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Analysis of Rainfall Trends in Three Selected Rain Gauging Stations from WL3, IL1a, and DL1f Agroecological Regions in Srilanka

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Abstract

Rainfall is the primary resource for freshwater. Changes in the rainfall trend pattern influence the economic development of the country by tremendously affecting different economic sectors due to the absence or shifting of rainfall at particular periods of the year. This research aims to find the monthly, seasonal, and annual trend in the precipitation pattern and the relationship between the precipitation and time in Keragala, Bingiriya, and Mahawilachchiya in Sri Lanka in the Agroecological Region WL3, IL1a, DL1f, respectively. Daily Rainfall data were collected from 1961 to 2005 from the selected rainfall gauging stations. The Mann-Kendall test and the Augmented Dickey-Fuller test indicate the stationarity of rainfall. Keragala and Bingiriya show the annually insignificant increasing trend and Mahawilachchiya shows the annually insignificant decreasing rainfall trend. Different seasons show different trends in different agroecological regions. These changes show that climate change has influenced the rainfall trends and hence some impacts are faced by the agriculture and aquaculture sector in the country due to these trend changes, even though those are statistically insignificant. Climate change has taken up an inordinate primary place in the water management system.

Keywords: *Trend analysis; Non-parametric test; Mann-Kendall trend; Sen's slope; Augmented Dickey-Fuller Test; Rainfall pattern*

1. Introduction

The amount of precipitation is a very important factor for those living all over the world. Knowledge of trends in precipitation and environmental changes is important to those who are interested in precipitation, its variation, and patterns related field (Wickramagamage, 2016; Aanderud et al., 2010). Precipitation trends play the primary role in precipitation analysis. While planning agricultural activities, rainfall frequency and the amount of water available through rainfall are considered very important factors (Ekanayake and Perera, 2014; Radaideh et al., 2009). Therefore, water is a critical concern for the farmers and timely rainfall is a major concern in land preparation water management (Lee et al., 2005). Extreme events based on rainfall also play a very important role in agriculture. Extreme floods and droughts affect the agriculture sector badly (Panda and Sahu, 2019). A trend is defined as a sequence of changes over time that are influenced by numerous variables in the series. In terms of variation in rainfall across time, rainfall time series can be defined as stationary or non-stationary. The time series is termed stationary if the averages and variances of rainfall do not vary significantly over the period (Nashwan et al., 2019). The time series has inconsistent patterns in the means or variances of rainfall over time defines as nonstationary (Nashwan et al., 2019).

Researchers are using many different data analysis techniques to find the trends in rainfall and forecast rainfall amounts but this task is very difficult (Burt and Weerasinghe, 2014). Precipitation varies according to months and seasons in every agroecological region. Nowadays, traditional rainfall patterns have changed due to many environmental factors and social factors (Pani et al., 2016). Recent past precipitation records help to find the trend and any relationship that prevail between the months and amounts of precipitation (Jayawardene et al., 2005). Finding the trend helps in water management (Manawadu and Fernando, 2008; Adler et al., 2017). There are two types of trend analysis which are, temporal and spatial. Temporal trend analysis is a technique for modeling and analyzing data over time (Şen, 2017a; Şen, 2017b).

As the Sri Lankan economy is dependent on agricultural products and hydropower, a conducive climate is mostly expected. The analysis of long-term changes in precipitation fluctuations is a fundamental task in studies on climate change detection (Karunathilaka et al., 2017). The understanding of past and recent precipitation trends has obtained significant interest through upgrades and extensions of many datasets and more advanced data analyses (Panda and Sahu, 2019). Further, anthropogenic activities have led to a decrease in the availability of freshwater sources (Al-Shibli et al., 2017; Obeidat and Awawdeh, 2021) . Therefore, maintaining and planning water resources has become crucial. Predicting the fluctuations in spatial and temporal variabilities in rainfall is essential to formulate effective management strategies in the management of water resources (Kaba et al., 2020).

Sri Lanka has been divided into three zones according

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to annual rainfall received, that are Wet Zone (annual precipitation > 2500 mm), Intermediate Zone (annual precipitation between 2500 mm and 1750 mm), and Dry Zone (annual precipitation <1750 mm) (Burt and Weerasinghe, 2014). The precipitation patterns in the three climatic zones have changed differently and the differences of these zones need to be investigated. Identification of changes in historical rainfall trends is important in climate change investigation (Pani et al., 2016). The most important physical parameter in climate change is rainfall variation (Manawadu and Fernando, 2008; Panda and Sahu, 2019). The analysis of long-term changes in rainfall is a fundamental task in studies on climate change detection. Rainfall trend investigations exhibit increasing or decreasing trends in Sri Lanka and which is most relevant to agriculture (Nisansala et al., 2020).

In addition, freshwater availability and changes in rainfall patterns affect biodiversity (Dinpashoh et al., 2011). On random certain days, extreme rainfall can be received due to sudden natural phenomena and extreme drought can also occur but the extreme drought is an accumulation of several natural phenomena for a longer term. The occurrence of drought has become more frequent in recent years (Wickramagamage, 2016). These are unavoidable circumstances in natural phenomena (Ahmad et al., 2015; Karunathilaka et al., 2017).

Jayawardene et al. (2005) analyzed 100 years of rainfall records from 15 rainfall stations in Sri Lanka to examine the annual trend of rainfall. The data set was divided into two categories which were short-term and long-term. They used a Mann-Kandall trend test, the Spearman rank statistic, and the regression slope methods in their analysis. However, during the previous century, no consistent growth or decline in trends was recorded for the stations in the wet and dry zones. Alahacoon and Edirisinghe (2021) analyzed the spatial variability of rainfall trends in Sri Lanka from 1989 to 2019. The Mann–Kendall test and Sen's slope estimators were used to study the trends in annual and seasonal rainfall across all the districts and climatic zones of Sri Lanka. The wet zone has the highest increasing trend, while the semi-arid zone has the lowest increasing trend. However, the results of The Mann–Kendall trend test show that there is an increase in rainfall in all the districts in Sri Lanka during the South West Monsoon. Nisansala et al., (2020) examined trend analysis of rainfall over Sri Lanka from 1987 to 2017 using Innovative Trend Analysis (ITA) and Mann Kendall test (MK) with Sen's slope estimator. The result shows that the eastern, south-eastern, north, and north-central regions of the country showed increasing rainfall trends while the western, part of the northwestern, and central parts of the country indicated a decreasing rainfall trend.

Wickramagamage (2016) analyzed daily rainfall records from 1981 to 2010 to identify the spatial pattern of rainfall trends using linear regression. This study illustrates that the rainfall trends of the Southwest Monsoon season are largely positive across the country. The Northeast and the Central Highlands had the most significant negative trends. The Inter-Monsoon (IM) periods have mostly positive tendencies practically everywhere, but there are still some negative trends in the highlands and Northeast region. Sayd et al. (2020) illustrated the rainfall trend in Nigeria using Pearson's Product Moment Correlation using 27 years of rainfall data. They showed a decreasing trend in the annual mean rainfall in the Kilange catchment in Nigeria. Salahat et al. (2015) analyzed the rainfall fluctuations in Jordan using Monthly rainfall data for the period from 1961 to 2012 using 22 weather stations covering the whole country. Salahat et al. (2015) analyzed ten years of moving average aridity trends and tested using the Tukey test, Mann-Kendall rank, and simple linear regression. According to the historical trend analysis, the overall rainfall trend is significantly decreasing in Jordan.

Literature gives information about the rainfall trend in Sri Lanka, but those studies did not talk about the monthly, seasonal, and annual rainfall trends in selected agro-ecological regions WL3, IL1a, and DL1f in Sri Lanka. Moreover, in addition to the Mann-Kendall trend test, this study attempted to analyze the stationarity of rainfall trends using the Augmented Dickey-Fuller test. The aim of this study focuses on extracting the trends, magnitudes of trends, and the stationarity of the rainfall data based on the monthly and seasonal pattern of rainfall on a set of selected weather stations by utilizing selected statistical techniques, where three selected rain gauging stations from three climatic zones which are, Bingiriya from Intermediate zone, Keragala from the wet zone and Mahawilachchiya from the dry zone were used.

2. Materials and methods

2.1 Study Sites and precipitation data collection

Daily precipitation records at Bingiriya, Keragala, and Mahawilachchiya rainfall stations in Low Country Intermediate Zone (IL), Low Country Wet Zone (WL), and Low Country Dry Zone (DL), respectively were collected for the period from 1961 to 2005 from the Department of Meteorology, Colombo. To understand the trend and the pattern of precipitation, daily precipitation records for 45 years (from 1961 to 2005) because of the availability of data were used in this study from randomly selected three rain gauging stations from three main climate zone in Sri Lanka which are, Bingiriya (7.62N, 79.95E) is located in IL1a Agro-Ecological Regions (AER) in Kurnuegala district. Keragala (6.80N, 80.36E) is located in WL3 AER in Rathnapura district, and Mahawilachchiya lies (8.48N, 80.18E) in DL1f AER in Anuradhapura district. Figure 01 illustrates the places on the Sri Lanka geographical map.

Very few amounts of missing data were supplemented by records from the nearest rain gauge. Missing data were a single day or a few consecutive days' data. The r software tool was used to calculate the Mann-Kendall statistics and the Augmented Dickey-Fuller test for the three AERs. These data were grouped into twelve calendar months and four seasons; North East monsoon (December, January, February), South West monsoon (May, June, July, August, September), First inter monsoon (March, April), Second inter monsoon (October, November).

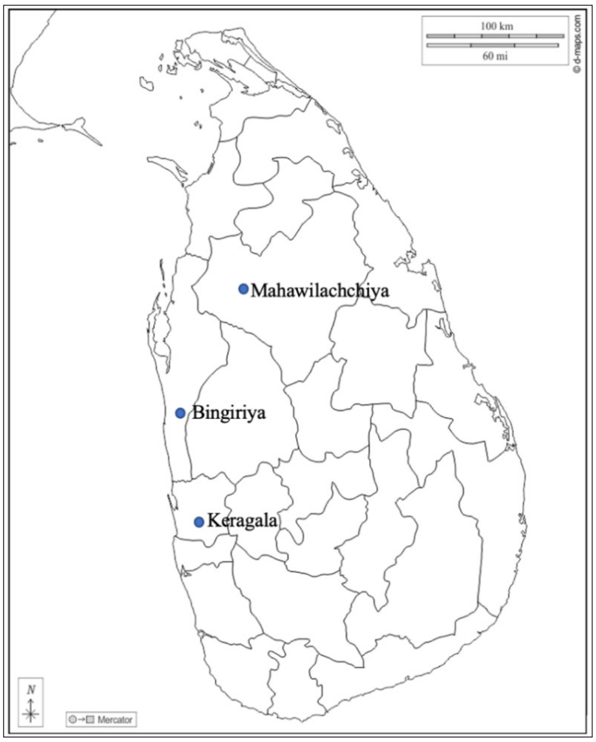

Figure 1. Selected rain gauges in Sri Lanka map

2.2 Mann-Kendall trend test

The Mann-Kendall trend test is the mostly used method to detect the trend in the data series. Parametric tests are more powerful than the non-parametric tests in trend analysis but require the data to be independent and normally distributed, which is rarely obtained for precipitation time series data (Karunathilaka et al., 2017; Prashanth, 2005) Mann-Kendall test is one of the non-parametric tests for diagnostic trends in the time series data. The advantage of this method is that it does not need to conform to the distribution and this test is not affected by the outliers in the data sample (Adler et al., 2017). Mann-Kendall values are calculated by comparing all subsequent data in the time series. Positive values of Mann-Kendall statistics indicate an increasing trend while negative values indicate a decreasing trend in the time series. The Z value indicates whether there are any significant trends in the series (Khambhammettu, 2005).

In this paper, the Mann-Kendall test and Sen's slope estimator methods were used to find the trend and magnitudes of the trends of rainfall distribution in the selected AERs (Khambhammettu, 2005). Mann- Kendall trend test is used to find the monotonic trend in the data series as well as Sen's slope helps to find the magnitude of the trend that appears in the data set.

If the trend in precipitation is monotonically decreasing, then the Z is negative and the computed probability value is greater than the significant level. If the Z value is negative but the computed probability value is not exceeding the significant level then it is a non-monotonically decreasing trend. If the trend is monotonically increasing, then the Z is positive and the computed probability value is greater than the significant level. If the Z value is positive but the computed probability value is not exceeding the significant level then it is a non-monotonically increasing trend.

Let x1, x2, … xn represent n data points where xj represents the data point at time j; n is the number of data points in the dataset, then the Mann-Kendall statistic (S) is given by,

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sign\ (x_j - x_k) \quad \text{.......... (1)}$$

Sign(x_j-x_k) is indicated as,

$$\text{Sign}(x_j\text{-}x_k) = \begin{cases} = 1\ ;\ x_j - x_k > 0 \\ = 0\ ;\ x_j - x_k = 0 \\ = -1\ ;\ x_j - x_k < 0 \end{cases} \quad \text{.......... (2)}$$

The procedure to calculate the Mean of S (E(S)) and Variance of S (Var(S)) is given as,

E(S)=0

$$\text{Var}(S)=\begin{cases} \frac{(n(n-1)(2n+5))}{18} & ;no\ ties \\ \frac{n(n-1)(2n+5)-\sum_{p-1} t_p(t_p-1)(2t_p+5)}{18} & ;tie\ is\ present \end{cases} \quad (3)$$

Where,

p- tied ranks

t_p- number of times that the rank p appears (i.e., frequency)

The standardized statistic (Z) of S for a one-tailed test is given as follows,

$$Z=\begin{cases} \frac{S-1}{[Var(S)]^{\frac{1}{2}}} & ;S>0 \\ 0 & ;\ S=0 \\ \frac{S+1}{[Var(S)]^{\frac{1}{2}}} & ;s<0 \end{cases} \quad \text{.......... (4)}$$

The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1 is,

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{\frac{-z^2}{2}} \quad \text{.......... (5)}$$

If Z is negative and the computed probability is greater than the level of significance, then the trend is said to be monotonically decreasing. If the Z is positive and the computed probability is greater than the level of significance, then the trend is said to be monotonically increasing. If the computed probability is less than the level of significance, there is no trend.

Kendall's tau indicates the statistical relation based on the ranks of the data, further, it ranges between -1 to 1. The positive values of Kendall's tau confirmed an increasing trend on the other hand and the negative values of Kendall's tau confirmed a decreasing trend in the data set (Tarawneh and Chowdhury, 2018).

Sen's slope estimator is used to estimate the magnitude of the trend. In this method, a linear model is assumed.

$$f(t)=Qt+C \quad \text{.......... (6)}$$

Where C is a constant, the slope of all data pairs is calculated as,

$$Q_i = \frac{x_i - x_j}{i-j}\ ;\ i=1,2,3\ldots\ldots\ldots,N \quad \text{.......... (7)}$$

x_i, x_j are the values at times i and j further i>j.

The median of these N values of is Sen's estimator (Q) of the slope, which is calculated as,

$$Q=\begin{cases} Q_{\left(\frac{N+1}{2}\right)}; N \text{ is odd} \\ \frac{1}{2}\left(Q_{\left(\frac{N}{2}\right)}+Q_{\left(\frac{N+1}{2}\right)}\right); N \text{ is even} \end{cases} \quad \text{.......................................} (8)$$

A positive value of Q indicates an upward trend and a negative value indicates a downward trend in the time series.

The hypothesis is,

H_0: There is no trend in the rainfall

H_1: There is a trend in the rainfall

The null–hypothesis is rejected if where is taken from the standard normal distribution table and α is the level of significance. The statistic was calculated as 1.96 at 5% of the significant level using the normal probability distribution table. When > 1.96, the rainfall will have a significantly increasing trend when < -1.96, the rainfall will have a significantly decreasing trend. Sen's Slope is used to find the magnitude of the trend (Karunathilaka et al., 2017). In R software, the Precintcon package was used to perform the Mann-Kendall analysis for the three agroecological regions separately.

2.3 Stationary test

If a series has a constant mean and variance at a level that stationary series besides nonstationary series has changing mean and variance (Nashwan et al., 2019). Augmented Dickey Fuller Test was used to test the stationarity in the rainfall time series data (Dickey and Fuller, 1979). The average monthly rainfall and average seasonal and annual rainfall were used to find the stationarity. The null hypothesis of this test is the time series is not stationary and the test was conducted at 0.05 significance level. Thus, the null hypothesis is rejected when the P value is smaller than the significant level (Nashwan et al., 2019; Dickey and Fuller, 1979).

A stationary error and random walk is expressed as,

$$X_t=r_t+\beta_t+\varepsilon_t \quad \text{.......................................} (9)$$

where,

X_t – Linear regression

r_t – Random walk

β_t – Deterministic trend

ε_t – Stationary error

A Dicky Fuller Regression is considered as,

$$\Delta x_n = \alpha + \beta t + \gamma x_{t-1} + \sum_{j=1}^{p}\left(\delta_t \Delta x_{t-j}\right) + e_t \quad \text{...................} (10)$$

where

Δx- differenced series at a lag of n years,

α - Drift,

β - Represents the coefficient on a time trend

p- Lag order autoregressive process

γ - Process root coefficient

δ_t- lag operator

e_t- Residual term

Residual is an independent identical distribution residual term with mean zero and constant variance σ^2.

3. Results and discussion

Table 1 interprets the results of the Mann-Kendall trend test in the Mahawilachchiya. This result revealed negative trends in February, March, May, July, August, September, October, December, South West monsoon, North East monsoon, Second inter monsoon as well as annual precipitation while the first inter monsoon is showing a positive trend. The Sen's estimator which is to measure the magnitude of rainfall was found as 0.38mm/y, 0.53mm/y, 0.63mm/y, 1.5 mm/y, 1.4 mm/y for South West monsoon, First inter monsoon, North East monsoon, second inter monsoon and annual rainfall, respectively. Highly insignificant increasing and decreasing trends appear in April as 1.05 mm/y, and in December as 1.92 mm/y in Mahawilachchiya. Moreover, the Tau value also indicates that downward trends persist in February, March, May, July, August, September, October, December, South West monsoon, North East monsoon, Second inter monsoon as well as annual precipitation, and also upward trends persist in January, April, June, November and First inter monsoon. Liyanaarachchi et al. (2017) attempted to identify trends of seasonal rainfall anomalies with the aid of SPI values calculated for different time scales and they suggested that Dry zone AER DL1f shows a significant increasing trend in the First inter monsoon rainfall anomalies. They also showed that the Second inter monsoon rainfall anomalies show a significantly increasing trend. Jayawardene et al. (2005) exhibited non-significant trends in rainfall by Mann-Kendall and Spearmann's test to the higher inter-annual variability of rainfall at this location. Karunathilaka et al. (2017) suggested that a significantly increasing trend was detected in the first inter-monsoon and annual rainfall, a non-significant decreasing trend in South West monsoon, a non-significant increasing trend in the second inter-monsoon and North East monsoon by Mann Kendall trend test.

Table 1. Result of Mann-Kendall analysis at Mahawilachchiya

Month and Season	Z-Value	Sen's slope	S	P-value	Tau
January	1.2658	0.2333	126	0.2056	0.1273
February	-0.0986	-0.0221	-11	0.9215	-0.0111
March	-1.5365	-0.5829	-158	0.1244	-0.1596
April	1.1054	1.0515	114	0.269	0.1152
May	-0.1859	-0.1274	-20	0.8526	-0.0202
June	1.2658	0.0121	126	0.2056	0.1273
July	-0.4063	-0.0133	-42	0.6845	-0.0424
August	-1.6315	-0.0111	-160	0.1028	-0.1616
September	-0.0392	-0.2910	-5	0.9688	-0.0051
October	-0.4402	-0.5375	-46	0.6598	-0.0465
November	0.0098	0.075	2	0.9922	0.002
December	-1.575	-1.9253	-162	0.1153	-0.1636
First inter monsoon	0.4011	0.5332	42	0.6884	0.0424
South West monsoon	-0.3815	-0.3812	-40	0.7028	-0.0404
Second inter monsoon	-0.7728	-1.465	-80	0.4396	-0.0808
North-East monsoon	-0.2837	-0.6291	-30	0.7767	-0.0303
Annual	-0.4989	-1.4117	-52	0.6179	-0.0525

Table 2 illustrates the results of the Mann-Kendall test at Keragala station. April, August, the First inter monsoon, and South West monsoon have a decreasing trend in rainfall. Kendall's Tau indicated increasing trends in January, February, March, May, June, July, September, October, November, Second inter monsoon, North East monsoon, and the Annual precipitation. November has a high amount of increasing trend at 2.93 mm/y whereas August has a high amount of decreasing at 1.31mm/yr. Although Jayawardene et al. (2005) used the Mann-Kendall test and Spearman's test to find the rainfall trend, they suggested that the annual trend exhibits a non-significant downward trend. Karunathilaka et al. (2017) suggested that a non-significant increasing trend was detected in the first inter-monsoon, second inter-monsoon, North East monsoon, and annually, and a non-significant decreasing trend in South West monsoon by Mann Kendall trend test.

Table 2. Result of Mann-Kendall analysis at Keragala

Month and Season	Z-Value	Sen's slope	S	P-value	Tau
January	0.8706	1.8768	90	0.384	0.0909
February	0.8414	0.9805	87	0.4001	0.0879
March	0.6163	0.9163	64	0.5377	0.0646
April	-0.4402	-1.0261	-46	0.6598	-0.0465
May	0.5967	1.6525	62	0.5507	0.0626
June	0.8706	1.8768	90	0.384	0.0909
July	0.2641	0.5453	28	0.7917	0.0283
August	-0.5185	-1.313	-54	0.6041	-0.0545
September	0.4011	1.6212	42	0.6884	0.0424
October	0.7337	1.6029	76	0.4631	0.0768
November	1.7315	2.9316	178	0.0834	0.1798
December	0.4793	0.7912	50	0.6317	0.0505
First inter monsoon	-0.675	-2.251	-70	0.4997	-0.0707
South West monsoon	-0.4402	-2.9225	-46	0.6598	-0.0465
Second inter monsoon	1.3793	4.5845	142	0.1678	0.1434
North-East monsoon	1.1054	2.3807	114	0.269	0.1152
Annual	0.7728	4.6564	80	0.4396	0.0808

Table 3 is showing the results of the Mann-Kendall test at Bingiriya. Table 3 indicated that February, March, May, July, August, September, and December, first inter-monsoon, North East and South West monsoon seasons show decreasing trends in precipitation. January, April, June, October, and November, the Second inter-monsoon as well as Annual precipitation show an increasing trend. November shows a highly increasing trend of 3.65 mm/y while May has a highly decreasing magnitude trend of 0.78 mm/y. The annual magnitude of the trend is 2.65 mm/y. Furthermore, Tau values also exhibit downward trends in February, March, May, July, August, September, and December, first inter-monsoon, North East and South West monsoon seasons and upward trends in January, April, June, October, November, Second inter-monsoon and annually. Udayanga and Najim (2014) also suggested a significant decrease in the dry events while a significant increase in wet events at Bingiriya, annually. However, Liyanaarachchi et al. (2017) attempted to identify any trends of seasonal rainfall anomalies with the aid of SPI values calculated for different time scales and they suggested that the Intermediate Zone IL1a showed a significant increasing trend in the Second inter-monsoon and North East monsoon rainfall anomalies.

Table 3. Results of Mann-Kendall analysis at Bingiriya

Month and Season	Z-Value	Sen's slope	S	P-value	Tau
January	0.2446	0.1608	26	0.8068	0.0263
February	-0.8529	-0.3238	-88	0.3937	-0.0889
March	-0.8022	-0.6353	-83	0.4224	-0.0838
April	0.1467	0.1488	16	0.8833	0.0162
May	-0.5576	-0.7896	-58	0.5771	-0.0586
June	0.2446	0.1608	26	0.8068	0.0263
July	-0.8119	-0.4115	-84	0.4168	-0.0848
August	-0.0294	-0.0057	-4	0.9766	-0.004
September	-0.0489	-0.0364	-6	0.961	-0.0061
October	0.7337	1.6253	76	0.4631	0.0768
November	1.937	3.6518	199	0.0527	0.201
December	-1.1054	-0.7338	-114	0.269	-0.1152
First inter monsoon	-0.1076	-0.2521	-12	0.9143	-0.0121
South West monsoon	-0.988	-1.9572	-102	0.3231	-0.103
Second inter monsoon	1.7902	6.1646	184	0.0734	0.1859
North-East monsoon	-0.675	-0.7966	-70	0.4997	-0.0707
Annual	0.5772	2.65	60	0.5638	0.0606

When the trends among the three AERs are compared for the four seasons and annual precipitation, Mahawilachchiya has shown an increasing trend while Keragala and Bingiriya have shown decreasing trends in the First inter monsoon. South West monsoon period shows a decreasing trend in all three stations. Mahawilachchiya has shown a decreasing trend whereas Keragala and Bingiriya have shown an increasing trend in the Second inter monsoon. Keragala has shown an increasing trend in the North East monsoon. Mahawilachchiya only shows a decreasing trend whereas Keragala and Bingiriya show increasing trends in annual rainfall. The increasing trends are higher than the decreasing trends, in all three stations. Further, annual rainfall trend analysis for the Mahawilachchiya is interesting to appraise water scarcity in future climate scenarios. The dry area would be drier in the future. At the same time, In Bingiriya and Keragala, the annual rainfall trend shows that it can be justified that water availability in the catchment was not affected over the 45 years and will not have a lack of water availability future. Furthermore, the wet zone and the intermediate zone would be wetter in the future.

According to Figure 2, the bimodal rainfall pattern due to both the monsoons is apparent at the three stations. Monthly precipitation at Keragala station has two peak points and the wet months are April, May, June, September, and October. The dry months are January and February. March is the transition month from the dry season to the wet season and December is the transition month from the wet season to the dry season. January has the lowest and May has the highest monthly mean rainfall. In Mahawilachchiya, the dry months are January, February, March, June, July, and August. April, October, November, and December are the wet months. March and September are the transition months from the dry season to the wet season and May and January are the transition months from the wet season to the dry season. June has the lowest and November has the highest monthly average rainfall. Monthly analysis of Bingiriya rainfall shows that October, November, April, and May are the wet season months, while the dry season months are January, February, July, and August. September is the transition month from the dry season to the wet season and December is the transition month from the wet season to the dry season. Monthly analysis of Bingiriya and Mahawilachchiya stations show a prominent bi-model pattern in April, May, and October, and November having peak precipitation.

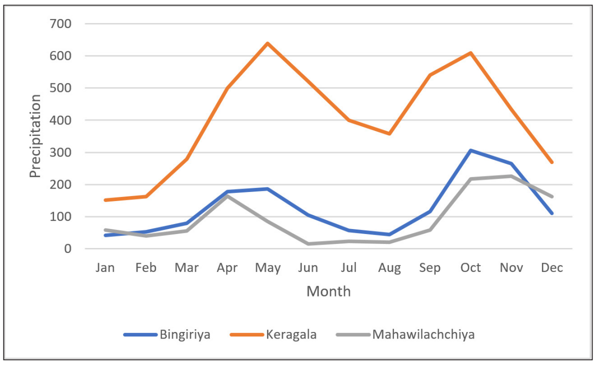

Figure 2. Monthly spatial rainfall at the three rain gauging stations

The results for the Augmented Dickey-Fuller test for monthly, seasonal, and annual average rainfall of selected rain gauges are shown in Table 4. In the Mahawilachchiya, January, March, May, June, July, and the First inter-monsoon were noted as stationary besides, other months and seasons were noted as non-stationary in rainfall pattern. August and September months have shown the highest changing rate of nonstationary monthly rainfall, P-values for August and September were higher than other months. Therefore, South West monsoon also appeared the highest rate of nonstationary.

Table 4. P –Values of Augmented Dickey Fuller Test at each station

Month and Season	P –Values		
	Mahawilachchiya	Keragala	Bingiriya
January	0.01	0.04944	0.05371
February	0.1363	0.01784	0.02872
March	0.04977	0.715	0.491
April	0.3035	0.9782	0.01047
May	0.01	0.06753	0.07357
June	0.01	0.3678	0.04739
July	0.01	0.01	0.01575
August	0.439	0.1554	0.02754
September	0.495	0.04733	0.07081
October	0.2466	0.2243	0.09831
November	0.1717	0.5491	0.07717
December	0.189	0.3653	0.14
North-East Monsoon	0.1314	0.99	0.03873
First inter Monsoon	0.03374	0.267	0.02984
South West Monsoon	0.2854	0.3747	0.08439
Second inter Monsoon	0.06782	0.1062	0.1066
Annual	0.08051	0.3903	0.2372

According to the results shown in Table 4, in Keragala station, January, February, July, and September months were shown a stationary rainfall pattern, on the other hand, other moths were shown a nonstationary rainfall pattern. March and April were shown the highest rate of nonstationary monthly average rainfall, with P-values noted as extremely large. Therefore, the First inter monsoon was also noted as having the highest rate of nonstationary.

In the Bingiriya station, February, April, June, July, and August were noted as stationary as well as other months and seasons show nonstationary in the average rainfall pattern. None of the months and seasons were shown the highest rate of nonstationary monthly average rainfall. When the three stations are compared, July was shown as stationary in monthly average rainfall and all the seasons and annual rainfall are not stationary.

4. Conclusion

On an annual and seasonal scale, statistically insignificant increasing and decreasing trends in rainfall are found in the three rain gauging stations that were studied. The rainfall patterns in the three AERs WL3, IL1a, and DL1f have changed differently in each season and annually. These changes show that climate change has influenced the rainfall trends and hence some impacts are faced by the agriculture and aquaculture sector in the country due to these trend changes, even though those are statistically insignificant. In the examined rain gauges, no significant increase or decrease in rainfall was found.

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