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Rainfall Variability and Drought Occurrences in the Batticaloa District, Sri Lanka

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ABSTRACT

Due to recent climate changes and monsoon variability, the amount, pattern, and intensity of rainfall are significantly changing in many Asian countries. This paper attempts to study the annual and seasonal rainfall patterns and their variability, and the occurrence of droughts. Monthly rainfall data have been collected from the Department of Meteorology, Colombo, from 1871-2020 for Batticaloa station. The Standard Deviation, Coefficient of Variation least-square trend had computed for annual and seasonal rainfall to study the rainfall variability as whole and different epochs. To study the drought scenario Standardized Precipitation Index had computed, and then the drought was categorized based on the SPI criteria, and the drought severity had distinguished. Spatial rainfall distribution maps had prepared using Arc GIS 10.4 software. The Standard Deviation and the Coefficient of annual rainfall variation are 423.9 and 24.8%, respectively. The epochal variability results reveal that the variability of rainfall is higher in 1961-1990 (CV: 28.9%), which indicates the low dependability, while variability is lower in the epochs of 1931-1960 (CV: 17.7%) and 1871-1900 and (19.6%) respectively. The long-term rainfall trend (1871-2020) results reveal the increasing trend and its $r^2 = 0.0271$. However, only the epoch 1961-1990 shows a downward trend with $r^2 = 0.2398$. The rainfall anomaly results reveal the extreme drought had occurred in 1968 and 1889. The severe droughts had occurred in 1998, 1983, 1981, 1980, 1909, and 1890. Out of 150 years of data periods, 25 years had been identified as drought years. The probability of drought occurrence is P = 0.167. Terefore once in five to six years, drought could have occurred.

Keywords: Rainfall Variability, Strandred Deviation, Drought Occurrence, Rainfall Trend

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1. INTRODUCTION

The economy of the Batticaloa district primarily depends on agriculture. The timely available sufficient water determines agriculture. Recent climate change plays a vital role in many economic activities that affect farming, drinking water supply, hydropower generation, and industrial activities. The rainfall is the most crucial factor that determines agricultural production in Sri Lanka.

The pattern of rainfall and its variability and drought is significant for agriculture as well as the economy of the country. The impact of climate variability on agriculture affects agricultural productivity. Precipitation plays a vital role in changing agricultural production [1]. Sri Lanka influence by two monsoons: the South West Monsoon (SWM) and the North-East Monsoon (NEM). In between Inter Monsoon (I.M.) seasons (First Inter Monsoon-FIM & Second Inter Monsoon-SIM) prevails. The southwestern part of Sri Lanka and the western hill slopes receive heavy rainfall during the SWM season. The NEM brings rain to the northern and eastern parts of the country [2].

Climate variability and change are directly influenced by the availability, supply, distribution, use, and conservation of water resources. Therefore, rainfall variability, climate hazard, and disaster-related studies are significant and need to minimize the impacts of agriculture and water resource management. Rainfall variability defines as the deviation of rainfall from the mean or the ratio of standard deviation to the mean or the variability of the coefficient of variation. It is considered an essential factor in agricultural and other economic development [3]. Various scholars have carried out numerous studies on rainfall variability and trend in climate change in South Asia and Sri Lanka. However, the region-based studies, particularly on drought, are very fewer in Sri Lanka. Precipitation is the most important climatic variable in climate science that has to pave more attention worldwide due to recent climate change and variability. Studies worldwide show that rainfall variability is increasing on both a spatial and temporal basis [4].

Rainfall variability and the trends of wet and dry periods in Bangladesh had studied using the Mann–Kendall trend test and the Sen's slope method to detect the significance and the magnitude of rainfall change [5]. Rainfall variability and the trends had studied by Shamsuddin Shahid (2010).

The Mann–Kendall trend test and Sen's slope method had used to detect rainfall change's significance and magnitude. Historical dry and wet months were identified using the standardized precipitation index method. Also the their trends are analyzed to assess the possible change in wet and dry events in Bangladesh [6]. The variation of rainfall over Bihar State, India had studied by Pratibha Warwade et al. (2018). This study detected the long-term annual and seasonal rainfall trends. The shift change point had identified with the cumulative deviation test and linear regression. The study was found that annual, and monsoon rainfall trends decreased significantly [7].

The analysis on annual and seasonal rainfall trend in the North-East region of India had studied. The results of the Mann Kendall test showed a decreasing trend in annual rainfall in east Siang, Upper Siang, and lowers Dibang valley and no trend in the West Siang district. Dibang valley districts, the decreasing trend of rainfall was observed in the post-monsoon season [8]. The rainfall trend and variability of Tamil Nadu studied, and the results have concurred that the rainfall trend and rainy days are decreasing throughout Tamil Nadu.

A Significant decreasing rainfall trend had been found in the southwest monsoon, and an increasing trend was reported in the post-monsoon season [9]. The variability of rainfall at Coimbatore and Erode assessed using Co-efficient of variation and the results revealed in increasing trends [10]. The study on rainfall trends in the recent past has shown an increasing tendency from 1989 to 2019 in all climatic zones in Sri Lanka [11]. The occurrence of rainfall in the wet and dry zones of Sri Lanka has been studied. The results revealed that a higher agreement is seen for stations in the dry zone of Sri Lanka than in the wet zone [12]. Trends of extreme temperature and precipitation indices had examined for Sri Lanka. The less spatially coherent pattern of change and a lower level of significance had observed in precipitation indices.

The annual precipitation indicated a significant increase over 1980-2015 [13]. The rainfall trend over Sri Lanka has been studied. The results showed increasing trends in annual rainfall at 24 stations and decreasing trends showed at 13 locations [14]. The trends of annual rainfall depth in Sri Lanka over the last century were carried out by Jayawardene et al. The study revealed the significant increasing trend at Colombo and decreasing trends at Nuwara Eliya and Kandy. Also, the study has shown that the downward trends in recent decades are steeper than the long-term variations [15].

Air Temperature and Rainfall variation during Yala and Maha Agricultural Seasons had studied by Basnayake et al. The study revealed a decreasing trend of mean annual rainfall during 1961-1990 compared to that during 1931 1960. Rain at 13 stations reveals decreasing trends with steeper downward trends in recent decades [16]. The annual and seasonal rainfall trends in Sri Lanka were studied. The results revealed the eastern region of the country over the last half-century, increasing rainfall trends. The country's central hills have decreased rainfall [17]. Spatial and temporal variations of rainfall trends of Sri Lanka were studied. About half of the series shows negative trends, while the rest shows positive trends. By contrast, the rainfall trends of the southwest monsoon season are predominantly negative throughout the country from 1981-2010 [18]. Rainfall trend analysis in Uma Oya Basin in Sri Lanka was studied, and the study noticed a positive trend [19]. The decadal trends in averages and extremes of rainfall and temperature were studied. The study showed the dynamic rainfall trends with both increasing and decreasing patterns in Sri Lanka [20].

Drought is a natural phenomenon that occurs recurrently, causing widespread depletion of water resources over a large geographical area in a considerable period. Drought is universally recognized as a phenomenon associated with water scarcity; they are recurring features of the climate. Drought occurs when the precipitation deficiency takes place over an extended period, particularly a season or more, resulting in water scarcity, causing adverse impacts on crops, vegetation, animals, people, and the ecosystem. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry. Drought is one of the natural disasters that can cause damage to the agriculture, economic sector, and social activities of the human system, and considerable damage caused to the ecosystem [21]. Drought is categorized into four types: meteorological, agricultural, hydrological, and socio-economic droughts. Meteorological droughts which mainly determined based on the degree of dryness compared to some normal quantity and the extent of the dry period [22].

Drought varies concerning the time of occurrence, duration, intensity, and extent of the area affected from year to year. It is broadly classified into four categories: meteorological drought, hydrological drought, agricultural drought, and socio-economic drought. Meteorological drought signifies the deficiency of rainfall compared to normal rainfall in a given region. Hydrological drought describes the scarcity of water in surface and underground resources. Agricultural drought occurs when the rainfall and soil are inadequate to meet the water requirements of crops, and socio-economic drought that expresses the socio-economic effects of drought can also incorporate meteorological, agriculture, and hydrological drought [23].

Sri Lanka is in the tropical region, has been experiencing cyclical droughts with high intensity, occurring once in three to four years. These droughts have had a series of adverse impacts on the economic and social life of people in the country. These frequent droughts created a series of adverse impacts on the economic and social life of the people of Sri Lanka [24]. The farmers' responses to drought in the dry zone had been studied. The study highlighted that in 2013/2014, drought has seriously damaged agricultural production, mainly in the paddy production in both Maha and Yala cultivation seasons. In 2013/2014, about one million people in Sri Lanka were severely affected by the drought in 2013/2014 for many districts in the Island [25]. In Sri Lanka, where rice is both the staple food and the primary crop grown by farmers, reductions in water availability for rice cultivation have serious impacts on farmers' welfare and national food security [26]. Spatial extent and temporal evaluation drought in Sri Lanka, especially one of the droughts affected districts of Polonnaruwa (during 2016-2017), have been studied [27]. The study stated, Sri Lanka experienced a severe drought in 2016/17, punctuated by a deluge of rain in May.

The drought-affected part of the Yala season of 2016 (June to September) and the Maha season of 2016/17 (October to March). The total water capacities at 73 major reservoirs had reported at 29%. During this Maha season, 612,223 hectares of paddy had been cultivated, of which 50,615 hectares had been damaged due to the drought, and it amounts to a loss of 4 053,395 bushels paddy. In the tropical region, Sri Lanka has been experiencing cyclical droughts with intervals of three to four years with high intensity. These droughts have had adverse effects on the economy, environment, and the people in Sri Lanka. In recent decades, droughts caused huge damage to the country's agriculture. The frequent occurrence of droughts and dry spells has been experiencing mainly in the dry zone of Sri Lanka. The district of Batticaloa also belongs to the dry zone and intensive agricultural areas of the country. Consequently, the district has been experiencing drought impacts on agriculture and water resources, creating numerous socio-economic and environmental problems. The higher rainfall variability leads to drought. The district of Batticaloa has been facing consecutive climatic extremes, which causes droughts some years and floods other years. For example, according to the Disaster Management Centre report (Situation Report 2021), about 163091 persons in 2019 and 19971 persons in 2020 were affected by drought in Batticaloa District.Therefore, the rainfall variability and drought-related studies are significant for water resource planning, management, drought mitigation, and sustainable agriculture [30-37].

2. STUDY AREA

The district of Batticaloa, located in the Eastern part of Sri Lanka, extends between 70°42'36" N latitude, 81°41'32" E. longitude (Figure 1). The area of the district is 2584 Km^2 (1,102 Sq. miles). For administration, the district had divided into 14 Divisional Secretariat Divisions and 346 Grama Niladhari divisions. Based on the 2012 census and statistics, the total population of the district is 525,142.

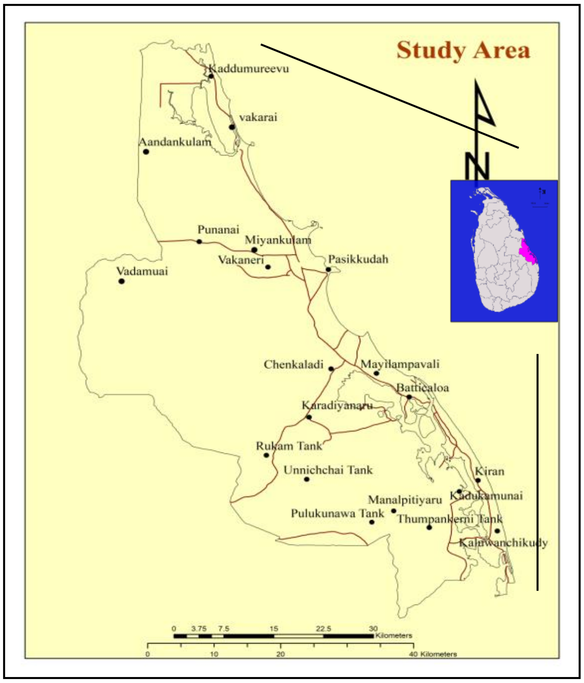

Fig. 1. Location of the study Area

Fig. 2. Rain Gauge Station

3. METERIALS AND METHODS

This paper attempts to study the annual and seasonal rainfall patterns and their variability, and the occurrence of droughts. Monthly rainfall data have been collected from the Department of Meteorology, Colombo, from 1871-2020 for Batticaloa station. Also collected the available rainfall data for Unnichchai, Rugam Tank, Vakaneri, Thumpankeny Tank, Pasikudah, Navakiri Aru, Mylabaveli, Kaddumurivu, Kiran, and Kalmunai (Figure 2) from Irrigation Department and Coconut research institute. Other related information had collected from various government departments' records, including Disaster Management Centre. The rainfall variability leads to drought. To study the rainfall variability of Batticaloa, mean annual rainfall (1871-2020) and the Standard Deviation (SD) and Coefficient of Variation (CV) had computed for the whole study period and different 30 years epochs and seasons. Also, least-square trends are fitted to study the long-term rainfall of Batticaloa as a whole and different epochs. To study the drought scenario, the Standardized Precipitation Index had computed, and then the droughts were categorized based on the SPI criteria, and the drought severity had distinguished. Spatial rainfall distribution maps had prepared using Arc GIS 10.4 software.

The Standardized Precipitation Index (SPI) is a drought index widely used by decision-makers worldwide to identify, monitor, and determine droughts' severity. McKee et al. (1993) developed the Standardized Precipitation Index (SPI) to monitor drought in Colorado. The SPI is a robust, flexible index that is easy to compute. Precipitation is the required input parameter to monitor the drought, flood, and intra-seasonal rainfall anomaly. Also, it is a powerful tool for analyzing wet and dry periods cycles. Thus, the US National Drought Mitigation Center recognized the SPI to monitor the rainfall anomaly and drought conditions.

Standardized Precipitation Index (SPI) was used to evaluate the drought in both the short-term (3 and 6 months) and the long-term (12 months) time scales. The SPI computation for any place is based on the long-term rainfall record for a chosen period or place. This long-term precipitation record fitted a probability distribution, and then it was transformed into a normal distribution. Therefore the mean SPI for a given place and desired period is zero (Edwards and McKee, 1997). SPIs had suggested (Guttman, 1998) type III distribution. Gamma distribution with three parameters was given as rainfall anomaly is then studied from the normalized rainfall series following the SPI criteria (Table-I).

Table 1. SPI Categorization

SPI Value	Condition
2.0 or more	Extremly wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderaly wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately Dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Source: Edwards and McKee, 1997

To study the frequency of occurrence of drought and its severity, the SPI has been computed. About 150 years of long-term monthly data of Batticaloa station was used in this study. Its popularity for application drought monitoring makes it possible to determine the drought, flood, and normal years [28]. SPI can be effectively used to determine long-term drought behavior. SPIs suggested type III distribution. Gamma distribution with three parameters given as rainfall anomaly then studied from the normalized rainfall series [29]. SPI is a standard variant that shows diversion values upper or lower than average. Further to study the annual and seasonal rainfall pattern, interpolated raster surface had created using Arc GIS 10.4 software and the spatial maps generated.

4. RESULTS AND DISCUSSION

4. 1. Rainfall Pattern, Variability and Trend

The annual average rainfall of Batticaloa is 1706 mm. In the study period (1871-2020), the highest rainfall was received (3581 mm) in 2011and. The massive flood had affected the district, and the lowest rainfall recorded (840 mm) in 1968, and extreme drought had prevailed. The study shows the spatial and temporal variations in annual rainfall that vary spatially from

1600 mm to 1900 mm. Temporal annual rainfall variation shows the above-normal rainfall (1851 mm) in the recent epoch of 1991-2020. The below-average rainfall had in 1871-1900 (1579 mm) and 1961-1990 (1640 mm). The annual rainfall was closer to the mean from 1901-1930 and 1931-1960 (Figure 3).

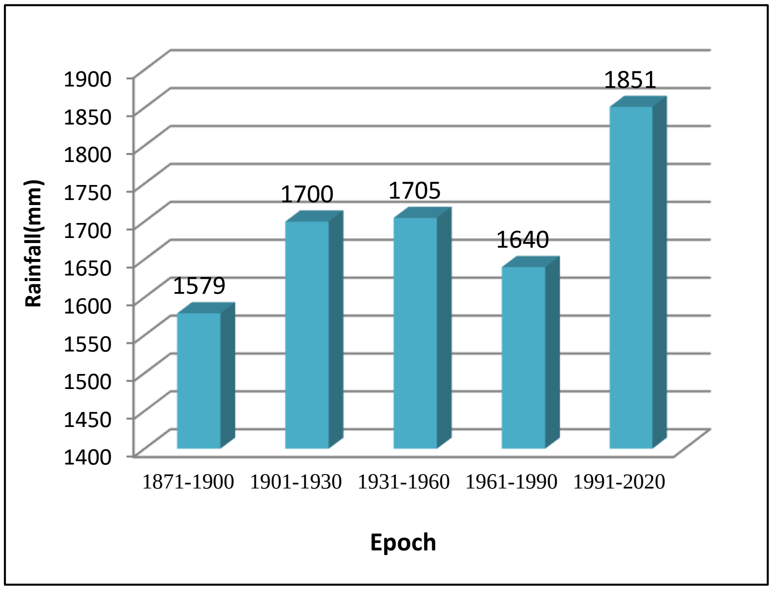

Figure 3. Epochal Annual Rainfall-Batticaloa

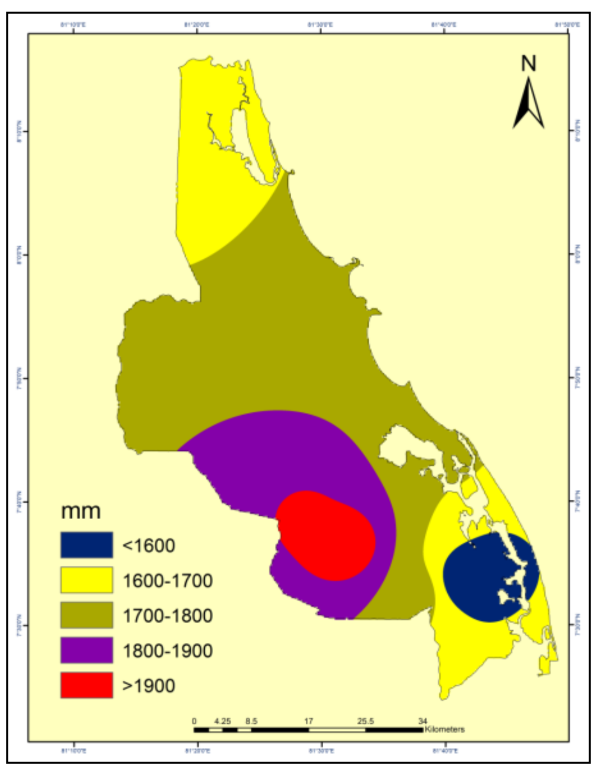

Figure 4. Annual Rainfall

The spatial pattern of annual rainfall shows in Figure 4 which exhibited that the southwestern part of the study area receives higher rainfall (>1900 mm) and lower rainfall in the southern and northern parts of the study area.

The SD and CV of the annual rainfall of the study area are 423.9 and 24.8 %, respectively. However, the variability significantly differs in the epochs. The SD of annual rainfall (301.4) and CV (17.7%) is lower in the epochs of 1931-1960 and 1871-1900 (310.1) and (19.6%), respectively, which indicates the high dependability of rainfall and good progress of monsoon in the above epochs. The rainfall variability is higher (CV is 29.1%) in 1991-2020 (CV is 28.9%) in 1961-1990. Table -2 shows the epochal annual rainfall and its variability in detail.

Table 2. Annual Rainfall & its Variability-Batticaloa-1871-2020

Epochs	AVG RF	SD	CV
1871-1900	1578.8	310.1	19.6
1900-1930	1699.8	382.7	22.5
1931-1960	1704.6	301.4	17.7
1961-1990	1639.8	473.7	28.9
1991-2020	1850.9	539.3	29.1
1871-2020	**1706.2**	**423.9**	**24.8**

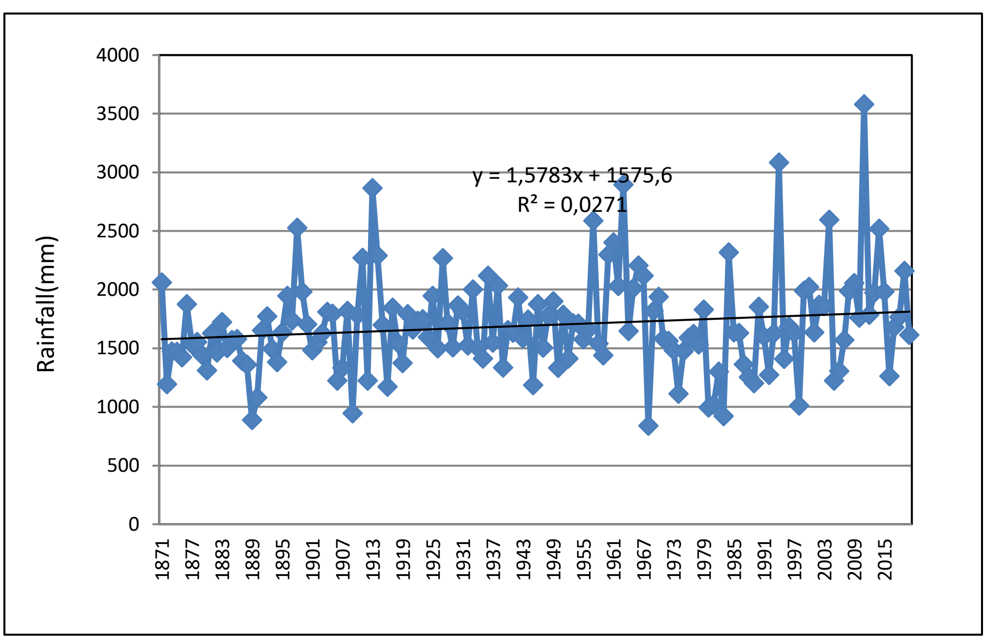

Figure 5. Rainfall Trend in Batticaloa (1871-2020)

The long-term rainfall trend results reveal the increasing trend (Figure 5) and $r^2 = 0.0271$. However, epochal trends show decreasing trend in 1961-1990 ($r^2 = 0.2398$). However, the increasing trend has been observed in the recent epoch (1991-2020). These increasing or decreasing trends indicate the enhancing rainfall fluctuation.

The climate of Sri Lanka describes as tropical monsoonal. The monsoon climatic conditions refer to the seasonality of the rainfall. Due to the movement of ITCZ, Sri Lanka has marked seasonal variations in climatic elements. There are four distinct weather seasons in Sri Lanka which also perceive the climate of Batticaloa viz.

Season	Period

1) First Inter Monsoon (FIM): March – April
2) South West Monsoon (SWM): May – September
3) Second Inter Monsoon (SIM): October – November
4) North-East Monsoon (NEM): December – February

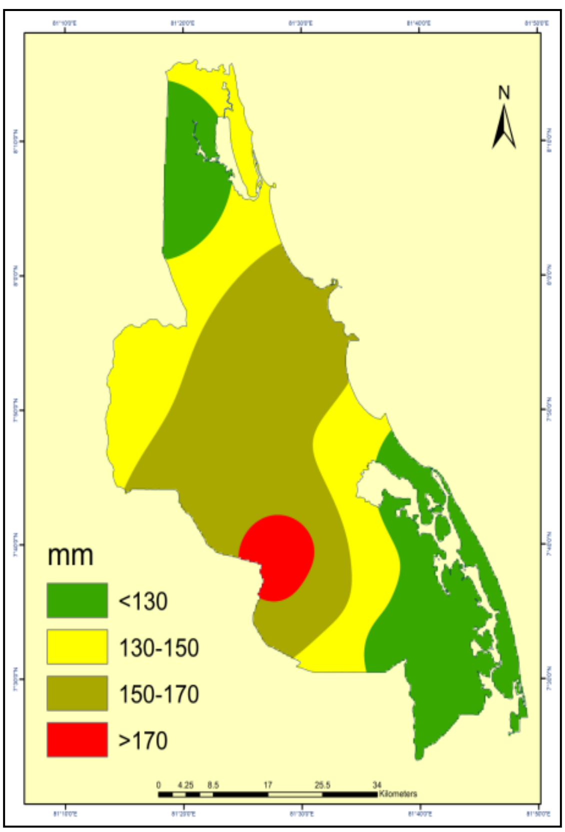

Figure 6a. FIM Season Rainfall

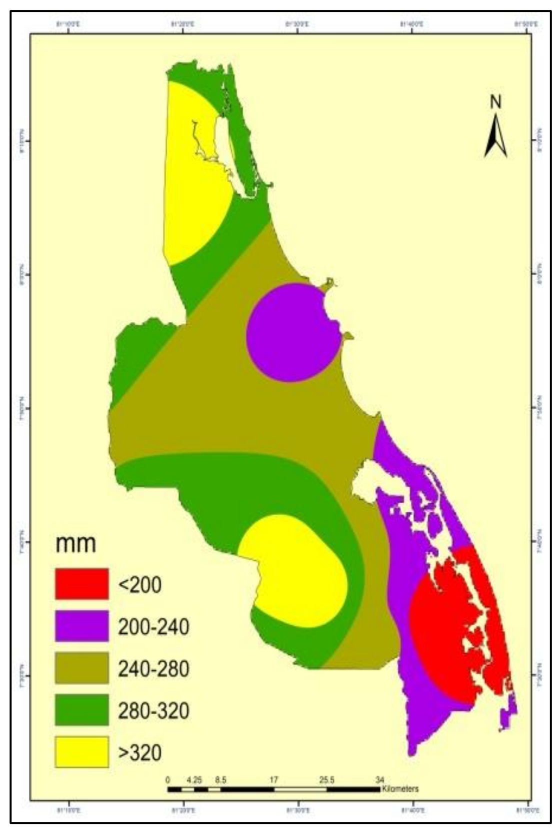

Figure 6b. SWM Rainfall

Convectional showers occur during the FIM season due to the northward movement of the ITCZ from the southern latitudes. During this season, the sun is overhead on the island. As a result, insolation is high. The temperature goes up about 28 °C in the lowland area of the country, including Batticaloa, and the formation of clouds is thermally controlled. These weather conditions are favorable to develop cumulonimbus clouds and thunderstorms. Intense convectional activity occurs with the characteristic thunderstorm showers in the late afternoon. FIM season average rainfall is 135 mm, which is about 8% of the annual rainfall. The spatial distribution of FIM rainfall shows in Figure 6a. The elevation of central high land reaches up to 2524m, acts as a distinct climatic divide. There are ample orographic rains on the windward side and, at the same time, significant '*foehn*' effects and less rainfall on the leeward side of the mountain. The Batticaloa is located on the leeward side and receives low rainfall during the SWM season (225 mm) than the NEM and SIM seasons. The spatial distribution of SWM season' rainfall shows in Figure 6b. The southwestern part of Sri Lanka and the western hill slopes receive heavy and intense rainfall. The mean rainfall of SWM in Batticaloa is about 225 mm, about 13% of the annual rainfall received during the season. The southeastern quarter of the district relatively receives low rainfall (<240 mm) during SWM season; however, the southwestern and the northern part of the district receives rainfall between 280-330 mm of rain

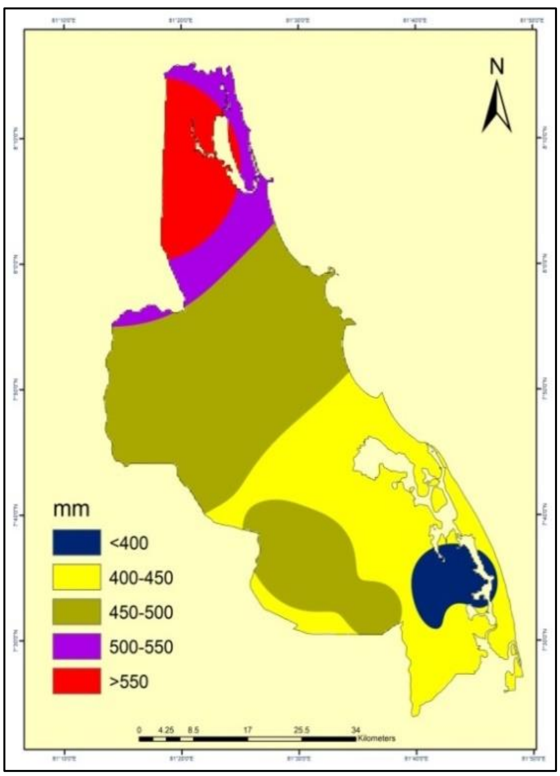

Figure 6c SIM Rainfall

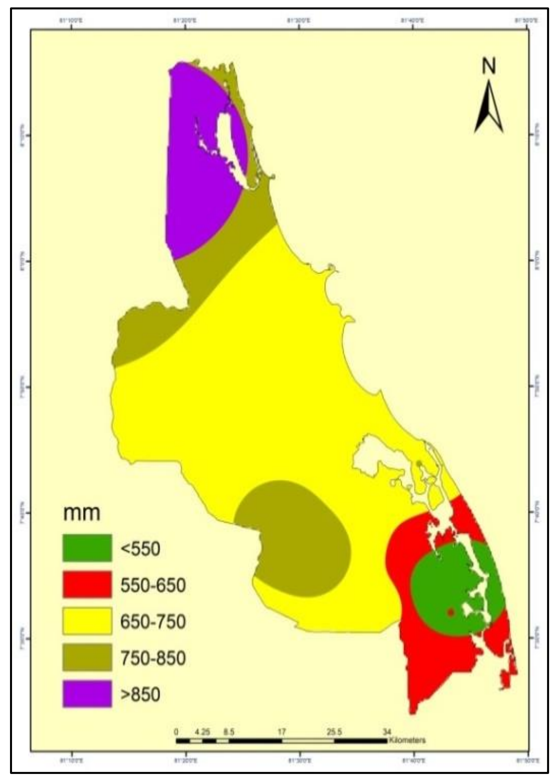

Figure 6d. NEM Rainfall

The CV of rainfall was increased by 43.9%. In SWM, the lesser variability shows in the epoch 1871-1900 (CV, 37%). The SIM rainfall distribution pattern shows in Figure 6c. About 31% of the annual rainfall receives during this SIM season. The mean seasonal rainfall of SIM is 526 mm. However, spatial variability has been observed in this region. The northern part of the district receives higher rainfall (>450 mm), and the southern part receives relatively low rainfall (<400 mm). The SIM rainfall CV is less (CV 39.8%) than other seasons, and the seasonal rainfall dependability is high. The study area receives the highest seasonal rainfall in the NEM season (809 mm), with 48% annual rainfall. The spatial distribution pattern of NEM season rainfall shows in Fig. 6d. The greater part of the study area (85%) receives higher rainfall between 550-850mm during this season. The epochal rainfall variability results reveal the CV of rainfall is high (49%) in 1901-1930 and 1991-2020 (48%). The variability is comparatively lower in 1931-1960 (35%). The monthly epochal rainfall distribution shows in Figure 7. Figure 7 illustrates that October, November (SIM Season), December, January, and February are the wettest, and the remaining months are dry, receive below 75 mm of rainfall. This average pattern has seen all the epochs. Accordingly, the monthly CV is less during the wettest month than the driest months (Figure 8). The higher rainfall variability is observed in June and lower in November.

Table 3. Seasonal Rainfall (mm) and its Variability

Details	FIM	SWM	SIM	NEM	Annual
AVG	135 (8%)	225 (13%)	526 (31%)	809 (48%)	1706.2 (100%)
SD	97	99	209	354	423.9
CV (%)	71.6	44.0	39.8	43.8	24.8

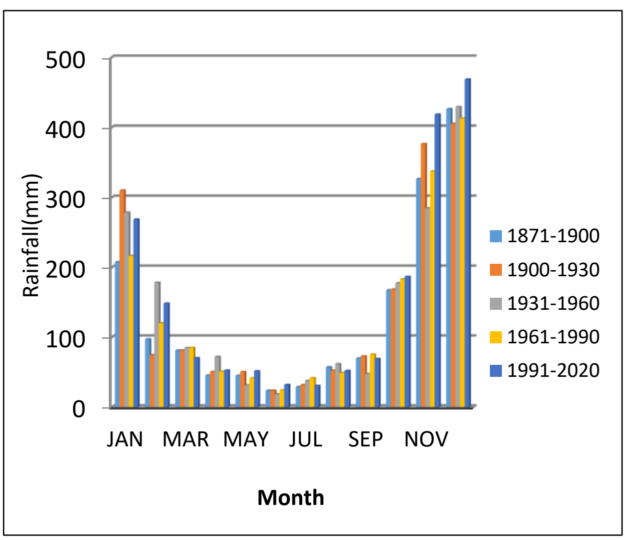

Figure 7. Epochal Monthly Average Rainfall

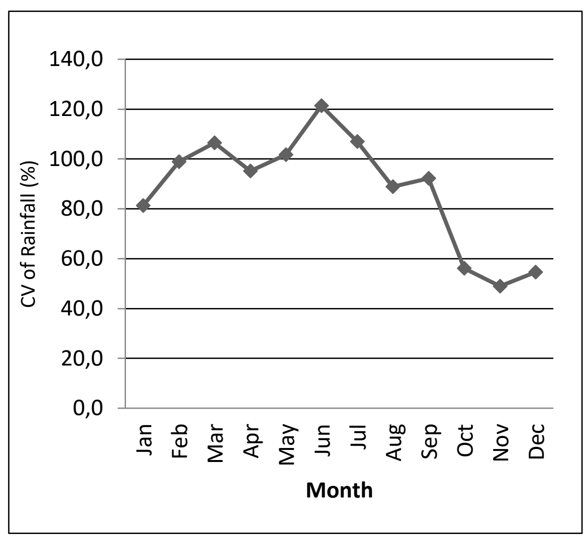

Figure 8. CV of Rainfall, Batticaloa

4. 2. Rainfall Anomaly and Drought Occurrences

Drought and its severity have been assessed based on the SPI, the anomalies of rainfall had categorized. According to SPI criteria, the drought years have been identified. Out of 150 years of data periods, 25 years were as drought years (Figure 10). The probability of drought occurrence is P = 0.167; a drought could have occurred once in five to six years. The extreme drought had occurred in 1968 and 1889. The severe droughts have occurred in 1998, 1983, 1981,1980, 1909, 1890. Further, the description of drought occurrences had explained in chronological order of different standard epochs as 1991-2020, 1961-1990, 1931-1960, 1901-1930, 1871-1900. In general, rainfall of Batticaloa (BT) has an increasing tendency in the epoch of 1991-2020 (Figure 10). As a result probability of occurrence of drought is P = 0.167. A severe drought (1998) and four moderate droughts occurred in this epoch (Table 4). The rainfall trend in 1961-1990 had experienced a downward trend compared with all other epochs (Figure 9b). As a result, the drought occurred more frequently in this epoch. Out of these 30 years, eight years had experienced droughts. An extreme drought had occurred in 1968, and its SPI reached up to -2.05. Similarly, severe droughts occurred in 1980, 1981 and 1983. Also, four moderate droughts were identified (Table 4). The frequency of occurrence of drought is comparatively less in the epoch of 1931-60. Out of 30 years, only three years we noticed moderate drought, and its probability is P = 0.10. The epoch of 1931-1960 had received good rainfall than the subsequent epoch. In the epoch of 1901-1930, five drought yeas had occurred. A severe drought had occurred in 1909. The epochal probability of drought was P = 1.67. The frequency of occurrence of the drought was secondly lower in the epoch of 1871-1900 (P = 0.13). However, extreme drought and severe drought occurred in 1998 and 1890, respectively.

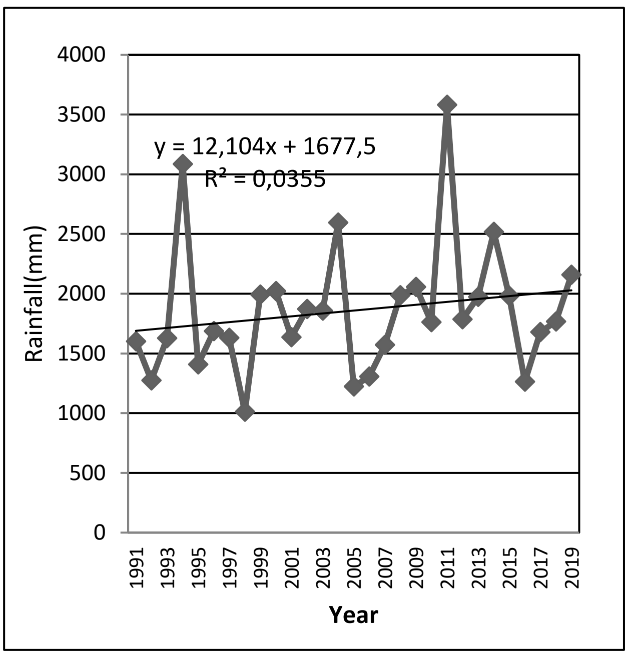

Fig. 9a. Rainfall Trend (1991-2020), BT

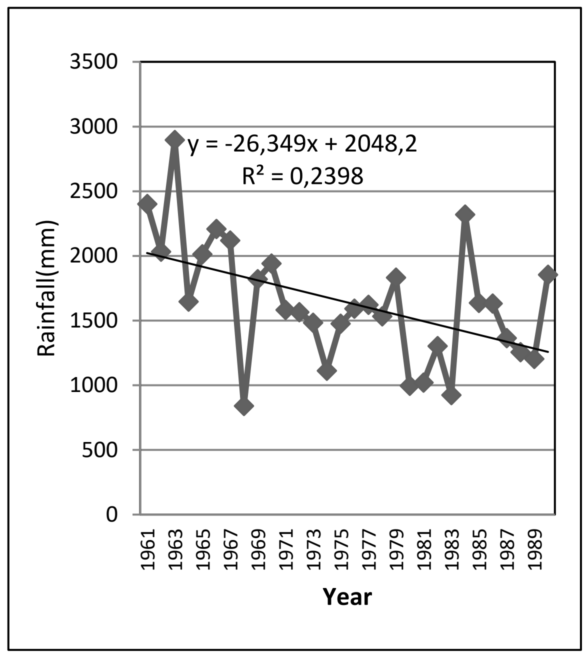

Fig. 9b. Rainfall Trend (1961-1990), BT

Table 4. Drought Years and its Severity in Batticaloa

Year	SPI	DS	Year	SPI	DS
1872	-1.20	M	1974	-1.40	M
1880	-1.02	M	1980	-1.68	S
1889	-2.03	E	1981	-1.62	S

1890	-1.51	S	1982	-1.01	M
1906	-1.13	M	1983	-1.86	S
1907	-1.00	M	1988	-1.06	M
1909	-1.80	S	1989	-1.18	M
1912	-1.13	M	1992	-1.01	M
1916	-1.26	M	1998	-1.64	S
1939	-1.01	M	2005	-1.13	M
1945	-1.22	M	2006	-1.00	M
1950	-1.00	M	2016	-1.03	M
1968	-2.05	E			
E = Extreme Drought, S = Severe Drought, M = Moderate Drought					

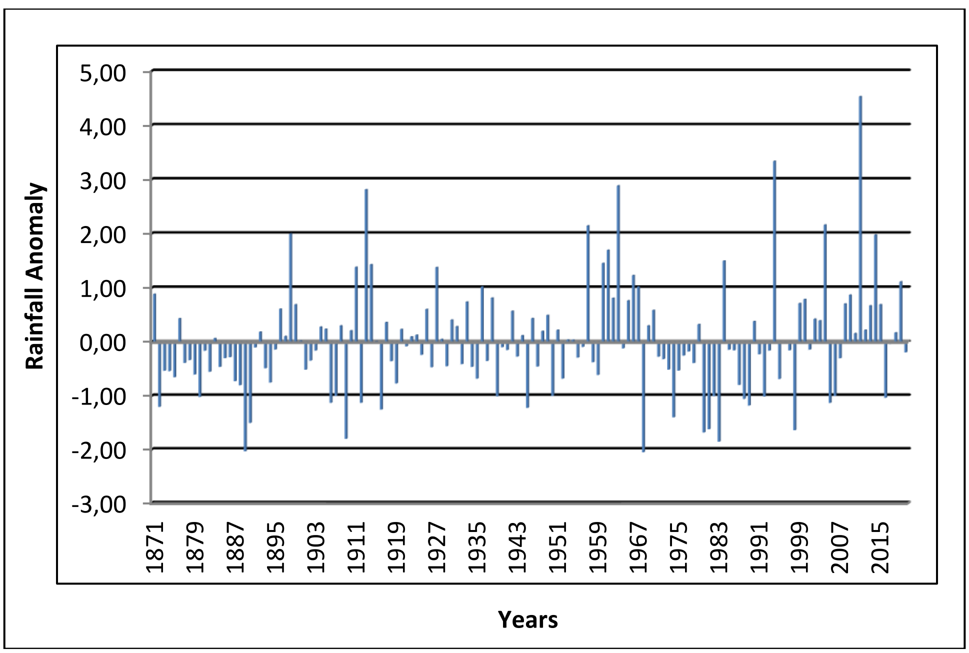

Figure 10. Rainfall Anomaly at Batticaloa (1871-2020)

5. CONCLUSIONS

Due to recent climate changes and monsoon variability, the amount, pattern, and intensity of rainfall are significantly changing in the study area. The SD & CV of annual rainfall variations are 423.9 and 24.8%, respectively. The epochal variability results reveal that the variability of rainfall is higher in 1961-1990 (CV: 28.9%), which indicates the low dependability, while variability is lower in the epochs of 1931-1960 (CV: 17.7%) and 1871-1900 and (19.6%) respectively. The long-term rainfall trend results reveal the increasing trend and its $r^2 = 0.0271$. However, only the epoch 1961-1990 shows a downward trend with $r^2 = 0.2398$. The rainfall anomaly results reveal the extreme drought had occurred in 1968 and 1889. The severe droughts had occurred in 1998, 1983, 1981, 1980, 1909, 1890. Out of 150 years of data periods, 25 years had been identified as drought years. The probability of drought occurrence is P = 0.167. Terefore once in five to six years, drought could have occurred. Approperiate drought management plan is required to adopt to minimize the drought disastrous effects. The short term and long-term drought management plan and strategies should be adopted with people participation to reduce the impacts. Drought plans contains three basic strategies such as Drought Monitoring and and Early Warning System, Risk Assessment, Mitigation and Response. Suitable water conservation, and drought management plan has to introduced wich may include to increase capacity of water in the irrigation tanks, adopt irrigation efficiency, reduce evaporation, introduce drought resistance crops, discouraging water intensive crops, encouraging sprinkler and drip irrigation systems, practicing alternate land use, conservation of water in soil, increase ground water recharge, optimum use of water, reduce the runoff, management crop land, and efficient water management, etc. can be assisted for long-term drought proofing in the study area.

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