain-gauge stations, Anuradhapura station, which represents the Western part of Anuradhapura district (Figure 4) shows a positive tendency for the occurrence of wet condition while other areas do not show such a tendency.

Changes in rainfall pattern in *Yala* season

Table 4 shows the results of Mann-kendall test for *Yala* season whereas Figure 5 gives temporal variation of 5-month SPI at four rain-gauge stations for *Yala* season. The Figure 5 clearly shows that Anuradhapura rain-gauge station has an increasing trend in the SPI values. Maha Illuppallama rain-gauge station does not show any outstanding trend in the SPI values while other two rain-gauge stations show decreasing trends. The increasing trend in Anuradhapura rain-gauge station is significant at 10% level of significance and Maradankadawala rain-gauge station shows a significance trend at 5% significance level (Table 4).

Table 4: Results of Mann-Kendall test for *Yala* season.

Rain-gauge station	Significance level`	***P***-value	Interpretation
Anuradhapura	0.1	0.056	Increasing trend
Maha Illuppallama	0.1	0.859	No trend
Maradankadawala	0.05	0.030	Decreasing trend
Kebithigollewa	0.05	0.271	No trend

Though Anuradhapura and Maradankadawala rain-gauge stations show significant trends, Maha Illuppallama and Kebithigollewa rain-gauge stations do not show significant trends in any period. When considering the results of SPI analysis and Mann-Kendall test for *Yala* season, there is a positive tendency to a wet occurrence in Anuradhapura rain-gauge station and negative tendency for a wet occurrence in Maradankadawala during *Yala* season. That means that the Maradankadawala rain-gauge station shows a positive trend for the occurrence of dry condition.

The significant increasing trends in both *Yala* and *Maha* seasons in Anuradhapura district show that there is a tendency to occur more wet spells in Anuradhapura rain-gauge station and nearby areas (Western part of the district) during both *Yala* and *Maha* seasons while Maradankadawala has a trend to occur dry conditions only in *Yala* season.

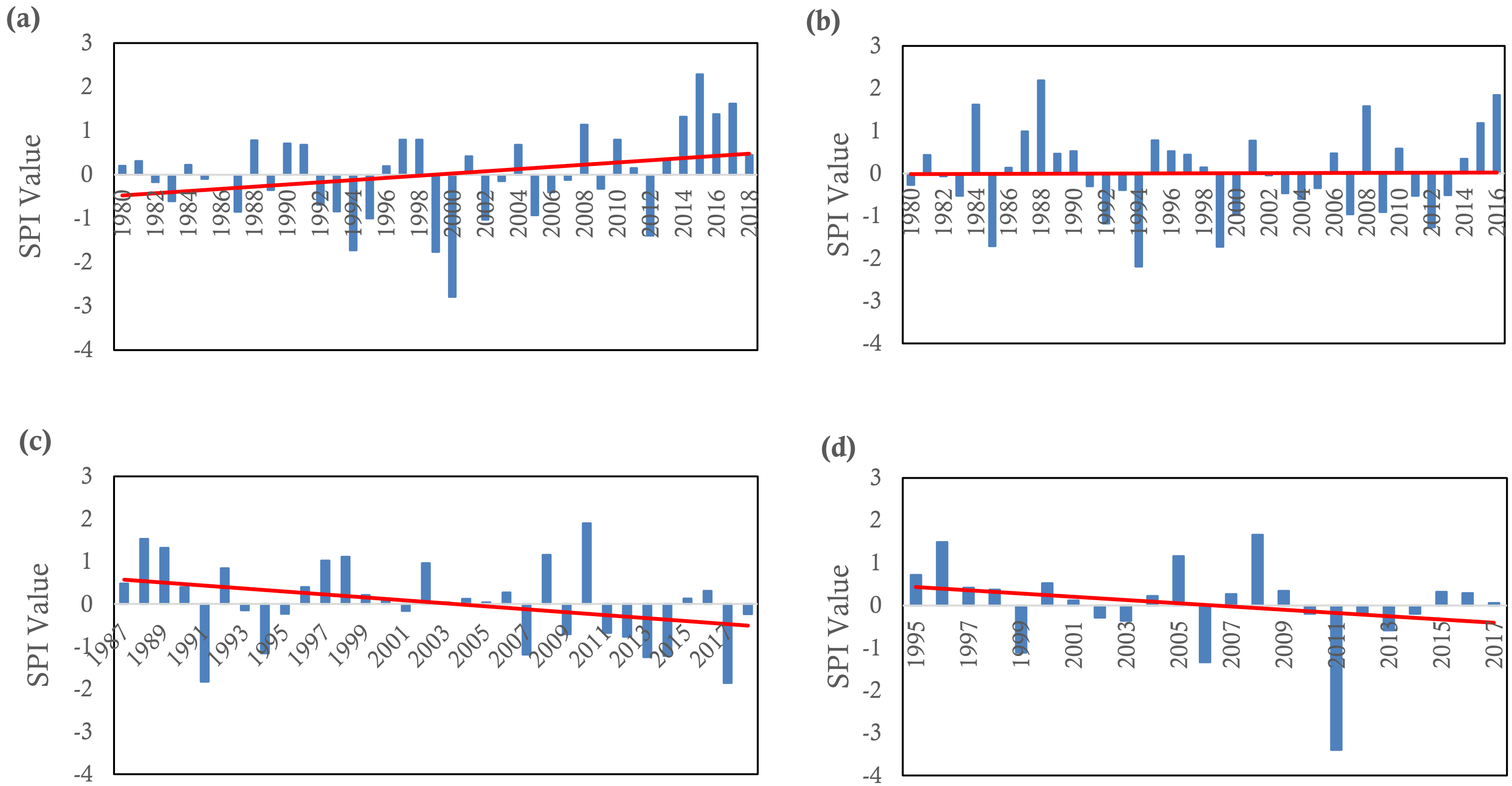

Figure 5: Temporal variation of 5-month SPI at four rain-gauge stations for *Yala* season at (a) Anuradhapura (b) Maha Ilukpallama (c) Maradankadawala (d) Kebithigollewa.

CONCLUSIONS

The present study could successfully identify the changes in rainfall patterns in Anuradhapura district during the period of 1980-2018. The significant increment in total annual rainfall and SPI of *Yala* and *Maha* seasons in Anuradhapura rain-gauge station indicate that there is a high chance of receiving expected rainfalls amount annually and during *Yala* and *Maha* seasons. On the other hand, it can be concluded that there is a low risk for rain-fed agricultural activities in Anuradhapura area which covers the Western part of the district as the prevailed dry occurrences in that area has changed into wet occurrences during last three decades.

Further, it can be observed that a significant increment in total annual rainfall in Maha Illupplama rain-gauge station which covers the Southwestern part of the district. However, there is no enough evidence to conclude that there is a significant change of SPI in *Yala* and *Maha* seasons from this study.

The area which covers by Kebithigollawa rain-gauge also does not show any significant changes during last three decades as it does not show any significant trend in total annual rainfall and SPI in both *Yala* and *Maha* seasons.

Even though the Western and Southwestern parts of Anuradhapura district become slightly wetter Maradankadawala rain-gauge station shows a significantly decreasing trend in total annual rainfall and *Yala* season SPI time series. It implies that there is a high risk of not receiving enough rainfalls in Maradankadawala area which covers the Southeastern part of the district and there is a chance for being drier.

Finally, it can be concluded that the entire Anuradhapura district is not getting dryer due to the predicted climate change. The Western and Southwestern parts of the district are being more towards wet occurrences and the paddy cultivation, which demands more water during almost entire growing period would not be in a high risk. However, the Southeastern part of the district is towards a dry occurrence and there would be a high risk for paddy cultivation emphasizing the need of strengthening the water conservation methods in order to minimize the risk in agriculture.

REFERENCES

Department of Agriculture (2016). Summarized Report [Online] (Accessed on: 28.06.2018) Available at: https://www.doa.gov.lk/ta/.

Department of Census and Statistics (2016). Summarized Report [Online] (Accessed on: 28.06. 2018) Available at: https://www.statistics.gov.lk/.

Eckstein, D., Künzel, V. and Schäfer, L. (2018). Global climate risk index 2018. *Germanwatch, Bonn*.

Edwards, C.D.C., McKee, T.B., Doesken, N.J. and Kleist, J. (1997). Historical analysis of drought in the United States. In 7th conference on climate variations, 77th AMS annual meeting, 27.

Ekanayake, E.M.R.S.B. and Perera, K. (2014). Analysis of drought severity and duration using copulas in anuradhapura, Sri Lanka. International Journal of Environment and Climate Change, 312-327.

Gunawardhana, L.M.A.P. and Dharmasiri, L.M. (2015). Drought Hazard and Managing Its Impacts through the Disaster Management Approach: A Study in the North Central Province of Sri Lanka.

Intergovernmental Panel on Climate Change Report (2014). Summarized Report [Online] (Accessed on: 16.01.2018) Available at: https://www. ipcc. ch/ report /ar5/syr/.

Jayawardane, H.K.W.I., Sonnadara, D.U.J. and Jayawardane, D.R. (2005). Trends of rainfall in Sri Lanka over the last century. Sri Lankan Journal of Physics, 6.

Mahato, A. (2014). Climate change and its impact on agriculture. International Journal of Scientific and Research Publications, 4 (4), 1-6.

McKee, T.B., Doesken, N.J. and Kleist, J. (1993). January. The relationship of drought frequency and duration to time scales. Proceedings of the 8th Conference on Applied Climatology, Boston, MA: American Meteorological Society, 17 (22), 179-183.

Punyawardana, B.V.R. (2002). Climate change: Challenges and opportunities in Sri Lanka. Natural Resource Management Centre, Sri Lanka.

Rachel, O. and Peter, K.A. (2017). Objective assessment of the Thiessen polygon method for estimating areal rainfall depths in the River Volta catchment in Ghana, Journal of Geography, 9 (2) (Special Issue), 151-174.

Stenseth, N.C., Ottersen, G., Hurrell, J.W., Mysterud, A., Lima, M., Chan, K.S., Yoccoz, N.G. and Ådlandsvik, B. (2003). Studying climate effects on ecology through the use of climate indices: the North Atlantic Oscillation, El Nino Southern Oscillation and beyond. Proceedings of the Royal Society of London. Series B: Biological Sciences, 270, 2087-2096.

Tomby, S. and Zhang, J. (2019). Vulnerability assessment of Guyanese sugar to floods. *Clim. Change*, 154 (1-2), 179-193.