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RAINFALL VARIABILITYAND TREND IN THE NORTHERN REGION OF SRI LANKA

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ABSTRACT

In this study, the rainfall variability and trend of the Northern Region of Sri Lanka (NRSL) isexamined. Long term monthly rainfall data (1881-2015) were obtained for sixrain gauge stations of Jaffna, Mannar, Kanukkeni, Vavuniya, Pavatkulam and Muttayankaddu. To study the inter-annual and decadal variability and trend, Coefficient of Variation (CV), least square trendand Standardized Precipitation Index (SPI) were used as descriptors of rainfall variability. The SPI had computed for 1, 2, and 3 -month time scale for all six rain gauge stations.The mean annual rainfall of NRSL is 1233mm and its CV range is varies spatially from 24.8% to 33.1%. The analysis demonstrates the intensity of flood, drought and normal years. Out of 135 years,40 years were experienced as flood and 20 years as drought. The probability flood year is 0.296 and drought year0.148. The study revealed that the occurrences of flood years are more (30%) than the drought years (15%). The decadal variability and trend of rainfall results revealed that the decreasing trend was prolonged in the decades of 1881-1890, 1901-1910, 1921-30, 1931-40, 1971-80 and 1981-90 and increasing trend noticed in the decades of 1891-1900 and 1951-1960.

Key words: Inter-annual rainfall variability, Decadal Variability, Standardize Precipitation Index, Coefficient of Variation, Flood and Drought years

1. INTRODUCTION

In the tropics, especially in developing countries, the agriculture sector plays a crucial role in the economy. The impact of climate and climate variability on agriculture affects agricultural planning and productivity (Jayawardene et.al.2015). Sri Lanka is a humid tropical country positioned on the path of two monsoons, the Southwest and the Northeast andmostly affected by the weather related hazards such as flood, drought, cyclone, thunderstorm etc. Floods occur due to intense monsoon rainfall when low pressure system develops in the Bay of Bengal or the Indian Ocean. Drought occurs either due to lesser annual or seasonal rainfall, and/or late onset of monsoon, or early withdrawal of monsoon or long dry spells during rainy seasons.Sri Lanka is divided into two major climatic regions viz., wet zone and dry zone. The southwestern part of Sri Lanka is wet, while the north and eastern zones are dry. The western wet zone is the water surplus area in the country; while acute deficit areas exist in the northern, northwestern, eastern and southeastern regions. The wet areas are characterized by low inter-annual variability and dry areas by higher inter-annual variability (Peiris and Mathes, 1995). The nature of monsoon rainfall in Sri Lanka makes irrigation indispensable for sustainable agriculture development. Unfortunately rainfall of the country mainly in the dry zone together with NRSL is variable, seasonal, and unevenly distributed. Consequently the variability of rainfall is indeed greater in

the dry zone than in the wet zone. The study area is belongs to a part of dry zone, thereby the studies relatedto rainfall variability has great significance.

The amount and pattern of monsoon rainfall in the Asia including Sri Lanka has significant variation due to recent climate changes.Increasing numbers of warm days and decreasing numbers of cold days have been observed, with the warming trend continuing into the new millennium. As a result precipitation trends including extremes are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia (Hijioka et.al. 2014). According to the WMO, thirteen out of fourteen hottest years were reported since 2000and each successive decade since 1980 has been warmer than the previous one, having 2001-2010 recorded as the warmest decade ever (WMO, 2014)

The long term rainfall patterns of a place may alter due to recent global climate change. The significant changes are observed in the pattern and amount of rainfall not only in Sri Lanka but also in the NRSL during recent epochs. The main objective of this study is to analyze the inter-annual rainfall variability and decadal trends and variability in the NRSL.Generally the recent warming tendencies modify the amount and patterns of rainfall which amplifies the extreme climatic anomalies such as flood, drought, cyclone, thunderstorm, etc. Some researchers reportedthat the decreasing tendency in mean annual rainfall (Fernando and Chandrapala, 1995;Chandrapala, 1996; De Costa 2008;Jayatillake et al., 2005,Peiris and Mathes, 1995) in several places in Sri Lanka. Many researchers seem toagree that the variability of rainfall has increased over time (Chandrapala 1996;Domros, 1996;Jayawardene et.al., 2005). Moreover, thenumber of consecutive dry days has increased and the consecutive wet periods have decreased.Studies also indicate that the spatial distribution of rainfall appears to be changing.

Due to the movement of ITCZ, Sri Lanka has marked seasonal variations in the climatic elements. While the seasonality is the pre-dominant characteristics in the island' weather and it has a major role to play in the weather and climate. The island and NRSL is influenced by two wind regimes, which are the Southwest monsoon (SWM: from May to September) and Northeast monsoon (NEM:from December to February). Between these two-monsoon periods [First Inter Monsoon (FIM): from March-April and Second Inter Monsoon (SIM) from October-November] convectional weather conditions prevails. Two monsoon winds, movement of ITCZ, cyclonic wind circulation; diurnal winds and orography are the major factors that determine the rainfall distribution in Sri Lanka. Rainfall of the NRSL mainly occurs during the period of NEM and SIM seasons. During the period of SIM season, ITCZ across the country, rain widespreaddue to convergence activities, lows, depression and cyclones. In December the passage of easterly wind stream and cyclonic wind is cause for spells of heavy rain.The study area hadexperiencedabundant rainfall in someyears and unfavorable droughts or dry spells in some other years. The intensity of extreme climatic events is heightened due to recent climate changes. Thereby the study on rainfall variability andtrend is great importance for a place like the NRSL which intensive agricultural area predominantly depends on monsoon rainfall.

2. STUDY AREA

The study area is located in the Northern part of Sri Lanka between 8'.30'N-10'.00'N and 79'.37'E-81'.00'E., andtotal area is 8,848.58 Sq. Km. The northern boundary of the study areais the Palk Strait, while the east is bounded by the Bay of Bengal. The Southern and Western boundaries are the North Central province and the ArabianSea respectively. Administratively the Northern

Provinceis divided into 5 Administrative Districts, 34 Divisional Secretary Divisions and 921 *GiramaNiladari* Divisions.

3.MATERIALS AND METHOD

In this study, annual rainfall is examined for the stations of Jaffna, Mannar, Kanukkeny, Vavuniya, Pavatkulam and Muttayankaddu (Table, 2).To study the annual and decadal rainfall variability and trend, monthly rainfall data wereobtained from the Department of Meteorology, Department of Irrigation and Department of Agriculturefor the period from 1881 to 2015. More than 25 rain gage stations were established by the Government of Sri Lanka, location of rain gauge stations are given in Fig.1, however, except the above six stations most of them do not have continues long term data due to existed war more than three decades in this region.To study the rainfall variability, standard deviation (SD), Coefficient of Variation (CV) of rainfallwas calculated as a whole as well as for decades. The reliability or dependability of the rainfall is closely related to its variability. The variability is defined as the ratio of the mean of deviations from the average to the mean itself (Peterssen, 1956, 1969). Moreover, variability may be defined as the deviation from the standard mean computed thirty years or more of observations (Trewartha, 1980, 1981). The Standard Deviation, Co-efficient of Variations is useful statistical parameters to study the rainfall variability of a place.

Moreover, to study the inter-annual variability, Standardized Precipitation Index (SPI) and least square trend werecomputed for annual rainfall for all stations. McKee, Doesken and Kleist developed the Standardized Precipitation Index (McKee, Doesken et. al., 1993, 1995). The SPI is a powerful, flexible index that is simple to calculate. In fact, precipitation is the only required input parameter to monitor the drought, flood and intra-seasonal rainfall anomaly. In addition, it is just as effective in analyzing wet and dry periods cycles. Thus the US National Drought Mitigation Center recognized the SPI to monitor rainfall anomaly and drought conditions. The SPI computation for any place is based on the long-term precipitation record for a chosen period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). SPIs were suggested (Guttman, 1998) type III distribution. Gamma distribution with three parameters α, σ, ρ (respectively mean, standard deviation and skewness) is given as follows:

$$\delta F = \left[\left(\frac{1}{\sigma \Gamma(p)} \right) \left(\frac{x-\alpha}{\sigma} \right)^{p-1} \left(e^{-\left(\frac{x-\alpha}{\sigma} \right)} \right) \right] \delta x \qquad (1)$$

Where, $\alpha \le x < \infty$, p>2 and $\Gamma(p)$is incomplete gamma function of p.

Rainfall anomaly is then studied from the normalized rainfall series in accordance with the SPI criteria (Table-1).The SPI was designed to quantify the precipitation anomaly for multiple timescales. This method has been applied by various scholars in many countries like Africa, India, Iran, Malaysia etc. (i.e. GirmaEshetu et.al. 2016;DipanwitaDutta et.al. 2015, Rajendram and Patel, 2012, Ravi Shah, 2015;TayebRaziei, BhramSaghafian. Ana A. Paulo Lois S. Pereira Isabella Bordi, 2009).

Table.1 Classification scale for SPI values

SPI Value	Category
2.0+	Extreme flood
1.5 to 1.99	Severe flood
1.0 to 1.49	Moderate flood
-.99 to .99	Near normal
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severely drought
-2 and less	Extreme drought

4. RESULTS AND DISCUSSION

4.1 INTRA-ANNUAL VARIABILITY OF RAINFALL

Rainfall of the NRSL is three types, which are monsoonal, convectional, and depressional. The average annual rainfall of NRSL is 1232.8mm (Table, 2) which less than the long-term mean annual rainfall of Sri Lanka(1995mm) and the dry zone (1562mm). The annual rainfall of study area has considerable spatial variations, which varies spatially from 997mm to 1368 mm (Fig 2). The Western part of study area receives less annual rainfall (997mm) than other places which represented by station Mannar. The higher rainfall is experienced on the Southern and South eastern region represented by station Vavuniya (1368mm) and Kanukkeny (1350mm) respectively.

Table2: Average Annual Rainfall and its Variability for the NRSL

Station	Jaffna	Mannar	Kanukkeny	Vavuniya	Pavatkulam	MuttayanKa	NRSL
AVG RF	1272.4	997.3	1349.8	1368.3	1139.1	1334.9	1232.8
SD	337.2	330.1	389.2	375.5	367.2	377.8	277.3
CV	26.5	33.1	28.8	27.4	32.2	28.3	22.5

AVG. RF- Average Rainfall, SD- Standard Deviation, CV- Coefficient of Variation

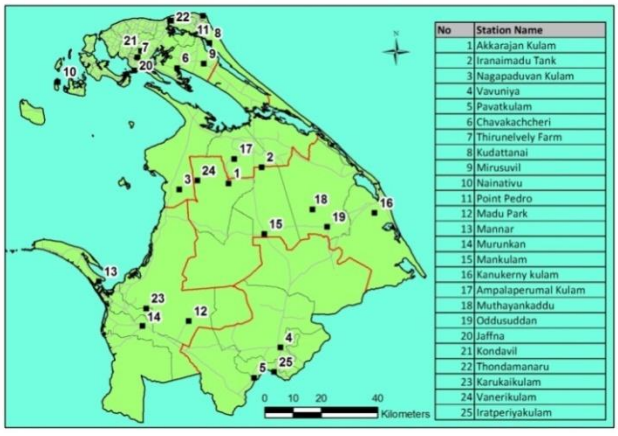


Fig.1Location of Rain Gauge Stations

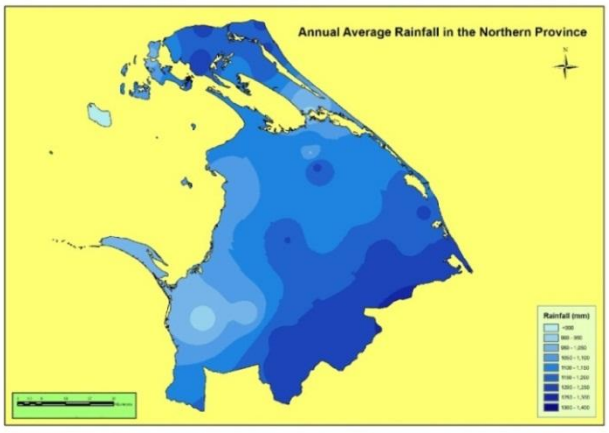


Fig.2 Distribution of Annual Rainfall

The SD and CV indicate the amount of variability inherent in rainfall data over a long period of time from the mean value. A low ratio indicates a high degree of dependability, and high ratio indicates an erratic behavior. According to Petterssen (1956), when the ratio of variability is less than 15 percent, there is a high degree of dependability. But in the areas with 20 to 25 percent variability, there is a constant fear of prolonged drought, and dependability of rainfall is minimal.

All the great deserts in the world have more than 30 percent variability. For example, in the severe drought prone area of western Rajasthan, coefficient of variation exceeds 60 percent. The coefficient of variation of annual rainfall is higher in the dry zone of Sri Lanka (23.8%) than in the wet zone (17.5 %). In greater part of dry zone rainfall CV is between 21 and 28 (Rajendram-2004). The CV of annual rainfall of the NRSL as a whole is 22.5% and its range varies spatially from 24.8% to 33.1% (Table, 1).The higher rainfall variability is noticed at Mannar (33.1%) and Pavatkulam (32.2%).

The frequency of occurrence of extreme climatic events is increasing over the years due to recent climate changes. As a result of which, droughts, floods are much more severe and widespread when the warm and cold ENSO episodes occurred.The strong influence of El Nino and La Nina phase on various aspect of rainfall distribution in Sri Lanka is confirmed (Burt and Weerasinghe, 2014;Suppiah, 1996).In this study El-Nino and La-Nina yearswere compared with rainfall anomalies. Based on the analysis of SPI, rainfall anomaly years are categorized. The analysis demonstrates the intensity of flood, drought and normal years. Out of 135 years of annual rainfall analysis 40 years were experienced asfloods.

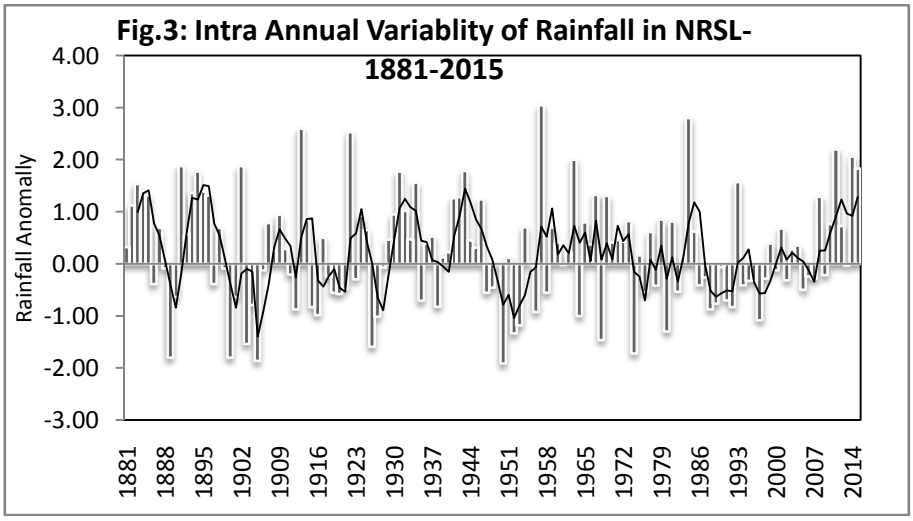
The probability of flood years is 0.30.In this region once in 3yers a flood year could be possible.The extreme flood years were experienced in 1913, 1922, 1957, 1984, 2011, 2014, 1963, and 2015 and its probability is 0.059. The year 2011 was extreme flood year as well as La-Nina year. Similarly the years, 1883, 1891, 1894, 1902, 1931, 1934, 1943, 1969, 1993, 2008, and 2015were experienced severe floods.There weresix La-Nina events and fifteen El-Nino events within the wet years. Flood years of 2008, 1943 and 1934 were associated with La-Nina events and the years 2015, 1931, 1902 and 1891were severe flood as well as El-Nino. Rainfall anomalies and their probabilities are given in Table 3.

The negative anomalies of rainfall revealed the drought condition. Out of 135 years 20 years were experienced as drought in the NRSL. The extreme and severe droughts were occurred in 1900, 1905, 1950, 1903, 1926, 1952, 1968, 1974 and 1980. The probability of drought years is 0.150, once in 6-7 years a drought could be possible. The extreme drought year of 1900, severe drought years of 1980, 1952, 1926 and 1903 is associated with El Nino episodes. Extreme drought years, severe drought years and moderate drought years

Table,3 Intra-Annual Rainfall Variability of the NRSL

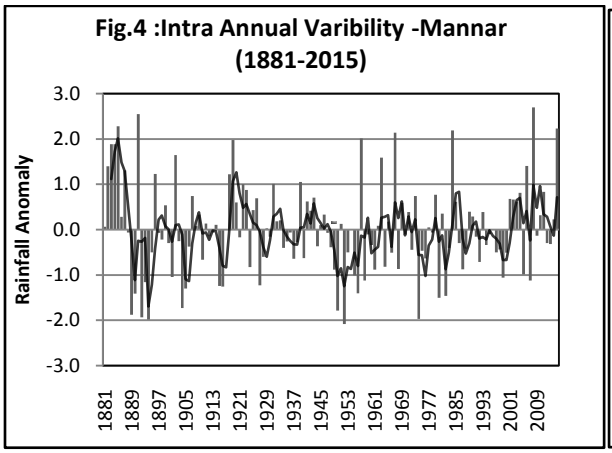
SPI Category	Intra- Annual Variability
Extre Flo	1913, 1922, **1957**, **1963**, **1984**, 2011, 2014,
Seve Floo	1883, **1891**, 1894, **1902**, **1931**, 1934, 1943, 1969, 1993, 2008, **2015**
Mod te Floo	**1882**, 1883,1884, 1885, 1893, 1895, 1896, 1907,1909 1914, 1924, **1930**, **1932**,**1941**,**1942**,**1946**,1954, 1967, 1979, 1981, **1991,2010**
Norr Year	1881,1886,1887,1888, 1890, 1892,**1897**,1898,1899,1901,**1906**,1908, 1910,1911,1917,1918,**1919**,1920,1921,1923,1925, 1928,1929, 1933,1935,1936,1937,1939,1940,1944,1945,1947,1948,1949,1951,1955,**1958**,1959,1960,1961,1 2,1965,**1966**,1970,1971,1972,**1973**, 1975,1976,1977,**1978**,1982,**1983**,1985,1986,**1987**,1990,1994,1995,1996,1997,**1998**,1999,2000,2 1,2002,**2003**,2004,2005,2006,**2007**,2009,2012,2013
Mod te Drou t	1904, 1912, **1915**, 1916, 1927, 1938, **1953**, 1956, 1964,1989, 1997
Seve Drou t	**1903**, **1926**, **1952**, 1968, 1974, **1980**
Extre e Drou t	**1900**, 1905, 1950

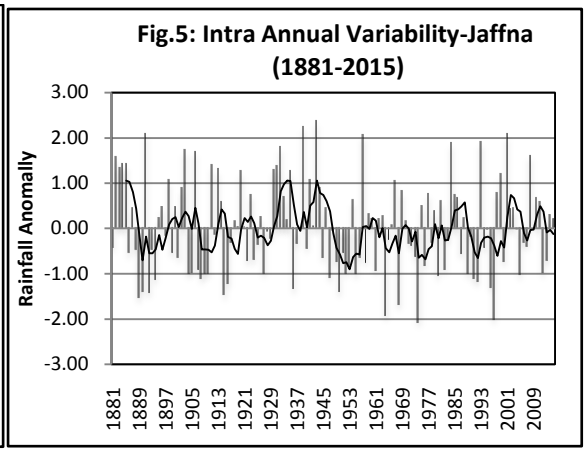
Highlighted (bold) Years = El Nino & Underlined Years =La Nina



5. RAINFALL ANOMALY FOR MANNAR AND JAFFNA

There are two regions receive lowest annual rainfall in Sri Lanka which located in the south eastern and north western parts of the country. The north western part represented by the station Mannar which belongs to study area and receives less annual rainfall (997mm) consequentlyvariabilityof rainfall is high. Comparatively station Jaffnareceives higher rainfall (1272mm)with lesser variability. Thereby these two stations are specially examined in this section.Poor rainfall, frequencyof occurrence of drought or dry spells is the predominant characteristics at Mannar. Consequently 54% (73 years) were reported negative anomaly of rainfall(Fig 4). Years 1889, 1892, 1894, 1950, 1952, and 1974 were experienced extreme droughts. Similarly,severe drought were occurred in 1890, 1904, 1905, 1927, 1956, 1980 and 1982, remaining years were moderatedrought (Table, 4)





Table, 4: Severity of Drought and their SPI for Station Mannar-1881-2015

Drought Years	SPI Value	Severity	Drought Years	SPI Value	Severity
1889	-2.08	E	1952	-2.08	E
1890	-1.51	S	1955	-1.01	M
1892	-2.04	E	1956	-1.51	S
1893	-1.16	M	1958	-1.12	M
1894	-2.08	E	1961	-1.08	M
1901	-1.04	M	1964	-1.02	M
1904	-1.73	S	1968	-1.07	M
1905	-1.50	S	1974	-2.07	E
1915	-1.24	M	1980	-1.50	S
1916	-1.25	M	1982	-1.56	S
1924	-1.03	M	1987	-1.08	M
1927	-1.53	S	1999	-1.06	M
1949	-1.08	M	2005	-1.09	M
1950	-2.09	E	2007	-1.13	M

E- Extreme Drought Year, S- Severe Drought Year, M- Moderate Drought Year

The flood years at Mannar and its severity are categorized based on SPI criteria. Out of 135 years of data period 60 years were reported as positive anomaly which include 44.4%. The extreme flood years were occurred (41.7%)in 1883, 1884, 1885, 1891, 1919, 1957, 1967, 1984 and 2008 and severe flood years were experienced (25%) in 1882, 1887, 1896, 1902, 1963, and 2006. (Table,5)

Table, 5: Severity of Flood and their SPI for Station Mannar-1881-2015

Flood Years	SPI	Severity	Flood Years	SPI	Severity
1882	1.50	S	1931	1.01	M
1883	**2.09**	**E**	**1939**	**1.05**	**M**
1884	2.08	E	1957	2.01	E
1885	2.28	E	1963	1.59	S
1887	1.51	S	1967	2.14	E
1891	2.55	E	1979	1.07	M
1896	1.53	S	1984	2.19	E
1902	1.65	S	2004	1.01	M
1918	1.22	M	2006	1.50	S
1919	2.08	E	2008	2.69	E
1922	1.00	M	2011	1.03	M
1923	1.07	M	2015	2.23	E

E- Extreme Flood Years, S- Severe Flood Years, M- Moderate Flood Years

Drought years and its SPI for station Jaffna is given in Table, 6. SPI demonstrates the intensity of drought years.

Table, 6: Severity of Droughts and their SPI for Station Jafffna-1881-2015

Drought Years	SPI	Severity	Drought Years	SPI	Severity
1889	-1.54	S	1952	-1.02	M
1890	-1.39	M	1953	-1.04	M
1892	-1.42	M	1955	-1.02	M
1894	-1.15	M	1961	-1.00	M
1904	-1.02	M	1964	-2.03	E
1905	-1.00	M	1968	-1.69	S
1907	-1.00	M	1974	-2.07	E
1908	-1.12	M	1980	-1.05	M
1909	-1.02	M	1982	-1.00	M
1910	-1.02	M	1989	-1.02	M
1915	-1.51	S	1991	-1.12	M
1916	-1.21	M	1992	-1.19	M
1927	-1.01	M	1996	-1.30	M
1936	-1.33	M	1997	-2.00	E
1947	-1.10	M	2005	-1.02	M
1950	-1.39	M	2012	-1.01	M

E- Extreme Drought Year, S- Severe Drought Year, M- Moderate Drought Year

Out of 135 years, a negative anomaly was 53% (72 years), according to SPI categorization the drought years are stated in table, 6. The extreme droughts were occurred in1964, 1974and 1997. Severe droughts were noticed in 1889, 1915 and 1968. About 83% of drought occurrences in Jaffna were moderate. Years 1890, 1892, 1894, 1904, 1905, 1907, 1908, 1909, 1910, 1916, 1927,1936, 1947, 1950, 1952, 1953, 1955,1961, 1980, 1882, 1989, 1991,1992,1996, 2005 and 2012 were moderate drought. Jaffna region has ground water potential due to formation of Miocene and quaternary sedimentary bedrock. Thus, there is an opportunity to utilize underground water during drought season.

The flood years of Jaffna and theirSPI values are given in table, 7. Out of 135 years of rainfall anomaly years about 47% (63 years) were noticed as positive rainfall anomaly(Fig.5), based on the SPI classification flood years and its severity were identified. The extreme flood occurred in 1891, 1939, 1943, 1957 and 2001. Severe flood were prevailed 1882, 1903, 1906, 1932, 1984, 1993 and 2008. Table, 7 and shown the flood severity. The station Mannar and Jaffna results revealed that the severities of drought and flood are higher at Mannar than Jaffna.

Table, 7: Severity of Floods and their SPI for Station Jafffna-1881-2015

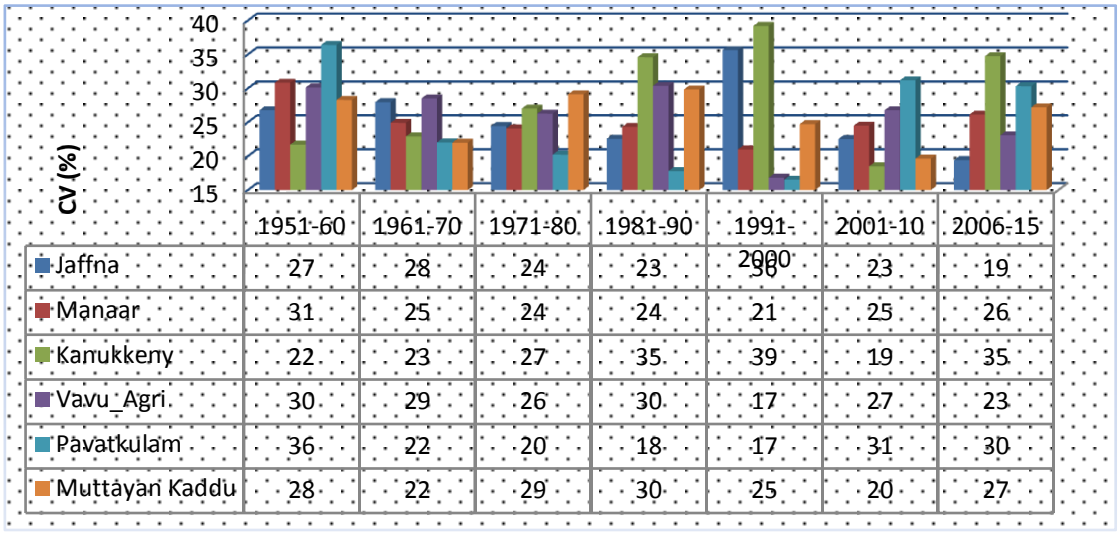
Flood Years	SPI Value	Severity of Flood	Flood Years	SPI Value	Severity of Flood
1882	1.57	S	1935	1.25	M
1883	1.32	M	1939	2.24	E
1884	1.41	M	1941	1.08	M
1885	1.40	M	1943	2.36	E
1891	2.08	E	1944	1.07	M
1898	1.06	M	1957	2.05	E
1902	1.01	M	1967	1.05	M
1903	1.71	S	1969	1.01	M
1906	1.68	S	1984	1.86	S
1911	1.38	M	1993	1.89	S
1913	1.30	M	1998	1.07	M
1920	1.25	M	1999	1.19	M
1930	1.28	M	2001	2.05	E
1931	1.36	M	2008	1.60	S
1932	1.78	S	1944	1.01	M

E- Extreme Flood Years, S- Severe Flood Years, M- Moderate Flood Years

6. DECADAL TRENDS AND VARIABILITY

In South Asia, mean rainfall shows inter-decadal variability, noticeably a declining trend with more frequent deficit monsoons under regional in homogeneities (Hijioka et.al. 2014). Some of the studies indicate that the annual rainfall over major part of Sri Lanka has shown decreasing trend from 1961-1990 (Fernando and Chandrapala, 1995). Present study revealed some decades have decreasing trend in annual rainfall and some other decades have increasing trend. The analysis results indicates that the decadal annual rainfall has decreasing tend in the decades of 1881-1890, 1901-1910, 1921-30, 1931-40, 1971-80 and 1981-90, and increasing trend in the decades of 1891-1900 and 1951-1960. Decadal liner trend line with r^2 values is shown in Fig. 6.

Fig.7: Decadal Variability of Annual Rainfall for Selected Decades



	1951-60	1961-70	1971-80	1981-90	1991-2000	2001-10	2006-15
Jaffna	27	28	24	23	36	23	19
Manaar	31	25	24	24	21	25	26
Kanukkeny	22	23	27	35	39	19	35
Vavu_Agri	30	29	26	30	17	27	23
Pavatkulam	36	22	20	18	17	31	30
Muttayan Kaddu	28	22	29	30	25	20	27

Coefficient of Variation of annual rainfall for the selected decades from 1951-60, 1961-70, 1971-80, 1981-90, 1991-2000, 2001-2010 and 2006-2015 is shown in Fig.7. In the decade of 1951-60, average annual rainfall was 1226mm and its CV 26.3%, however the variability is observed between the stations, higher rainfall variability was noticed at Pavatkulam (36%) and lover value (22%) recoded at Kanukkeny (Fig.7). During the decade of 1961-1970 above normal rainfall was received. Average rainfall of this decade was 1285mm which 52mm higher than the long term mean; consequently rainfall variability significantly declined in this decade (CV, 21.6%) and ranges among the stations was 22%-29%. In the decade 1971-80, average annual rainfall was 1148mm and higher rainfall CV was reported at Muttayankaddu (29%) lower in Pavatkulam. During the decades of 1981-90 and 1991-2000 significant variability was reported among the stations (Fig.7). CV of station Kanukkeny was increased noticeably as 35% and 39% in both decades respectively. Decade 2006-2015 has overlapping years with decade 2001-2010. Average rainfall of the decade 2006-2015 was higher (1385mm) than the normal (+152.6mm) due to heavy rainfall was occurred in the year 2014(1718.3mm) and 2015 (1655.6mm) and their SPI was 2.07(Extreme flood) and 1.83 (Severe flood) respectively. Also the year 2010 was above normal rainfall (1375mm) with moderate flood condition and 2011 extreme flood (1755mm) not only in NRSL but also the entire North eastern part of Sri Lanka. The higher rainfall variability was noticed at Pavatkulam (31%) in 2001-2010 and Kanukkeny (35%) in 2006-20015 (Fig. 7).

7. CONCLUSION

This study was under taken to study the inter-annual, decadal variability and trend of long term rainfall in the NRSL, Thecoefficient of variation annual rainfall of this study area is spatially varies from 24.8% to 33.1%, significant inter-decadal variability was reported among the station, higher decadal variability were observed in the Eastern part during the decade of 1991-2000 (39%) and 1981-1990 (35%) and lesser variability was reported in the South eastern part.Out of 135 years analysis 40 years were experienced flood. Once in 3yers a floodcould be possible. The extreme flood years were occurred in 1913, 1922, 1957, 1984, 2011, 2014, 1963, and 2015. The

year 2011 was extreme food year as well as La-Nina event. Similarly the years, 1883, 1891, 1894, 1902, 1931, 1934, 1943, 1969, 1993, 2008, and 2015were experienced severe floods. There were six La-Nina events and fifteen El-Nino events within the flood years. Flood years of 2008, 1943 and 1934 were associated with La-Nina events. The years 2015, 1931, 1902 and 1891were severe flood as well as El-Nino years. Out of 135 years 20 years were drought. The extreme and severe droughts were occurred in 1900, 1905, 1950, 1903, 1926, 1952, 1968, 1974 and 1980. The probability of drought years is 0.150, once in 6-7 years a drought could be possible. The extreme drought year of 1900, severe drought years of 1903, 1926, 1952and1980, is coincide with El Nino episodes. The station Mannar and Jaffna results revealed that the severities of drought and flood are higher at Mannar than Jaffna. The decadal variability and trend results revealed that the decreasing rainfall trend was noticed in the decades of 1881-1890, 1901-1910, 1921-30, 1931-40, 1971-80 and 1981-90 and increasing trend was observed in the decades of 1891-1900 and 1951-1960. The study revealed that the occurrences of flood years are more (30%) than the drought years (15%). Out of 135 years, more than half of the period (55%) was normal years.

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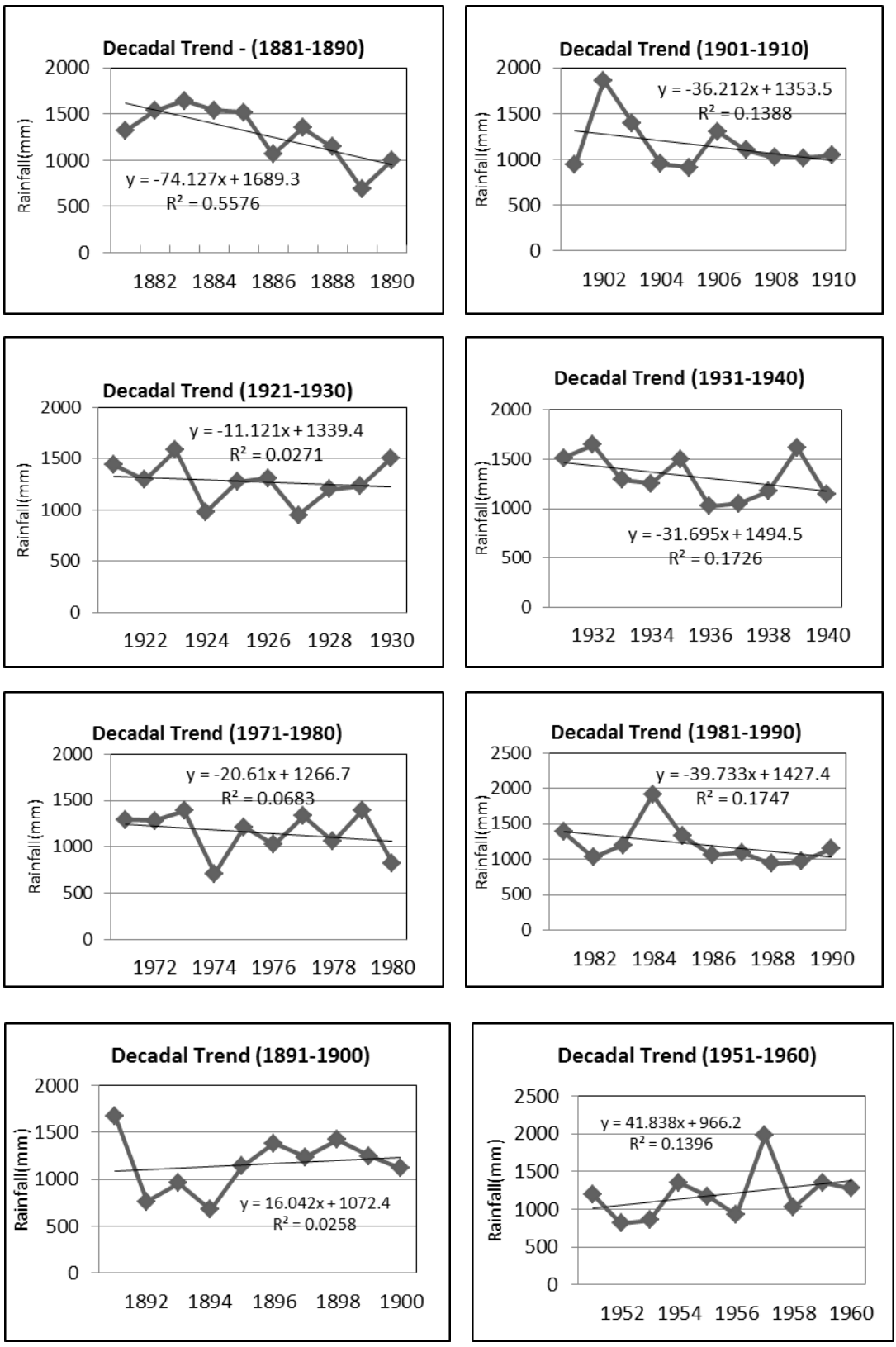

Fig. 6Annual Rainfall Trends for different Decade in NRSL