Journal of Technology and Value Addition, Volume 2 (2), 2020:85-96

Research Article

Changes Observed in Rainfall Pattern in Uva Province: An Application of Standardized Precipitation Index (SPI)

P.W. Jeewanthi[1*], W. Wijesuriya[2], A.M.C. Amarakoon[1]

**wasana.wish@gmail.com*

[1]*Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University of Sri Lanka, Passara Road, Badulla, 90000, Sri Lanka*
[2]*Biometry Section, Rubber Research Institute of Sri Lanka, Agalawatta, Sri Lanka*

Abstract

Changes in rainfall pattern and distribution are very important as it is mainly connected with the all agronomic practices in agriculture sector. Standardized Precipitation Index (SPI) is one of versatile tools for understanding the variations in monthly rainfall under different scenarios. Rainfall data were recorded in four Meteorological Stations which represent different regions in Uva Province namely Badulla, Monaragala, Okkampitiya and Wellawaya. The 12-month SPI from January to December which gives an idea about annual rainfall anomalies and, 6-month SPI from October to March and April to September and 3-month SPI from December to February were used for the analysis. Changes in SPI time series were analyzed using Change Point Analyzer software and Mann-Kendall test was used to identify the trends in SPI time series. There is a significant increasing trend in the annual rainfall anomalies in Wellawaya. However, there is low risk of having drought years in Badulla, Monaragala, Okkampitiya and Wellawaya after 2004. There is a significant increasing trend in North East monsoon period in Wellawaya and it implies high chance of getting extreme wet occurrences compared to previous years. However, there is no enough evidence of changes in the rainfall pattern of 6-month from April to September and 3-month from December to February. Finally, it can be concluded that there is a change in the pattern of rainfall anomalies in some locations of Uva Province.

Keywords: *Change point analysis, Drought risk, Rainfall anomalies, Standardized Precipitation Index (SPI), Uva province*

1. Introduction

Since Sri Lanka is an agricultural country, rainfall plays a major role since it is the main water income resource in the country. Uva Province, one of the hilly areas in Sri Lanka is a combination of two districts called Badulla and Monaragala which belong to Intermediate Zone (IMZ) and Dry Zone (DZ). IMZ reflects a combination of rainfall characteristics of both Dry Zone and Wet zone. Even though annual average rainfall of this region varies from 1750-2500 mm, it is not uniformly distributed throughout the year. Rainfall amount as well as the rainfall pattern is certainly crucial in agriculture sector, because all agronomic practices depend on the rainfall distribution.

Changes in rainfall pattern mainly effect on agricultural production. Both quality and quantity of the production can be vary depending on the changes in rainfall pattern. However, as far as the agriculture sector is concerned climate variability is paramount important, as we have to face to extreme weather situations currently as well as in future that can have a great impact on performance of crop. Under such climate variability steady rise in ambient temperature together with severe dry spells and excessive rains or frost damages in the hill country could be experienced. Changes in climate factors such as rainfall amount and its pattern are not a short-term process but a long-term process.

Vulnerability of different agro-ecological regions for droughts has been identified by Chithranayana and Punyawardene (2008) and according to their findings; almost all the regions of the island have a potential threat to droughts. However, the degree of vulnerability is more in the DZ. Hence, agriculture is a challenge that needs to be handled carefully in drier areas to avoid detrimental effects due to adverse environmental conditions. If rainfall pattern follows unique pattern throughout the year, farmers can use technologies such as irrigation methods to maintain the water requirement of crop. The effects that they could not manage are unexpected extreme events of droughts and wet. Hence that it is very much important to study the rainfall anomalies such as extreme Wet and Dry occurrences.

There are several records about the changes in rainfall pattern in Wet Zone (WZ) (Jeewanthi *et al.*, 2014) and DZ (Wijesuriya *et al.*, 2014). Even though it is known that seasonal and temporal variability of the IMZ plays a significant role in the rainfall climatology of Sri Lanka and also the deficit of rainfall found in the period of 1971-2000 (Wickramanayake, 2012) , it can be concluded that no enough studies recorded about changes in rainfall pattern in Uva province which belongs to both DZ and IMZ. The effect of the changes in rainfall pattern on agriculture production in Uva Province also can be varying region to region as it shows characteristics in both IMZ and DZ. Under these circumstances, it is really essential to study the changes in rainfall pattern in Uva Province as it is the heart of some agriculture-based industries in Sri Lanka including tea industry. So, this study was carried out to study about the changes in rainfall amount and rainfall pattern in Uva Province using Standardized Precipitation Index (SPI). Even though there have been several drought indices which are being used for drought monitoring and planning, SPI was used for this study as it is one of commonly used indices in Sri Lankan research.

2. Materials and Methods

2.1 Data Collection

Four sites were selected to represent the Uva Province based on the data availability as listed in Table 1. Daily rainfall data of all four stations were collected from Meteorological Department of Sri Lanka and converted those in to monthly basis.

Table 1: Details of the meteorological stations selected for the study

Locations	Latitude	Longitude	Agro-ecological Region	Duration
Badulla	6.98 N	81.05 E	IM 1	1980 – 2015
Monaragala	6.89 N	81.34 E	IL1c	1980 – 2015
Okkampitiya	6.75 N	81.30 E	DL1a	1980 – 2015
Wellawaya	6.73 N	81.10 E	IL1	1980 – 2015

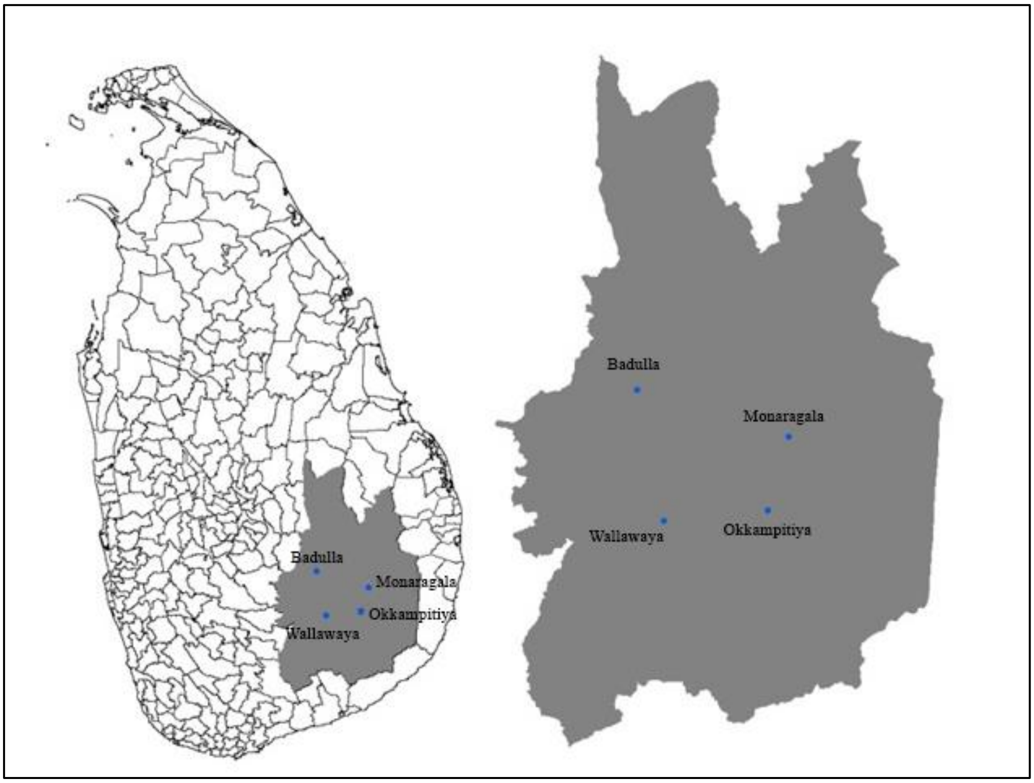


Figure 1: Selected locations for the study

2.2 Calculation of SPI

SPI was proposed by McKee *et al*. (1993, 1995) to assess anomalous and extreme precipitation. Since Precipitation data are mostly skewed, in order to compute SPI, precipitation data were normalized using gamma function. SPI was based on the probability of precipitation for any desired time scale and was computed by dividing the difference between the normalized seasonal precipitation and its long-term seasonal mean by the standard deviation.

The SPI was computed by fitting a probability density function to the frequency distribution of precipitation summed over the desired time scale. This was performed separately for each month or period for each location. The probability density function was then transformed into time scales, namely 1-month, 3-month, 6-month and 12-month to reflect short-term and long-term precipitation patterns. For example, a 1-month SPI at the end of January compares the 1-month precipitation total for January in that particular year with the January precipitation totals of all the years on record. Similarly, a 3-month SPI at the end of January compares the November-December- January precipitation total in that particular year with the November to January precipitation totals of all the years on record for the same location. A 6-month SPI at the end of June compares the January to June precipitation total in that particular year with the January to June precipitation totals of all the years on record for the same location. Similarly, a 12-month SPI at the end of December compares the January to December precipitation total that means annual rainfall amount in that particular year with the annual precipitation of all the years on record for the same location.

The SPI time series were computed using the open source program available from National Drought Mitigation Centre (http://drought.uni.edu/monitor/spi/program/spi_program.htm). Table 2 illustrates the drought and wet classes, their description and SPI values originally proposed by McKee *et al. (*993).

Table 2: Description of SPI index

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

2.3 Analysis of Changes in SPI

Monthly SPI series of precipitation of all four locations were categorized as 1-month, 3-month, 6-month and 12-month according to the objective of the analysis. Let annual time series of SPI as y_t where t=1, 2…T then defined the centered series as y_t^* such that $y_t^*=(y_t-\bar{y})$ where $\bar{y}$ is the grand mean and where t=1, 2…, T. We define s_0, s_1, s_2, …. s_T as the cumulative sum of y_t^*. Once a change point (k) has been detected, an estimator of the change point can be defined such that;

$$|s_k| = \max_{i=0,1\dots T} |s_i| \tag{1}$$

s_k can be viewed as the point furthest from the zero in the series of cumulative sum. Further it can be seen that s_0 and s_T equal to zero. The confidence interval of s_k was taken using bootstrap procedures defined by Efron and Tibshirani (1993). Inference on s_k was made based on the confidence intervals. The change point in the variance was detected using d_i and its cumulative sum defined as q_0, q_1, q_2, q_T where d_i is defined such that;

$$d_i = |y_{2i} - y_{2i-1}| \tag{2}$$

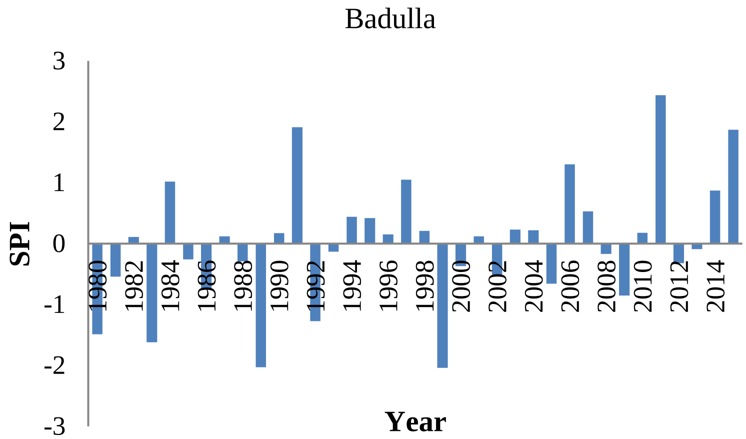
where i=1,2,…. $\frac{T}{2}$. The same procedure adopted before was implemented for making inferences on the change point detected in variance. Change points of SPI in mean and variance together with their 95% confidence intervals were obtained using change point analyzer software in this study (Taylar, 2000).

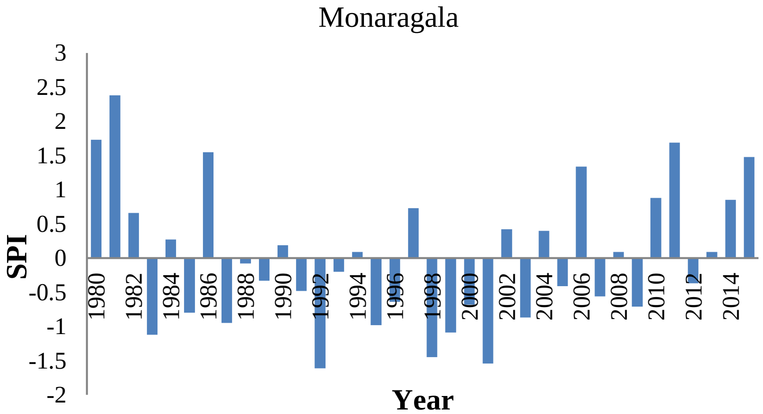
3. Results and Discussion

3.1 Temporal Variation in 12-Months SPI

The 12-month SPI compares the precipitation for 12 consecutive months with the recorded in the same 12 consecutive months in all previous year. The consecutive 12 months from January to December which gives an idea about annual precipitation were considered for the analysis. The variations among 12-month SPI from January to December of four different locations are depicted in Figure 2. The annual behaviors of SPI were plotted against the year.

According to the change point analyser, there is no any significant change in the pattern of 12-month SPI in Okkampitiya and Monaragala, nevertheless some significant changes were detected in the pattern of annual rainfall anomalies in Badulla and Wellawaya. SPI for the period of January to December in Badulla indicates a significant change in the pattern of annual SPI after 1983, based on 12-month SPI, a severely dry occurrence is evident which we could not detect before 1983 in Badulla district. Even though any change in the pattern of rainfall in annual rainfall anomalies in Badulla district was not detected, 12-month SPI indicates some continuous occurrence of moderate wet and very wet event after 2006. Annual changes in Wellawaya is different form the changes in Badulla. It shows a significant change in the pattern of 12-month SPI after the 2005 and It indicate continuous occurrence of moderate wet and very wet event which is rare to identify before 2005. According to the results of Mann-Kendall test, there is a significant increasing trend in annual SPI time series in Wellawaya. Therefore, it can be concluded that there is a high possibility of having wet occurrences in Wellawaya compared to past years. According to 12-month SPI from January to December for all four locations Badulla, Monaragala, Okkampitiya and Wellawaya, it indicates moderate wet, very wet and extremely wet occurrence after 2004, nonetheless no any records about dry occurrence.





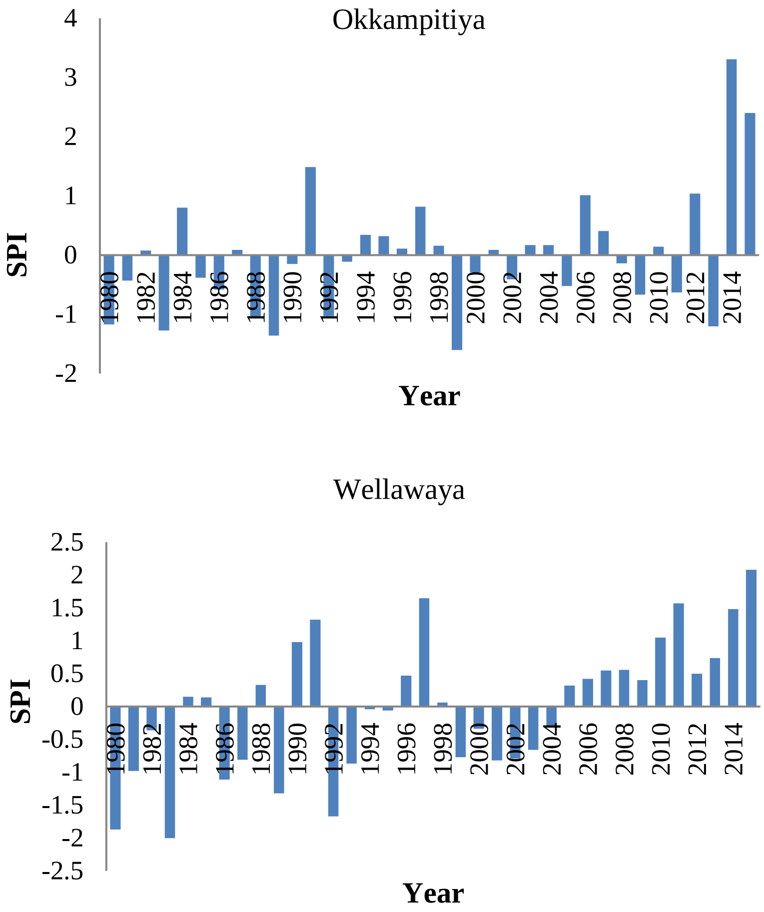


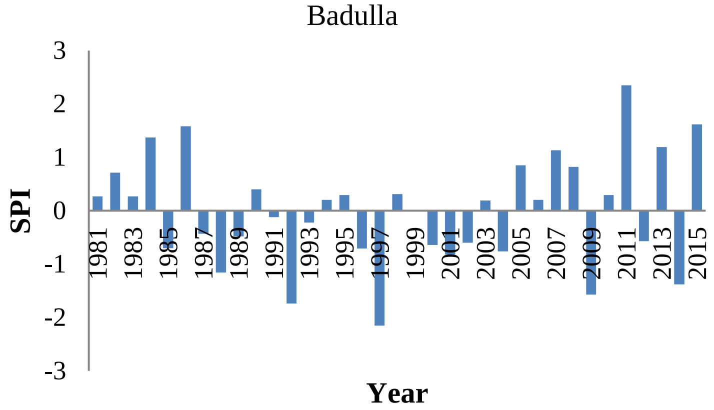
Figure 2: Temporal variation in 12-month SPI in selected locations.

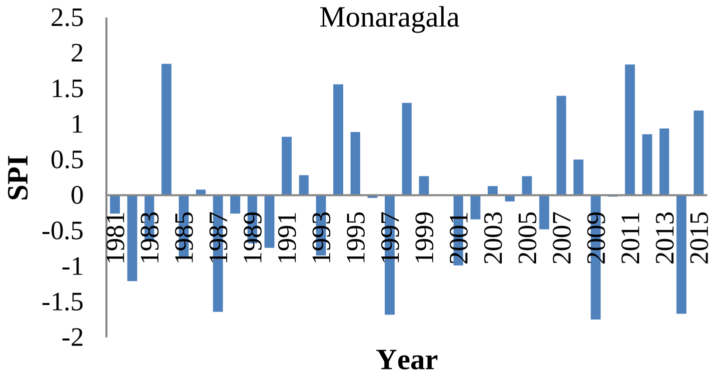
Table 3: Mann-Kendall results for 12- month SPI in selected locations

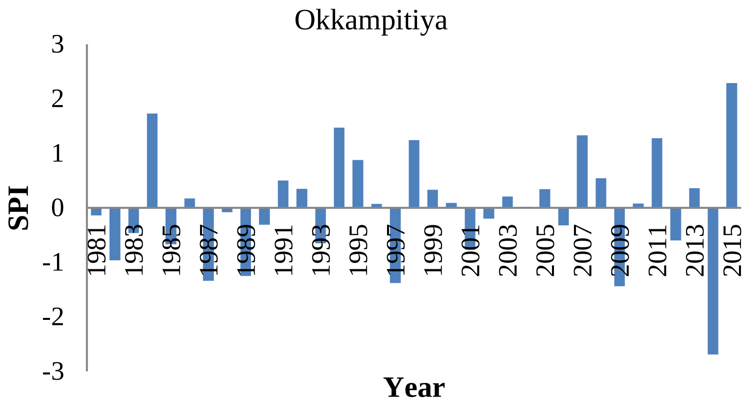
Location	P-Value	Interpretation
Badulla	0.5398	No trend
Monaragala	0.091*	No trend
Okkampitiya	0.126	No trend
Wellawaya	0.0000**	Significant increasing trend

3.2 Temporal Variation in 6-Month SPI

The 6-month SPI compares the precipitation for 6 consecutive months with the recorded in the same 6 consecutive months in all previous year. The consecutive 6 months from April to September and October to March were considered for the analysis based on the rainfall pattern in IMZ. October to March is the monsoon period for IMZ. Hence it is expected to have higher rainfall amount and it is the recommended period for planting many crops such as Tea and Rubber in IMZ. Therefore, it is important to discuss about temporal variation in 6-month rainfall anomalies for the periods mentioned above. The 6-month behaviors of SPI were plotted against the year for each and every location and it is shown in Figure 3. There is no any significant change in the pattern of 6-month SPI, from October to March in Okkampitiya, and Monaragala locations yet there is a significant change in the pattern of 6-month SPI in Badulla after 2005 and Wellawaya after 2013. There are several moderately wet and very wet occurrences after 2005 in Badulla for the 6 consecutive months from October to March while a significant increasing trend in the 6-month SPI time series can be detected from October to March. Consequently, it can be concluded that there is a high chance of getting enough rainfall in North-East monsoon period compared to the previous years. However, 6-month SPI comparison for 6 consecutive months from April to September doesn't show any significant change in the pattern for all four locations.







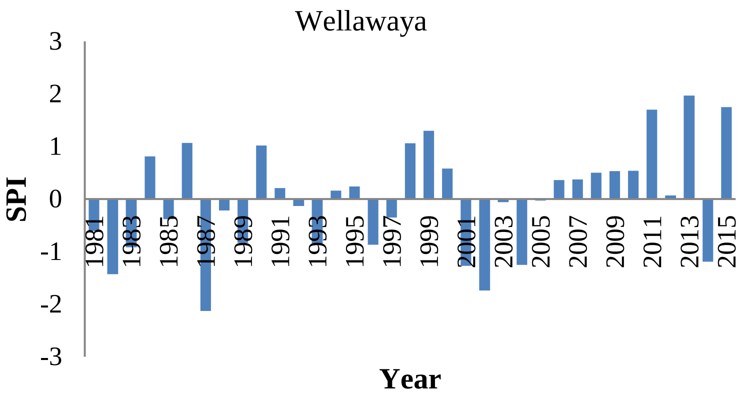


Figure 3: Temporal variation in 6-month SPI from October to March in selected locations.

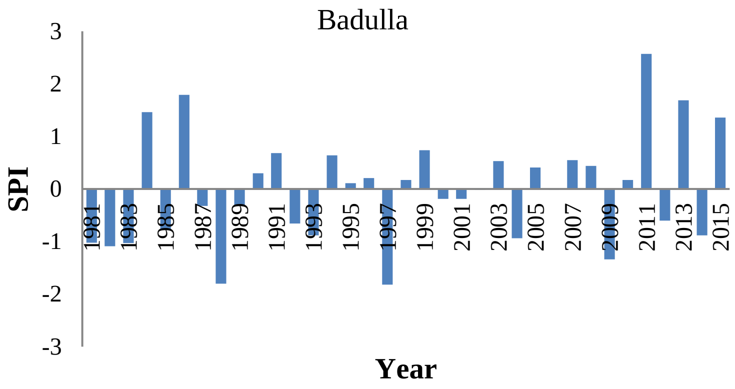
Table 4: Mann-Kendall results for 12- month SPI in selected locations

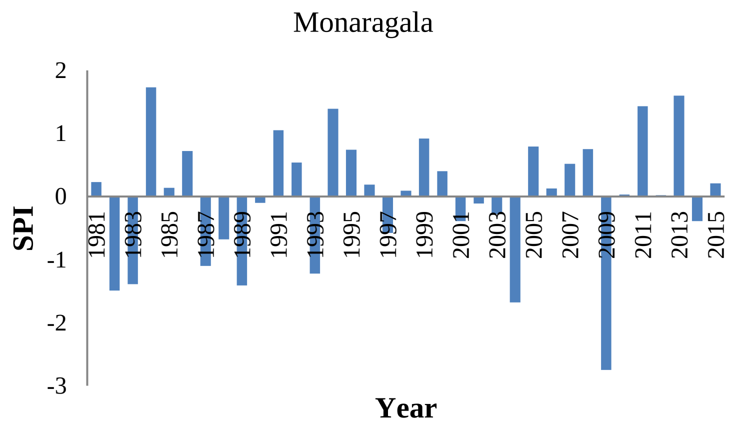
Location	P-Value	Interpretation
Badulla	0.65	No trend
Monaragala	0.138	No trend
Okkampitiya	0.3078	No trend
Wellawaya	0.001**	Significant increasing trend

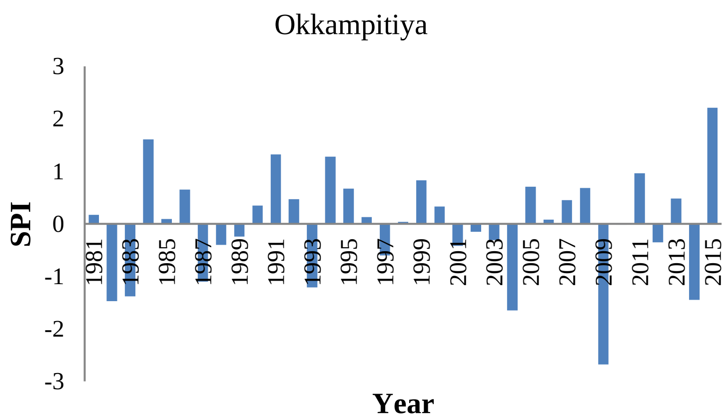
3.3 Temporal Variation in 3-Month SPI

The 3-month SPI compares the precipitation for three consecutive months with the recorded in the same three consecutive months in all previous year. The consecutive three months from December to February were considered as it is the North-East monsoon in Sri Lanka which gives approximately 25% of total rainfall to the country as well as main rainy season in Intermediate Zone (Domroes, 1979).

The 3-month behaviors of SPI from December to February were plotted against the year for each and every location and it is depicted in Figure 4. There is no any significant change in the pattern of 3-month SPI values from December to February Badulla, Monaragala and Okkampitiya locations but there is a significant change in the variation of 3-month SPI from December to February in Wellawaya after 1987.







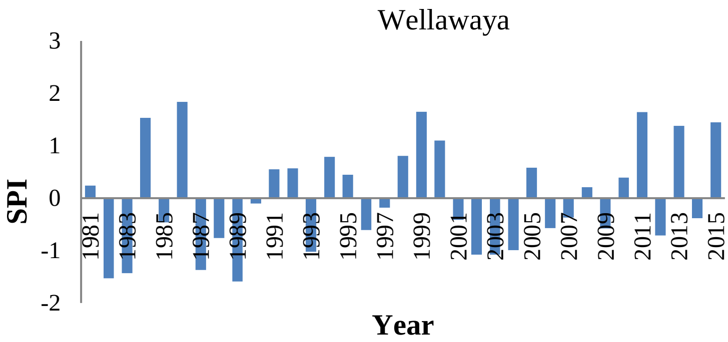


Figure 4: Temporal variation in 3-month SPI from December to February in selected locations

Table 5: Mann-Kendall results for 03- month SPI in selected locations

Location	P-Value	Interpretation
Badulla	0.1032	No trend
Monaragala	0.4532	No trend
Okkampitiya	0.7114	No trend
Wellawaya	0.1868	No trend

4. Conclusion

There is sufficient evidence from the analysis to conclude that SPI is a versatile tool for understanding the variation in rainfall and drought which is important in agriculture sector. The SPI values for different time scales can be used in identifying any deviation from the general behavior. The 12-month SPI from January to December which gives an idea about annual rainfall pattern, indicates less risk of increasing the conditions of droughts in Badulla, Monaragala, Okkampitiya and Wellawaya. There is a significant increasing trend in annual SPI time series in Wellawaya.

The 6-month SPI values for the period of October to March in Monaragala, Badulla and Okkampitiya indicate high risk of having the conditions of drought while Wellawaya indicates low risk of having the conditions of drought for the same period. No any significant changes were recorded from 6-month SPI for the period of April to September and 3-month SPI for the period of December to February for all four locations. With these evidences it can be concluded that there is a change in rainfall anomalies for the period of 1980- 2015 in Uva province.

5. References

Chithranayana, R. and Punyawardena, B., (2008). Identification of drought prone agro-ecological regions in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, 36(2), pp.117–123. DOI: http://doi.org/10.4038/jnsfsr.v36i2.143

Domroes, M., (1979). Monsoon and land use in Sri Lanka, *Geographical Journal 1979*, London 3(2).pp. 179-192.

Efron, Bradley and Tibshirani, Robert(1993), An introduction to the Bootstrap, Chapman & Hall, New York 1993.

Jeewanthi, P.W., Wijesuriya, W. and Sankalpa, J.K.S. (2016), Changes Observed in Rainfall Patterns in Three Major Rubber Growing Areas. *Proceedings of Annual Research Colloquium on Agrarian Studies in Sri Lanka*, pp.25.

McKee, T.B., Doesken, N.J. and Kleist, J,(1993). The relationship of drought frequency and duration to time scale. *Proc. Eighth Conference on Applied Climatology*, Anaheim,California, Boston American Meteorological Society,. pp.179-184.

McKee, T.B. , Doesken, N.J. and Kleist, J. (1995). Drought monitoring with multiple time scales. *Proc. Ninth Conference on Applied Climatology*, Dallas, Texas, Boston American Meteorological Society. pp.233-236.

Taylor WA (2000), Change –point Analysis: A Powerful New Tool for Detecting Changes. Web:http://www.variation.com/cpa/tech/changepoint.html on October 2019.

Wijesuriya, W., Sankalpa, J.K.S., Jeewanthi, P.W., Karunaratne, S.B. and Herath, H.M.L.K (2014), Identifying Spatial and Temporal Behaviour of Droughts Using the Standardized Precipitation Index (SPI). *Proceedings of the International Statistics Conference*, pp.102.

Wijesuriya, W., Sankalpa, J.K.S., Karunaratne, S.B., Dissanayake, D.M.A.P., Jeewanthi, P.W., Abeywardene, O.V. (2014), Identifying Rainfall and Drought Dynamics Using Standardized Precipitation Index (SPI): An Application in Non-traditional Rubber Growing Areas in Eastern, North Central and Northern Provinces of Sri Lanka. *Proceedings of the 5th symposium on crop research*, pp. 275-285

Wickramanayake, L., Weerasekera, M. and Ranasinghe,S. (2012), Seasonal and Temporal Rainfall Variability in the Intermediate Zone of Sri Lanka during 1941-1970 and 1971-2000. *Annual Research Symposium 2012 Converging Technologies & Sustainable Communities, pp.*52

WMO, Standardized Precipitation Index User Guide. *World Meteorological Organization*, Geneva, Switzerland, 2012.