ANALYSIS OF RAINFALL DISTRIBUTION IN KURUNEGALA DISTRICT, SRI LANKA

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ABSTRACT

Investigating the dynamics of rainfall has become very crucial in managing water resources efficiently for sustainable development. The present study aimed to analyze the rainfall distribution in Kurunegala district. Historical rainfall data collected from four gauging stations were subjected to both mathematical and statistical analysis. In addition, trends of rainfall, probability of exceedance and meteorological drought conditions were studied. Rainfall distribution in the district shows high variations. Bathalagoda records the highest mean annual rainfall of 1843 mm. The corresponding values for Wariyapola, Mediyawa and Siyambalagamuwa are 1629 mm, 1315 mm and 1222 mm, respectively. Rainfall is concentrated only in certain months in a year. Annual rainfall exceedance at 50% probability is 1825 mm at Bathalagoda. The corresponding figures for Wariyapola, Mediyawa and Siyambalagamuwa are 1662 mm, 1284 mm and 1226 mm, respectively. Mediyawa, Wariyapola, and Siyambalagamuwa show a decreasing trend in annual rainfall while Bathalagoda shows an increasing trend. Southwest monsoonal (SWM) and 2nd inter-monsoonal (IM2) rainfalls show a decreasing trend at all gauging stations. Mediyawa and Bathalagoda show a positive trend in both 1st inter-monsoonal (IM1) and Northeast monsoonal (NEM) rainfalls. A negative trend in *Maha* seasonal rainfall is observed in all regions except Bathalagoda. A positive trend of *Yala* seasonal rainfall is observed at Mediyawewa and Bathalogoda. Further, severe drought conditions were experienced in the recent years at Wariyapola, Mediyawa, and Siyambalagamuwa. Compared to other regions, rainfall at Mediyawa and Siyambalagamuwa highly deviates from the long-term mean. In the study area, rainfall distribution shows a cyclic pattern over time. However, the amount of rainfall received in the recent years is lower than the amount received in the immediate past decade at all stations except Bathalagoda. Hence, proper management decisions based on rainfall distribution patterns is vital for the efficient management of water resources while guaranteeing sustainable agricultural production in this district.

Keywords: Dynamics of rainfall, rainfall distribution, climate change, meteorological drought, water resource management

1. INTRODUCTION

Agriculture has always been the backbone of Sri Lanka's rural population and paddy cultivation is the most common type of agriculture practiced by about 1.8 million farming families across the island. However, climate change has significant impacts on agriculture [1], [2]. In the field of climate sciences, rainfall and temperature are the important variables which have great influence on crop production. Alteration in the seasonal distribution and amount of rainfall, and increased evapotranspiration and reduced soil moisture are the key changes in the hydrological system induced by climate change [3]. Availability of water for agriculture is dependent on effective rainfall as well as the availability of surface and groundwater resources, which depend in turn on the amount and distribution (spatial and temporal) of rainfall [4]. The erratic distribution of rainfall due to climate change greatly affects the agriculture sector, especially in developing countries as it directly depends on rainfall. Adverse impact of climate change will be felt most acutely by the smallholder farmers particularly in developing countries. The main reason is that they are largely dependent on natural systems for growing crops [5].

Quantifying hydrological responses to climate change has become extremely important for proper water resources management [6]. Detailed analysis of long-term rainfall in the context of a changing climate are required to assess climate-induced changes on water resources and extreme weather conditions. Further, investigating the spatio-temporal trend of meteorological variables has become very crucial to assess the changes in natural systems and to suggest feasible adaptation strategies and agricultural practices [7].

Kurunegala is one of the major agricultural districts in Sri Lanka with a wide range of crop cultivation. In the recent decades, erratic and uneven rainfall distribution has resulted in low crop yields, crop failures, abandonment of cultivation seasons, etc. In addition, extreme weather phenomena such as floods and droughts are often experienced in the recent years. Hence, spatiotemporal analysis of rainfall as an indicator of climate change is vital for improved water resources planning and to propose feasible adaptation strategies for sustainable crop production under changing climate. This study is therefore aimed to analyze rainfall distribution in Kurunagela district using long-term daily rainfall data.

2. MATERIAL AND METHODS

Study area

Kurunegala is one of the major agricultural districts located in the North-Western province of Sri Lanka. This district falls partially in the dry zone and partially in the intermediate zone. In the present study, rainfall data from 1961-2017 were collected from Wariyapola, Mediyawa, and Siyambalagamuwa regions. For Bathalagoda, rainfall data from 1976-2017 were used for analysis due to unavailability of past data. Figure 1 shows the location of the study area and data collection points.

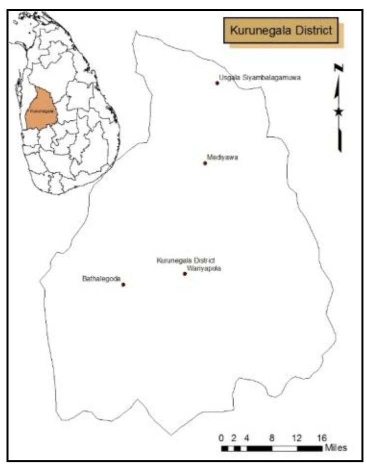

Figure 1. Location of the study area and gauging stations

Preparation and analysis of rainfall data

Historical rainfall data collected from four gauging stations in Kurunegala district were tested for missing values, outliers, homogeneity and normality. Missing values were estimated using the normal ratio method. Homogeneity is an important test to detect the variability of the data. In this study, Pettitt's test [8] and Buishand's test [9] were used to test the homogeneity of the data sets. Table 1 shows the results of two homogeneity tests. According to the results, it could be assumed that the collected data sets are homogeneous.

Table 1: Homogeneity test of rainfall data

Region	Pettitt's test	Buishand's test
Wariyapola	0.093	0.111

Mediyawa	0.388	0.299
Siyambalagamuwa	0.188	0.110
Bathalagoda	0.640	0.709

H0: Data are homogeneous; Ha: There is a date at which there is a change in the data. If the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

In general, climate data sets are normally distributed. However, checking the data sets for its normality is important before analysis. Table 2 presents the results of two normality tests. Since the p-values are greater than α value of 0.05, it could be assumed that the data sets are normally distributed.

Table 2: Normality test of rainfall data

Region	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Wariyapola	.076	43	.200*	.980	43	.642
Mediyawa	.097	43	.200*	.964	43	.201
Siyambalagamuwa	.091	43	.200*	.989	43	.945
Bathalagoda	.087	43	.200*	.972	43	.375

*a. Lilliefors Significance Correction; *. This is a lower bound of the true significance.*

Analysis of time series rainfall data

Long-term rainfall data were analyzed using mathematical and statistical methods. Arithmetic mean, minimum, maximum and standard deviation (SD) were analyzed using XLSTAT software.

Analysis of rainfall distribution

PCI (Precipitation Concentration Index) of Oliver [10], further developed by [11] has equally been expressed as an indicator of rainfall concentration for annual and seasonal scales (wet and dry seasons). In this study, rainfall distribution in different regions in the study area was analyzed based on PCI values, estimated using the below equation.

$$PCI_{anual} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{12} P_i)^2} \times 100$$

P_i - rainfall of the i^{th} month

PCI value less than 10 indicates a uniform distribution of monthly rainfall whereas the higher values indicate that the rainfall is concentrated in a certain month/s in a year.

Estimation of rainfall depth (Xp) expected for a specific probability

In this study, data sets were tested for goodness of fit. Based on the coefficient of determination (R^2) of the fitted line and statistical tests, some data sets were transformed for accurate estimation of the probability of extreme rainfalls using the Weibull method.

Analysis of the coherent trend of annual and seasonal rainfalls

Trend analysis generates valuable information regarding the trend of a series of observations. It helps to measure the deviation from the trend and also provides information pertaining to the nature of trend [12]. The direction of the trend of annual, monthly and seasonal rainfalls was assessed using the non-parametric Mann–Kendall test. The magnitude of the trend was estimated using Sen's method.

Analysis of meteorological droughts

Drought indices are commonly used for the detection, monitoring, and evaluation of drought events. In this study, meteorological drought was analyzed based on the Standardized Precipitation Index (SPI) using Meteorological Drought Monitoring (MDM) software.

Analysis of recent changes in rainfall distribution

Recent changes in rainfall distribution were analyzed based on rainfall departure from the base period average. Historical rainfall data sets were grouped into four; 1991-2000, 2001-2010, and 2011-2017 for comparison.

3. RESULTS AND DISCUSSION

Descriptive analysis of rainfall data

Bathalagoda shows the highest long term annual mean rainfall of 1843mm whereas the annual mean rainfall of 1629mm, 1315mm and 1222mm were observed at Wariyapola, Mediyawa and Siyambalagamuwa, respectively (Table 3). According to the statistical analysis, the mean annual rainfall of both Wariyapola and Bathalagoda shows significant variation from the mean annual rainfall of Mediyawa and Siyambalagamuwa at 5% significance level. However, the variation is not significant between Bathalagoda and Wariyapola, and between Mediyawa and Siyambalagamuwa. Proper rainwater harvesting systems particularly in Bathalagoda and Wariyapola can help to reduce the risk of floods and relieve pressure on water supply systems in dry season.

Table 3: Descriptive statistics of annual rainfall data in different regions

Station	Min.	Max.	Mean	SD
Wariyapola	371.9	2401.8	1629.1	331.8
Mediyawa	564.2	2586.7	1315.0	405.1
Siyambalagamuwa	300.9	2078.6	1222.1	322.9
Bathalagoda	1259.9	2634.6	1842.6	319.7

Further, annual rainfall substantially deviates from the long-term mean in all regions (Figure 2). Rainfall recorded in 2017 was far below to the long-term average. It was also noted that rainfall peaks occurred in different years in different regions. It reveals high spatial and temporal variations in rainfall distribution in the study area.

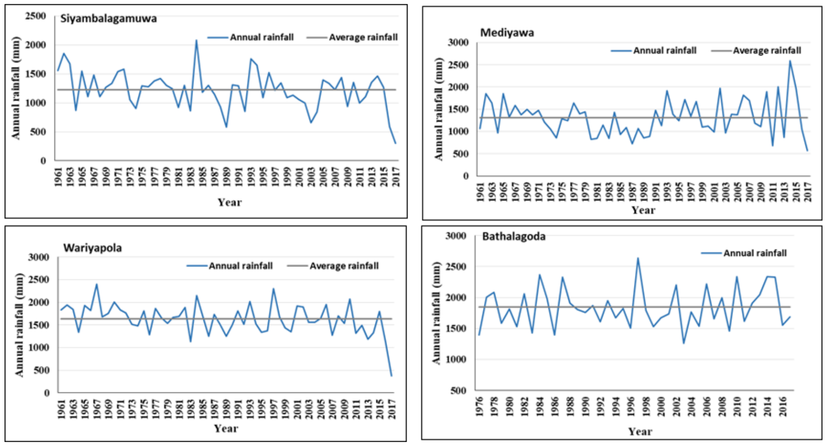

Figure 2. Distribution of annual rainfall in different regions

Rainfall in *Maha* season ranges from 80mm – 1625mm in this district. Bathalagoda shows the highest mean rainfall of 1064mm in *Maha* season. Wariyapola receives the second highest of 941mm. Mediyawa and Siyambalagamuwa receive nearly same amount of rainfall during *Maha* season (Table 4). The amount of rainfall received each year in *Yala* season fluctuates highly, ranging from 107mm – 1311mm. The highest mean rainfall of 774mm was recorded at Bathalagoda in *Yala* season, while the lowest mean rainfall of 391mm was observed at Siyambalagamuwa. Wariyapola shows fairly good rainfall in *Yala* season.

Table 4: Descriptive statistics of seasonal rainfall in different regions

	Maha season				*Yala season*			
Station	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Wariyapola	79.5	1583.9	940.8	251.5	292.4	1136.4	688.3	197.6
Mediyawa	142.8	1619.3	826.6	321.0	106.8	967.4	488.4	164.3
Siyambalagamuwa	100.2	1466.9	831.5	298.7	112.8	788.0	390.5	142.3
Bathalagoda	453.0	1625.3	1063.7	256.3	441.6	1310.8	773.5	196.8

Compared to other regions, Bathalagoda receives higher amount of rainfall during all monsoonal seasons (Table 5).

Table 5: Descriptive statistics of monsoonal rainfalls in different regions

Monsoon	Station	Min.	Max.	Mean	SD
IM1	Wariyapola	32	700	337	139
	Mediyawa	0	614	283	135
	Siyambalagamuwa	20	609	232	125
	Bathalagoda	93	674	346	138
SWM	Wariyapola	67	822	465	145
	Mediyawa	21	722	270	134
	Siyambalagamuwa	9	578	228	118
	Bathalagoda	155	1013	545	176
IM2	Wariyapola	0	1062	568	209
	Mediyawa	0	1081	502	241
	Siyambalagamuwa	0	972	480	204
	Bathalagoda	268	1212	634	220
NEM	Wariyapola	26	791	259	145
	Mediyawa	23	611	260	132
	Siyambalagamuwa	20	694	283	154
	Bathalagoda	81	795	312	166

In this district, SWM and IM2 rainfalls are more effective. However, monsoonal failure is observed during inter-monsoonal periods, particularly during IM2. Hence, cultivation during inter-monsoonal periods is dependent on water supply.

Rainfall distribution based on PCI

In general, rainfall distribution in the study area shows moderate or high concentration. It means rainfall is concentrated in certain months in a year (Table 6). Compared to other regions, nearly 74% of the annual rainfall showed moderate concentration at Bathalagoda, while it was 54% at Wariyapola. Nearly 44% of years at Mediyawa showed high concentration, while about 39% of the years showed high concentration at Siyambalagamuwa. At Siyambalagamuwa, 30% of the years showed very high concentration. The corresponding value for Mediyawa is 18%. According to the analysis, it could be understood that the rainfall distribution in this district is not uniform throughout the year. Hence, there are chances for weather extremes such as floods and droughts in a year.

Table 6: Rainfall distribution based on PCI in different regions

Index	Description	Number of years			
		Wariyapola (1961-2017)	Mediyawa (1961-2017)	Siyambalagamuwa (1961-2017)	Bathalagoda (1976-2017)
<10	Low concentration (almost uniform rainfall)	2	0	0	1
11-15	Moderate concentration	31	22	18	31
16-20	High concentration	21	25	22	9
≥20	Very high concentration	3	10	17	1

Estimation of rainfall depth (Xp) expected for a specific probability

Estimation of rainfall depths for selected probabilities is required for many practical applications including designing hydraulic structures, assessing the risk of failures, project designing, and flood management and forecasting. Bathalagoda shows higher rainfall extremes at all probability levels. For instance, annual rainfall exceedance at 50% probability is 1825 mm (Figure 3). However, the corresponding figures for Wariyapola, Mediyawa and Siyambalagamuwa are 1662 mm, 1284 mm and 1226 mm, respectively. Further, rainfall depth at 80% probability level is 1575 mm at Bathalagoda and it is 1380 mm, 974 mm, 956 mm at Wariyapola, Mediyawa, and Siyambalagamu, respectively.

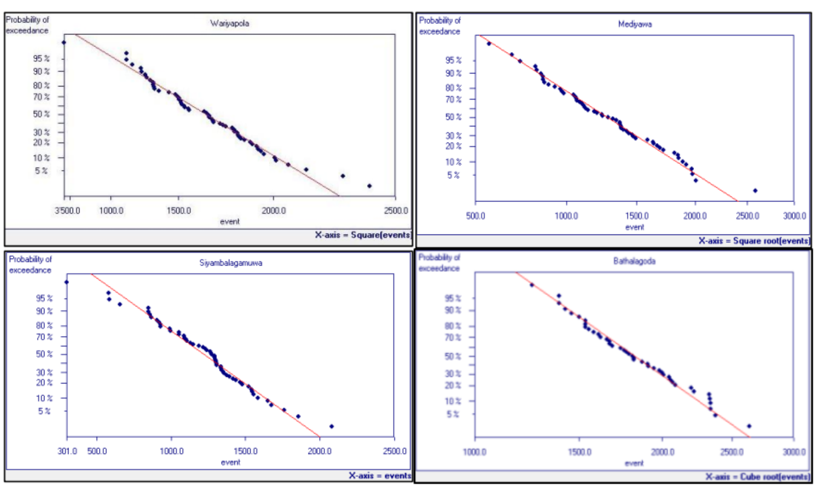

Figure 3: Probability of extreme rainfall depths in different regions

Trend analysis

Trend of annual rainfall

Figure 4 demonstrates the trend of rainfall recorded in different regions in Kurunegala district. Accordingly, annual rainfall in all regions except Bathalagoda shows a decreasing trend.

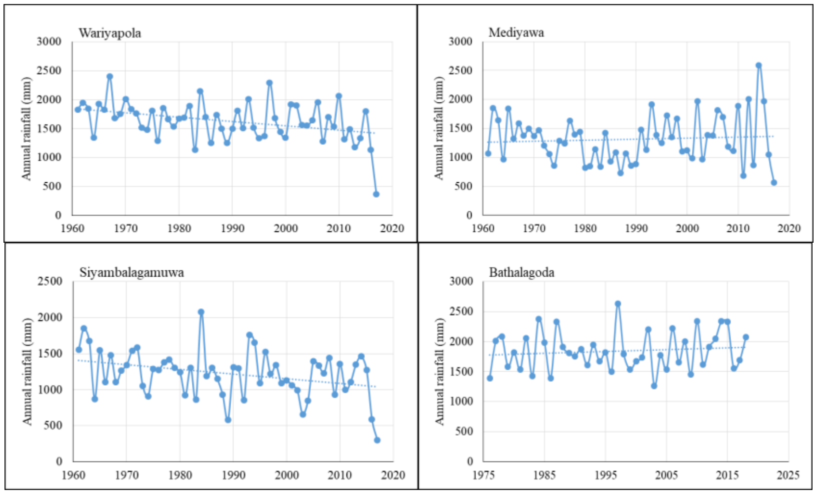

Figure 4: Trend of annual rainfall recorded in different regions in Kurunagela district

However, the trend is significant only at Wariyapoala and Siyambalagamuwa at 95% confidence level (Table 7). Farmers in this district mainly cultivate paddy which requires huge quantity of water compared to other field crops. Crop diversification would be viable options for the regions which show negative trend in annual rainfall.

Table 7: Trend of annual rainfall recorded at different regions in Kurunegala district

Station	Sen's slope	p-value	Sig.
Wariyapola (1961-2017)	-7.352	0.006	*
Mediyawa (1961-2017)	-0.041	1.000	ns
Siyambalagamuwa (1961-2017)	-6.433	0.028	*
Bathalagoda (1976-2017)	2.726	0.532	ns

** Significant at 5% significance level; ns-not significant*

Trend of monthly rainfall

Table 8 shows the trend of monthly rainfall in different regions in the study area. Accordingly, monthly rainfall except January, February, and December shows decreasing trend at Wariyapola. However, an increasing trend was observed in December, but not significant at 95% confidence level. Positive trend of rainfall was observed in January, March, April and November at Mediyawa. However, rainfall in July shows significant decreasing trend. Trend was negative almost in all months and significant in the months of July and December at Siyambalagamuwa. At Bathalagoda, a decreasing trend was observed in June, July, September, October and November. The trend was significant in November. However, the trend was positive in other months but not significant at 95% confidence level. Hence, appropriate crop calendar is required for each region based on the rainfall distribution.

Table 8: Statistical parameters of trend analysis of monthly rainfall

Month	Wariyapola		Mediyawa		Siyambalagamuwa		Bathalagoda	
	Sen's slope	p-value	Sen's slope	p-value	Sen's slope	p-value	Sen's slope	p-value
January	0.000	0.683	0.319	0.392	-0.383	0.378	0.475	0.470
February	0.000	0.739	0.000	0.641	-0.070	0.479	0.768	0.107
March	-0.004	0.995	0.242	0.549	-0.234	0.389	0.200	0.819
April	-0.649	0.453	0.285	0.757	-0.362	0.635	0.857	0.603
May	-1.573	0.082	-0.353	0.577	-0.242	0.591	0.925	0.618
June	-0.451	0.250	-0.029	0.777	0.000	0.396	-0.213	0.739
July	-0.531	0.247	-0.372	0.026	-0.228	0.046	-0.833	0.103
August	-0.126	0.577	0.000	0.617	0.000	0.805	0.500	0.252
September	-0.883	0.123	-0.240	0.224	-0.754	0.084	-0.038	0.983
October	-1.621	0.162	-1.018	0.474	-1.39	0.302	-0.994	0.479
November	-1.110	0.302	0.649	0.470	-1.059	0.409	-4.117	0.009
December	0.139	0.826	-0.311	0.695	-1.747	0.015	2.103	0.082

The trend is significant at p-value less than 0.05 at a 5% significance level.

Trend of seasonal rainfall

A decreasing trend was observed in *Maha* season rainfall in all regions except Bathalagoda. A significant negative trend was observed at Siyambalagamuwa (Table 9). Further, a negative trend in *Yala* season rainfall was observed at both Wariyapola and Siyambalagamuwa whilst Mediyawa and Bathalagoda showed a positive trend.

Table 9: Trend analysis of rainfall data for *Maha* and *Yala* seasons

Station	*Maha season*			*Yala season*		
	Sen's slope	p-value	Sig.	Sen's slope	p-value	Sig.
Wariyapola	-2.807	0.167	ns	-3.160	0.048	*
Mediyawa	-0.555	0.853	ns	0.218	0.896	ns
Siyambalagamuwa	-5.437	0.015	*	-0.991	0.413	ns
Bathalagoda	0.661	0.846	ns	2.317	0.413	ns

Trend is significant at p-value less than 0.05 at 5% significance level.

Table 10 shows the trends of monsoonal rainfalls in different regions in the study area. A positive trend of first inter-monsoon (IM1) was observed at both Mediyawa and Bathalagoda while Wariyapola and Siyambalagamuwa showed a negative trend. All regions show a negative trend of southwest monsoonal (SWM) rainfall and it is significant at Wariyapola and Siyambalagamuwa. Further, the second inter-monsoonal (IM2) rainfall shows a decreasing trend in all regions and the trend is significant at Bathalagoda. Trend of north-east monsoonal (NEM) rainfall is negative at Wariyapola and Siyambalagamuwa. However, Bathalagoda shows a significant positive trend of NEM rainfall.

Table 10: Trend analysis of monsoonal rainfalls in different regions

Region	IM1		SWM		IM2		NEM	
	Sen's slope	p value	Sen's slope	p value	Sen's slope	p value	Sen's slope	p value
Wariyapola	-0.775	0.470	-3.464	0.001	-2.889	0.068	-0.198	0.885
Mediyawa	1.260	0.268	-1.812	0.101	-0.821	0.665	0.352	0.746
Siyambalagamuwa	-0.123	0.907	-2.150	0.032	-2.341	0.173	-2.464	0.027
Bathalagoda	1.561	0.388	-0.594	0.714	-5.973	0.041	6.241	0.001

Trend is significant at p-value less than 0.05 at 5% significance level.

Trend of number of rainy days

In the present study, a day with rainfall more than 2.5 mm is considered as rainy day. Figure 5 shows the trend of rainy days in different regions in Kurunegala district. Number of rainy days show a decreasing trend in all regions except Bathalagoda. Number of rainy days is an indication of frequency of occurrence which has agricultural and hydrological significance.

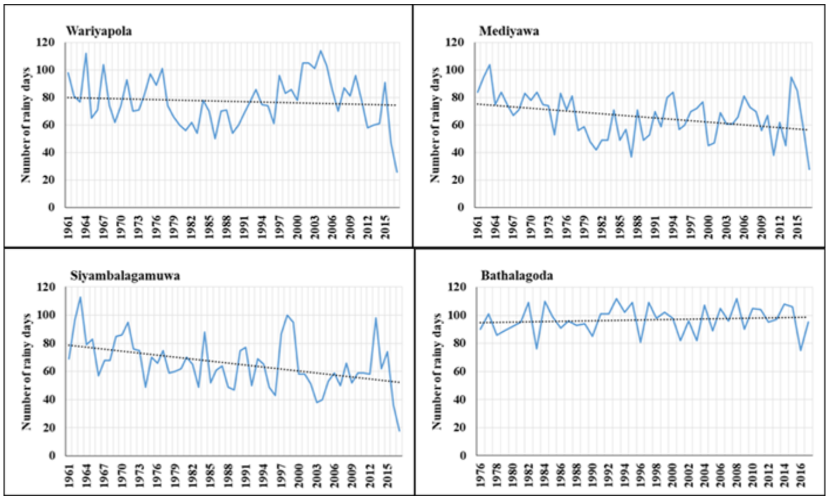

Figure 5. The trend of the number of rainy days in different locations in Kurunegala

Drought analysis based on Standardized Precipitation Index (SPI)

Positive SPI values indicate wet conditions with greater than median precipitation and negative SPI values indicate dry conditions with lower than median precipitation [13]. The severe dry condition was observed in 2017 in all regions except Bathalagoda (Table 11). There were only two very wet events in 1967 and 1997 at Wariyapola. Further, moderate wet events were observed in 1970, 1984, 1993, and 2010. Moderate dry events were observed in 1983, 1986, 1989, 2013, and 2016. Other years were showed a normal observation at Wariyapoala. At Mediyawa, an extreme wet event was observed in 2014 whereas very wet events were observed in 2002 and 2005. Moderate wet conditions were observed in 1962, 1965, 1993, 1996, 2006, and 2010.

The years 1974, 1980, 1981, 1983, 1989, 1990 were moderately dry while 1987 and 2011 were very dry. An extreme wet event was observed in 1984 at Siyambalagamuwa. The years 1962, 1972 were very wet whereas 1963, 1993, and 1994 were moderately wet. Moderately dry events were observed in 1964, 1983, 1992, and 2004. Severe dry events were observed in 1989 and 2003. The years 2016 and 2017 were extremely dry. At Bathalagoda, very wet events were in 1984, 2010, and 2014 while the years 1987, 2006, and 2015 were moderately wet. The moderate dry condition was observed in 1983, 1996, and 2009. The years 1976 and 1986 were severe dry while 2003 was extremely dry. As a whole, the rainfall distribution in the study area is not very uniform, substantially varies from year to year and location to location. The result of this analysis shows frequency of drought or phenomenon related to severity of drought at different regions of Kurunagela district.

Table 11: Annual drought condition based on SPI at different regions in Kurunegala

Year	Wariyapola		Mediyawa		Siyambalagamuwa		Bathalagoda	
	SPI	Condition	SPI	Condition	SPI	Condition	SPI	Condition
1961	0.59	Normal	-0.57	Normal	0.96	Normal	-	-
1962	0.86	Normal	1.29	Moderate wet	1.64	Very wet	-	-
1963	0.62	Normal	0.86	Normal	1.24	Moderate wet	-	-
1964	-0.73	Normal	-0.87	Normal	-1.01	Moderate dry	-	-
1965	0.82	Normal	1.28	Moderate wet	0.94	Normal	-	-
1966	0.57	Normal	0.11	Normal	-0.24	Normal	-	-
1967	1.86	Very wet	0.74	Normal	0.78	Normal	-	-
1968	0.20	Normal	0.25	Normal	-0.25	Normal	-	-
1969	0.39	Normal	0.53	Normal	0.22	Normal	-	-
1970	1.00	Moderate wet	0.24	Normal	0.42	Normal	-	-
1971	0.59	Normal	0.48	Normal	0.92	Normal	-	-
1972	0.43	Normal	-0.18	Normal	1.03	Moderate wet	-	-
1973	-0.22	Normal	-0.58	Normal	-0.4	Normal	-	-
1974	-0.32	Normal	-1.21	Moderate dry	-0.89	Normal	-	-
1975	0.54	Normal	0.02	Normal	0.29	Normal	-	-
1976	-0.89	Normal	-0.08	Normal	0.24	Normal	-1.49	Severe dry
1977	0.66	Normal	0.85	Normal	0.51	Normal	0.58	Normal
1978	0.16	Normal	0.30	Normal	0.63	Normal	0.81	Normal
1979	-0.17	Normal	0.40	Normal	0.31	Normal	-0.8	Normal
1980	0.18	Normal	-1.34	Moderate dry	0.14	Normal	-0.01	Normal
1981	0.24	Normal	-1.26	Moderate dry	-0.83	Normal	-0.97	Normal
1982	0.73	Normal	-0.35	Normal	0.33	Normal	0.73	Normal
1983	-1.39	Moderate dry	-1.26	Moderate dry	-1.05	Moderate dry	-1.36	Moderate dry
1984	1.32	Moderate wet	0.37	Normal	2.11	Extreme wet	1.62	Very wet
1985	0.27	Normal	-0.98	Normal	-0.01	Normal	0.51	Normal
1986	-1.01	Moderate dry	-0.51	Normal	0.33	Normal	-1.49	Severe dry
1987	0.36	Normal	-1.68	Severe dry	-0.11	Normal	1.49	Moderate wet
1988	-0.27	Normal	-0.55	Normal	-0.81	Normal	0.28	Normal
1989	-1.01	Moderate dry	-1.22	Moderate dry	-2.18	Extreme dry	-0.03	Normal
1990	-0.27	Normal	-1.11	Moderate dry	0.34	Normal	-0.2	Normal
1991	0.54	Normal	0.48	Normal	0.29	Normal	0.16	Normal
1992	-0.24	Normal	-0.39	Normal	-1.08	Moderate dry	-0.71	Normal
1993	1.02	Moderate wet	1.42	Moderate wet	1.44	Moderate wet	0.4	Normal
1994	-0.21	Normal	0.27	Normal	1.19	Moderate wet	-0.49	Normal
1995	-0.74	Normal	-0.07	Normal	-0.29	Normal	0	Normal
1996	-0.63	Normal	1.03	Moderate wet	0.88	Normal	-1.08	Moderate dry
1997	1.64	Very wet	0.18	Normal	0.08	Normal	2.3	Extreme wet
1998	0.21	Normal	0.92	Normal	0.42	Normal	-0.1	Normal
1999	-0.44	Normal	-0.46	Normal	-0.29	Normal	-0.97	Normal
2000	-0.72	Normal	-0.41	Normal	-0.17	Normal	-0.48	Normal
2001	0.81	Normal	-0.8	Normal	-0.39	Normal	-0.26	Normal
2002	0.76	Normal	1.53	Very wet	-0.59	Normal	1.14	Moderate wet
2003	-0.1	Normal	-0.85	Normal	-1.85	Severe dry	-2.02	Extreme dry
2004	-0.11	Normal	0.28	Normal	-1.09	Moderate dry	-0.16	Normal
2005	0.13	Normal	0.25	Normal	0.56	Normal	-0.96	Normal
2006	0.88	Normal	1.23	Moderate wet	0.41	Normal	1.19	Moderate wet
2007	-0.93	Normal	0.97	Normal	0.12	Normal	-0.53	Normal
2008	0.26	Normal	-0.23	Normal	0.67	Normal	0.56	Normal
2009	-0.17	Normal	-0.43	Normal	-0.79	Normal	-1.25	Moderate dry
2010	1.14	Moderate wet	1.37	Moderate wet	0.45	Normal	1.53	Very wet
2011	-0.81	Normal	-1.86	Severe dry	-0.58	Normal	-0.67	Normal
2012	-0.3	Normal	1.59	Very wet	-0.25	Normal	0.29	Normal
2013	-1.24	Moderate dry	-1.19	Moderate dry	0.44	Normal	0.70	Normal
2014	-0.76	Normal	2.6	Extreme wet	0.74	Normal	1.52	Very wet
2015	0.51	Normal	1.53	Very wet	0.23	Normal	1.50	Moderate wet
2016	-1.38	Moderate dry	-0.63	Normal	-2.16	Extreme dry	-0.89	Normal
2017	-5.03	Extreme dry	-2.34	Extreme dry	-3.83	Extreme dry	-0.43	Normal

Recent changes in rainfall distribution

The departure of annual rainfall from the average rainfall of the base period was analysed to examine the recent changes in rainfall distribution in the study area. Figure 6 shows a high fluctuation in annual rainfall in all regions. Mediyawa and Siyambalagamuwa show high fluctuations from the long-term average, e.g., in some years deviation was nearly 1000 mm per year. Compared to other regions, Wariyapola and Bathalagoda show a low departure from the base period average.

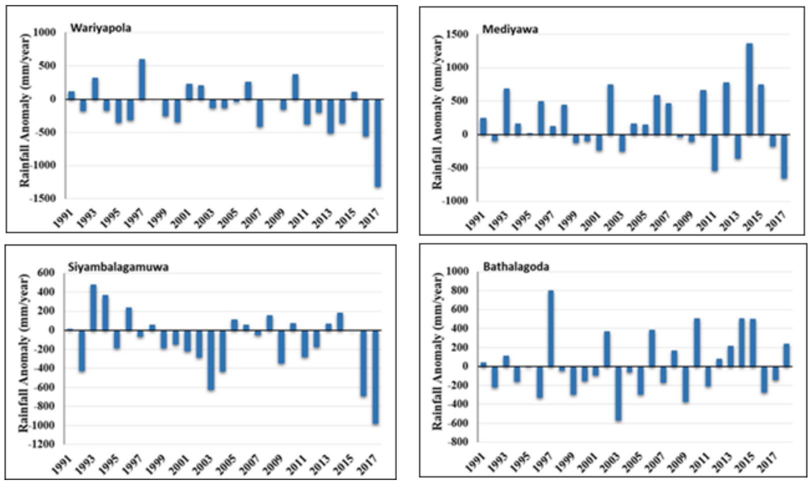

Figure 6. Departure of annual rainfall with respect to base period (1961-1990). Base period for Bathalagoda is from 1976-1990

Coefficient of variation (CV) in annual rainfall highly increased in the recent years in all regions except Bathalagoda. Highest CV of 65.6% observed at Siyambalagamuwa whereas Bathalagoda showed lowest CV of 16.8% during 2011-2017 (Table 12). Variation in rainfall distribution has been increasing at Mediyawa and Siyambalagamuwa since past three decades. Compared to other regions, variation in annual rainfall distribution is low at Bathalagoda.

Table 12: Descriptive statistics of rainfall data analysed for different time periods

Period	Wariyapola			Mediyawa			Siyambalagamuwa			Bathalagoda		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Base period	1689	282	16.7	1224	317	25.9	1280	314	24.5	1825	323	17.7
1991-2000	1633	320	19.6	1411	282	20.0	1294	281	21.7	1805	325	18.0
2001-2010	1713	244	14.3	1439	380	26.4	1124	265	23.6	1818	360	19.8
2011-2017	1232	439	35.6	1388	789	56.8	818	536	65.6	1945	326	16.8

4. CONCLUSION

Rainfall distribution in Kurunegala shows high spatio-temporal variations. Annual, monthly and seasonal rainfalls show positive and negative trends. Extreme events were experienced in many years over the past three decades. However, the amount of rainfall received in recent years is lower than the immediate past decade in all locations, except for Bathalagoda. Hence, proper management decisions based on distribution patterns of rainfall would ensure the efficient management of water resources while guaranteeing sustainable agricultural production in this district.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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