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Sri Lankan Rainfall Climate and its Modulation by El Niño and La Niña Episodes

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Abstract: Seasonal and inter-annual rainfall variations have profound influence on sectors of engineering concern such as water resources, agriculture, energy, fisheries, environment and construction. One of the dominant mechanisms of global inter-annual climate variability is the El Nino-Southern Oscillation (ENSO). ENSO is a shift in the pattern of oceanic warming and atmospheric circulation centered in the Pacific Ocean with implications on the climate across the tropics. Anomalously warm sea surface temperatures in the equatorial Eastern Pacific is referred to as El Nino phase and its cold analogue is referred to as La Niña. Here, the historical relationship of ENSO to Sri Lankan rainfall is described. Ranking both the seasonal Sri Lankan rainfall and its contemporaneous ENSO index shows a modest but significant association in the January to March, May, July to August and October to December periods. El Nino leads to wetter conditions during May, October, November and December and to drier conditions during January, February, March, July and August. Except for January to March the impacts of La Niña are inverse of that for El Nino. The rainfall during this period declines for both El Nino and La Niña. This relationship between rainfall and ENSO during October to December, January to March and July to August are statistically significant. This association can be used to predict the rainfall during the planting phase and the harvesting phase of the Maha (October to March) and during the harvest season of Yala (April to August). Rainfall predictions can be provided 3-6 months in advance based on the availability of ENSO predictions. The predictability has implications for agriculture, irrigation engineering, hydro-electricity generation and demand, construction planning and disaster risk for planning, operational management and policy formulation.

Keywords: Rainfall, ENSO, Predictability, Yala, Maha

1. Introduction

The rainfall in Sri Lanka is important as it affects many sectors such as agriculture, water resources, fisheries, infrastructure and tourism and in inducing disasters ([22- 29]). The bimodal rainfall over Sri Lanka is related to the pattern of solar radiation forcing the atmosphere around the regions of its 6-10 oN latitude. The seasonal tilt of the earth with respect to the sun is such that solar radiation over the surrounding seas and the ensuing convection is maximized around April to May and October to November. A central mountain massif that approximates an anchor, lies with its arm located along the centre of the southern part of the island. Rainfall in the western part of the island is augmented by orographic influences due to the rapid and moist Westerlies from April to October. Rainfall in the Eastern hill slopes is enhanced due to the North-easterlies from November to March.

On top of the seasonal variation, there are also inter-annual variation changes driven by the variability of the oceanic and land surfaces and volcanic activity. Oceans dominate the earth's surface and atmospheric energy budgets, and the dominant mechanism of tropical inter-annual variability is related to the variations in the largest Pacific Ocean - the El Nino-Southern Oscillation (ENSO) mechanism.

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ENSO is a shift in the pattern of oceanic warming and atmospheric circulation centered in the Pacific Ocean with implications across the tropics that recurs typically 2 to 7 years apart. Anomalously warm sea surface temperatures in the equatorial Eastern Pacific is referred to as El Niño phase and its cold analogue is referred to as La Niña.

The influence of ENSO on the South Asian climate system differs by season: while the summer (June to September) rainfall in Northern India decreases with the El Niño, it increases in Sri Lanka and Southernmost India from October to December ([13], [14], [18]).

Previous analyses of ENSO-rainfall relationships for Sri Lanka have been provided ([13], [3], [11], [15], [16-18], [6], [8], [30]). Many of these analyses were based on meteorological seasons on wind-directions which range in duration from two to five months. However, these meteorological seasons do not line up well with the traditional agricultural seasons ([4], [20], [22], [9]), each year predictions are needed [24] for the seasonal planning ("Kanna") meeting which is conducted in March and September.

The predictability of streamflow has been investigated using the principal component regression scheme in a cross validated mode taking the principal components of sea surface temperature (SST) as the predictors [2]. This has resulted in skillful predictions in Yala and Maha seasons. A significantly correlated rainfall and ENSO means higher degree association between the two parameters will thus result in high predictability using the SST predictors.

At present, several forecast centers issue skillful predictions of the seasonal evolution of tropical (SST) six months in advance [5]. Thus relationships between rainfall and ENSO can be exploited to predict seasonal rainfall.

Here, we consider the agricultural season along with the annual cycle of ENSO influence to choose the seasons that give the highest utility and predictability. Note, also that from the point of view of users, it is useful to quantify all ENSO based relationships even when these are weak, as they may have profound implications in their respective sectors. This paper provides an evaluation of the association between ENSO and Sri Lanka rainfall through correlation analysis, composite analysis and ranked rainfall and ENSO indices.

2. Data and Methods

2.1 *Rainfall Data:*

The monthly data for 16 observatories were obtained from the Sri Lanka Department of Meteorology from 1869 to 1998 (Fig. 1). A rainfall index for the entire island was constructed by averaging the monthly rainfall for these stations. In addition, regional rainfall indices were constructed by averaging the rainfall of stations falling within climatically homogenous regions that are described in section 3. Basic statistics for rainfall are provided on a seasonal and regional basis (Table 1 and Fig. 2). Rainfall anomaly is the departure of rainfall from its long-term average and ranked rainfall anomalies are presented in table 3.

2.2 *ENSO Index:*

An ENSO index in common use known as NINO3 had been constructed as the average SST anomaly for the eastern equatorial Pacific Ocean region of (90oW - 150 oW, 5oS to 5oN) [6]. The ENSO phases are defined as: El Niño (NINO3 > 0.5oC), La Niña (NINO3 < 0.5oC) and Neutral phases (-0.5o <NINO3 < 0.5oC) [13], [14].

2.3 *Composite Analysis:*

Composites of rainfall for three regions and all Sri Lanka are shown in Fig. 2, and composites of rainfall are also presented for the El Niño, Neutral and La Niña phases (Fig.3).

2.4 *Correlation Analysis:*

The Pearson correlation coefficient was used to identify relationships between ENSO indices and rainfall [10]. A correlation was taken to be significant when the no-correlation null hypothesis was exceeded with a probability of 95%.

3. Climatology

3.1 *Mean annual cycle:*

The mean annual cycle of rainfall in Sri Lanka is bimodal ([12], [19], [24]), with a major mode from October to December and a subsidiary mode from April to June (Fig. 2). The October to December rainfall coincides with the commencement of the main cultivation season of Maha (October to March). The April to June rainfall coincides with the commencement of the subsidiary cultivation seasons of Yala (April to August) [22]. The rainfall peaks coincide with the passage of the Tropical Convergence Zone (TCZ) over the island [17]. Rainfall during these seasons is relatively high throughout the island. During other periods, there is regional variability primarily due to orographic and cyclonic influences.

3.2 *Cyclonic Influences:*

From November to January, storms and cyclones are steered towards North-Eastern Sri Lanka by prevailing North-easterlies and affect the rainfall particularly along the North-Eastern coast.

3.3 *Orographic Influences:*

An anchor shaped central mountain massif runs North-South in Southern Sri Lanka. The rainfall in the Western region is enhanced from April to October due to orographic rainfall on the windward side of this mountain ridge during the South-West monsoon. Similarly, there is enhanced orographic rainfall in the Eastern side from November to February during the North East monsoon [21].

3.4 *Regionalization:*

The character of the annual climatology by region (Fig. 2) confirms that there are distinct rainfall characteristics for each region [12]. The Plains region may be divided between the Northern and Southern lobes. The Western and Eastern region may be further divided into the coastal (<200 m) and hill (>200 m) (Fig. 1). This regionalization differs from the demarcation into dry, wet and intermediate zones which is based on the annual total rainfall and does not segregate the island into regions that distinguish the contrasting seasonality in different parts of Sri Lanka due to dominance by different rainfall mechanisms [24], [30]. Accordingly, the "Plains" region includes the stations at Jaffna, Mannar, Anuradapura, Puttalam and Hambantota. The "Eastern" region includes Trincomalee, Batticaloa, Ampara Tank, Badulla and Diyatalawa. The "Western" region includes Kurunegala, Kandy, Nuwara Eliya, Colombo, Ratnapura and Galle (Fig. 2 and Table 1).

3.5 *Seasons:*

Up to the early 20th century, meteorologists demarcated seasons as the North-East monsoon (November to March) and South-West monsoon (April to October). This demarcation was revised so as to introduce two additional intervening seasons termed "Inter-Monsoons"; Since that period, the following seasons have been used in meteorological analysis: December to February, March to April, May to September, and October to November [1]. While, these are useful for analysis of some meteorological properties such as temperature and wind, they do not match well with the agricultural seasons of *Maha* (October to March) and *Yala* (April to August).

The consistent ENSO influences for October to December, January to March, April to June and July to August suggests a quarterly breakdown of seasons that correspond to the planting phase and harvest phase of *Maha* and *Yala*. Therefore, here we describe the ENSO influence by quarters starting in October.

4. ENSO-Rainfall Relationships

The composite rainfall is constructed by averaging rainfall values when only the particular ENSO phase was prevalent.

4.1 *October to December:*

October is the start of the main Maha cultivation season and the entire island gets high rainfall. The Plains region get 60% of its rainfall during these three months and this percentage drops slightly in the Eastern and Western regions to about 45% (Table 1).

ENSO indices provide strong correlations (Table 2) and the significance of these correlations was at the 99% level in all regions. During the 35 seasons in which the El Niño phase prevailed, 23 had rainfall in the above normal tercile (Table 3a). Note, that there is a slight drop of predictability in the Eastern Hills region that is subjected to orographic rainfall. Based on these correlation values and contingency table, the rainfall in early Maha has high predictability.

4.2 *January to March:*

This is the harvesting phase of the Maha season and it is generally a dry period in the entire island. The seasonal rainfall has inverse correlations with NINO3 that was significant at the 5% level.

The rainfall in all regions shows significant correlations with ENSO save the coastal Eastern region (Table 2). While the overall correlation between NINO3 and rainfall for the entire record is modest, an examination of the annual climatology (Fig. 3) shows that the rainfall during La Niña and particularly during El Niño phases is diminished in comparison to that during the Neutral phase. This relationship leads to low correlation values that mask the actual predictability. Of the 43 wettest tercile of seasons, 30 had neutral ENSO conditions (Table 3b).

The diminishment of predictability in the Eastern coast is likely due to cyclonic storms from the Bay of Bengal that pass on to this coast.

4.3 April to June:

This is the start of the subsidiary Yala cultivation season and most of the island gets high rainfall. This period accounts for 24% of the annual island-wide rainfall. The negative rainfall correlations with NINO3 indices are significant at the 5% level except for the Eastern record (Table 2).

In the last three decades this correlation has dropped to insignificant levels due to a drop of the ENSO influence on the rainfall of April and June but not May (Table 2). Of the 43 seasons that accounts for the wettest tercile, 18 were in the El Niño phase whereas 14 are assumed by chance (table 3c). This is a small tilt of the odds due to ENSO. In contrast to the weak relationship between ENSO and rainfall during the April to June season, the May ENSO-rainfall correlation has strengthened since then to 5% significance levels. Of the 43 seasons that account for the wettest tercile, 22 were in the El Niño phase (Table 3d).

4.4 July to August:

This is the harvest phase of the Yala season and it is generally a dry period in the entire island except in the South-West. September is a transitional month from a dry to a wet period and form and between periods of opposing ENSO influences: the rainfall in the latter half of September has characteristics akin to the October to December season and thus is omitted from this analysis. The July-August rainfall has a NINO3 correlation (r=-0.29) that is highly significant. Of the 43 seasons that accounts for the wettest tercile, 18 were in the La Niña phase whereas only 14 would be expected by chance (Table 3e). Similarly, of the 43 driest tercile of seasons, 18 were coincident with the El Niño phase.

5. Discussion

The ENSO rainfall correlation during Yala is greater outside the Western region which garners orographic rainfall in this season. Orographic rainfall and cyclonic storms in Sri Lanka diminish the correlation between ENSO and rainfall. For instance, the Eastern region receives cyclonic storms from the Bay of Bengal and orographic rainfall from November to January: the ENSO correlations are diminished for the Eastern region during this period. Similar The Western region receives orographic rainfall when the westerlies are strongest from July to August and the ENSO correlations are diminished in the Western region.

The predictability based on ENSO for rainfall is robust from October to December. Even while, the predictability is modest for rainfall from January to September, the accumulation of modest influence of ENSO over January to March and July to August leads to profound implications for various sectors. For example, there is reduction of stream flow for Yala during El Niño episodes [24]. The rice cultivation in the Yala (April to August) season is significantly reduced during El Niño period [22]. As the role of regional land surface and Indian Ocean sea surface conditions in modulating the climate is understood, then the predictions scheme presented here based on ENSO is likely to be improved.

6. Conclusions

The seasons that show consistent ENSO-rainfall relationships were identified as January-March, May, July-August and October - December. During January to March and July to August, El Niño leads to drier conditions. During May and October to December, El Niño leads to wetter conditions. For La Niña, this relationship was inverted for all seasons except for January to March: the rainfall during both the El Niño and La Niña phases decline.

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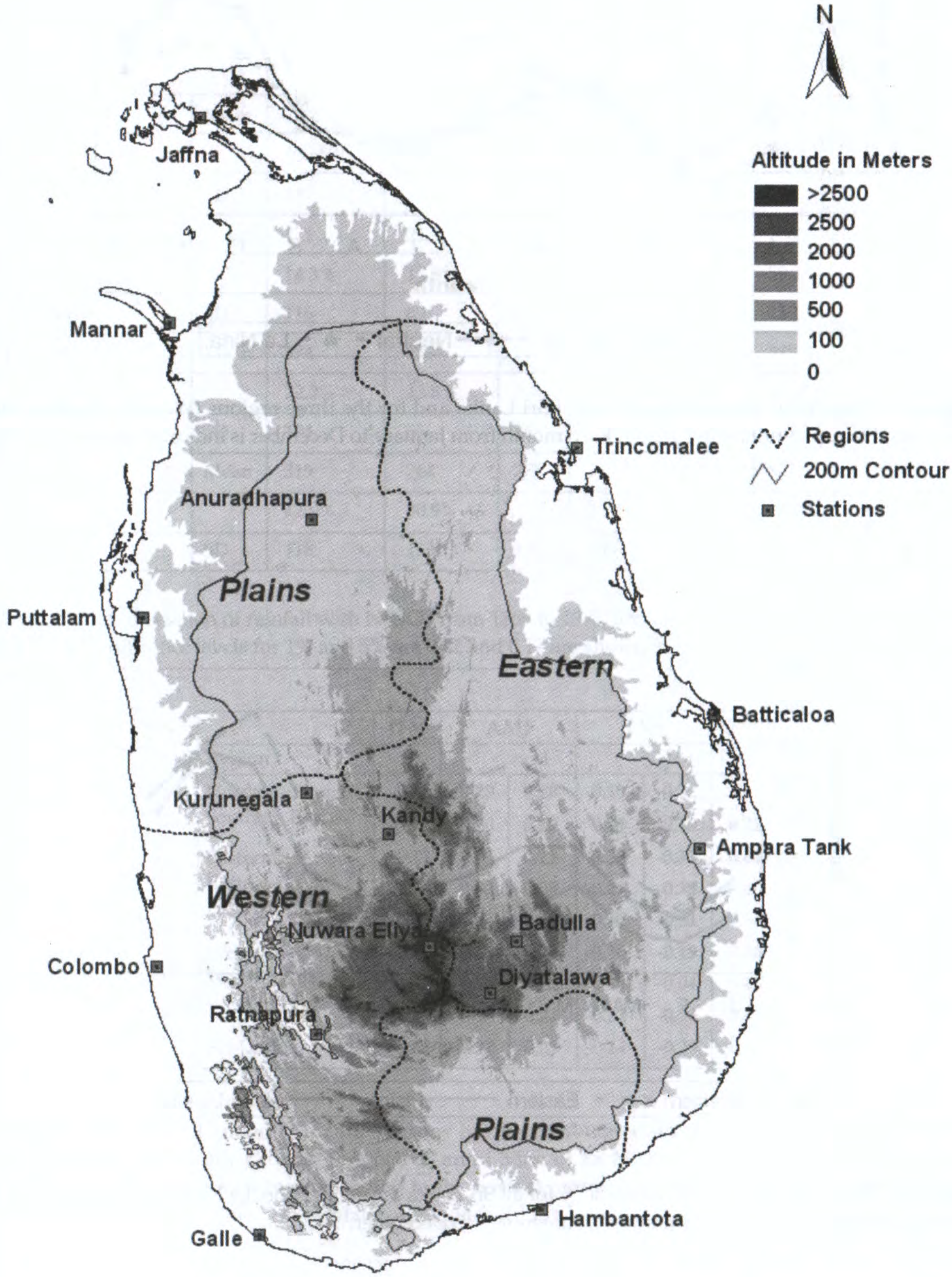

Figure 1: Topography, location of meteorological observatories, and regionalization for Sri Lanka. The 200 m contour that separates the low areas from the hilly areas is indicated.

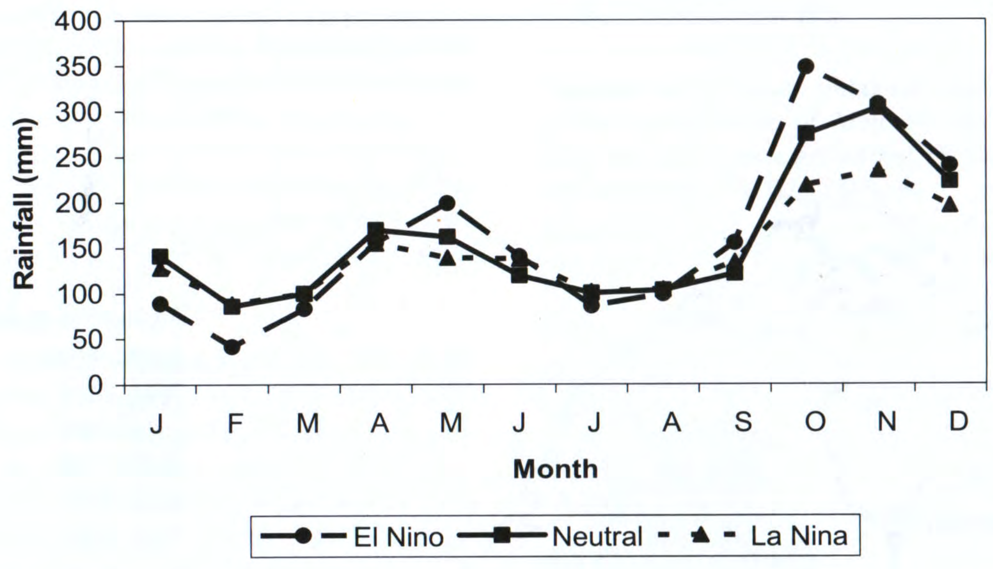

Figure 2: The rainfall climatology for all of Sri Lanka and for the three regions (Western, Eastern, and Northern Plains) identified in figure 1. Each month from January to December is indicated by its first letter.

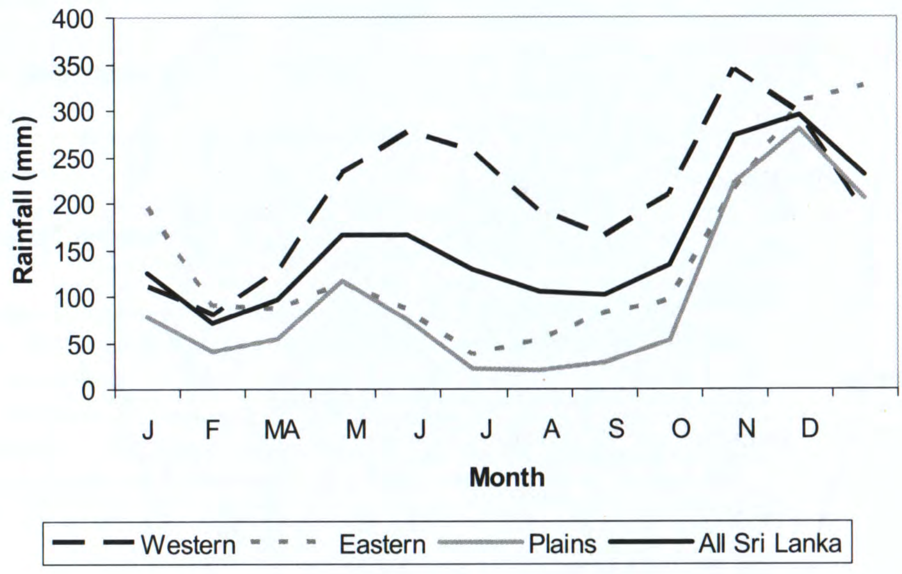

Figure 3: The composite rainfall climatology for all Sri Lanka during El Niño, La Niña and Neutral phases. The characters J to D stands for months from January to December.

Table 1: The mean, standard deviation (SD) and percent of annual rainfall for quarterly and annual rainfall for all of Sri Lanka and for the three climatic regions are provided in mm. Details are provided for May (M) and July to August (JA) periods as well.

Region		JFM	AMJ		JAS		OND	Total
				M		JA		
Sri Lanka	Mean	292	460	165	340	207	799	1891
		15.4%	24.3%		17.9%		42.2%	100%
	SD	127	101	76	95	67	184	217
Plains	Mean	171	212	74	100	49	706	1191
(Northern and		14.3%	17.8%		8.4%		59.2%	100%
Southern)	SD	116	89	62	58	40	210	230
Eastern	Mean	374	233	84	227	133	848	1682
		22.2%	13.8%		13.5%		50.4%	100%
	SD	194	65	44	78	58	227	282
Western	Mean	319	764	276	563	356	827	2473
		12.9%	30.9%		22.8%		33.4%	100%
	SD	118	163	125	169	125	180	285

Table 2: The correlation of rainfall with NINO3 from 1869 to 1998, for different regions. Correlation values that have significance levels for 1% and 5% are 0.22 and 0.17 are shown in bold and bold italics respectively (n=130).

	JFM	AMJ		JAS		OND
Region			M		(JA)	
Northern Plains	**-0.23**	**0.23**	**0.28**	**-0.19**	**-0.32**	**0.41**
Southern Plains	**-0.17**	**0.20**	**0.17**	**0.24**	-0.10	**0.41**
Eastern	-0.11	0.11	**0.22**	**-0.25**	**-0.37**	**0.44**
Eastern Coast	-0.04	0.02	0.09	**-0.25**	**-0.30**	**0.40**
Eastern Hills	-0.13	0.07	**0.23**	-0.15	**-0.31**	**0.34**
Western	**-0.20**	**0.18**	**0.25**	-0.10	**-0.19**	**0.46**
Western Coast	**-0.18**	**0.16**	**0.22**	0.11	-0.04	**0.45**
Western Hill	**-0.17**	**0.18**	**0.23**	**-0.22**	**-0.26**	**0.48**
Sri Lanka	**-0.18**	**0.22**	**0.29**	-0.14	**-0.29**	**0.51**

Table 3: The rainfall anomaly for the seasons has been tabulated according to rank along with the NINO3 value and whether it was assigned as an El Niño or La Niña year. The rainfall departures are presented in three columns corresponding to the wettest, normal and driest terciles of years. Rainfall anomaly for a period is equal to rainfall for the period-long term average rainfall for the same period.

Table 3a: Ranked rainfall anomalies for Sri Lanka, corresponding NINO3 index and ENSO condition during the October to December season. (EC - ENSO Condition, E - El Niño, L - La Niña)

Wettest Tercile of Seasons				Normal Tercile of Seasons				Driest Tercile of Seasons			
Year	Rain mm	NIN03	EC	Year	Rain mm	NIN03	EC	Year	Rain mm	NIN03	EC
1957	232.9	1.1	E	1932	21.6	0.0		1871	-34.8	-0.1	
1891	167.9	0.1		1919	17.2	0.7	E	1926	-37.1	0.0	
1896	143.9	1.7	E	1982	17.2	2.8	E	1904	-37.8	0.8	E
1877	122.2	2.6	E	1922	15.9	-0.6	L	1980	-38.8	0.1	
1911	119.6	1.3	E	1943	14.2	-0.4		1874	-39.1	-1.0	
1887	107.9	0.2		1970	11.2	-1.3	L	1915	-40.1	-0.1	
1884	95.9	0.8	E	1939	10.6	0.3		1958	-40.1	0.1	
1902	95.2	1.6	E	1910	9.6	-0.6	L	1903	-41.1	-0.8	L
1913	94.9	0.8	E	1930	7.6	1.9	E	1934	-42.4	-0.1	
1946	93.9	-0.1		1954	7.2	-0.7	L	1929	-45.1	0.6	E
1993	89.9	0.4		1973	7.2	-1.5	L	1968	-45.8	0.5	E
1997	89.2	3.5	E	1899	6.6	1.4	E	1876	-46.1	0.4	
1967	86.6	-0.9	L	1961	3.2	-0.4		1996	-48.8	-0.4	
1963	85.6	1.0	E	1990	3.2	0.2		1989	-50.4	-0.1	
1885	81.9	0.7	E	1880	2.6	0.4		1901	-52.1	-0.1	
1994	70.9	1.0	E	1900	-0.8	0.4		1908	-53.1	-0.9	
1969	68.9	1.1	E	1936	-2.8	0.2		1937	-53.1	-0.3	
1906	66.2	-0.5	L	1942	-4.4	-1.6	L	1870	-53.4	-0.8	L
1931	65.2	-0.6	L	1875	-6.8	-0.8	L	1905	-54.8	1.5	E
1972	65.2	2.2	E	1953	-6.8	0.4		1981	-55.1	0.1	
1898	61.6	-0.7	L	1992	-7.1	0.0		1873	-57.1	-0.9	L
1895	59.9	0.7	E	1912	-9.4	0.0		1960	-57.1	-0.4	
1914	58.2	1.3	E	1966	-9.4	-0.3		1947	-61.1	-0.3	
1979	57.2	0.5		1907	-9.8	0.0		1917	-62.8	-1.0	L
1944	56.2	-0.6	L	1983	-10.4	-0.2		1995	-63.1	-0.6	L
1923	55.6	0.9	E	1971	-11.8	-0.9	L	1892	-63.4	-1.5	L
1965	55.2	1.5	E	1985	-14.4	-0.5	L	1924	-66.1	-0.7	L
1882	51.9	-0.6	L	1956	-16.4	-0.7	L	1909	-67.1	-1.1	L
1935	50.6	0.2		1975	-18.1	-1.2	L	1886	-69.8	-1.0	L
1925	47.9	1.3	E	1869	-19.4	-0.8	L	1964	-70.4	-0.9	L
1881	46.6	-0.3		1991	-20.4	1.2	E	1986	-71.4	1.0	E
1977	44.6	0.5		1921	-20.8	-0.2		1890	-71.8	-0.7	L
1940	41.6	1.0	E	1894	-21.1	-0.3		1952	-72.1	-0.3	
1918	38.6	1.8	E	1872	-22.4	-0.9	L	1984	-73.1	-0.7	L
1945	35.6	-0.1		1959	-22.4	0.0		1950	-76.8	-0.6	L
1976	35.2	1.2	E	1949	-23.1	-1.3	L	1955	-78.8	-1.5	L
1888	33.9	2.0	E	1893	-23.4	-0.7	L	1927	-82.4	0.3	
1978	29.6	0.0		1987	-24.4	1.4	E	1878	-87.4	-0.4	
1920	27.6	-0.1		1962	-25.4	-0.6	L	1988	-95.4	-1.5	L
1948	27.2	-0.4		1879	-27.1	-0.7	L	1889	-97.4	-1.1	L
1928	23.2	-0.2		1897	-30.1	-0.4		1916	-102.8	-1.2	L
1883	22.9	-0.1		1933	-30.4	-1.0	L	1974	-107.8	-0.4	
1941	22.6	1.5	E	1998	-30.8	-0.5	L	1938	-116.1	-0.8	L
				1951	-33.1	0.9	E				
Total	43	E-23	L-6	Total	44	E-7	L-19	Total	43	E-5	L-18

Table 3b: January to March. (EC - ENSO Condition, E – El Niño, L – La Niña)

Wettest				Normal				Driest			
May Year	Anomaly mm	NIN03	EC	May Year	Anomaly mm	NIN03	EC	May Year	Anomaly mm	NIN03	EC
1984	166.8	-0.2		1879	14.5	0.0		1949	-24.5	-0.2	
1913	116.2	0.2		1893	12.2	-1.3	L	1914	-25.5	0.8	E
1934	92.2	-0.5	L	1908	11.2	-0.2		1929	-25.5	0.0	
1986	84.5	-0.4		1928	10.5	0.0		1900	-26.5	1.3	E
1938	84.2	-0.5	L	1965	8.2	-0.3		1956	-26.8	-0.5	L
1917	78.2	-1.3	L	1967	7.8	-0.2		1968	-27.8	-1.1	L
1927	77.2	0.2		1915	7.2	1.5	E	1987	-29.2	1.3	E
1925	76.2	-0.5	L	1869	6.8	0.8	E	1969	-29.2	0.7	E
1871	71.8	-0.3		1995	6.2	0.6	E	1932	-29.5	0.1	
1933	71.2	0.0		1882	6.2	-0.4		1903	-29.8	0.9	E
1951	67.2	-0.1		1958	5.8	1.1	E	1910	-30.2	-1.0	L
1963	65.5	-0.2		1918	5.2	-0.7	L	1894	-31.2	-0.7	L
1944	65.2	-0.1		1943	4.8	-1.1	L	1875	-32.2	-0.6	L
1923	63.8	-0.2		1899	2.5	-0.4		1976	-32.2	-1.0	L
1955	60.5	-0.4		1962	1.8	-0.3		1981	-33.5	-0.5	L
1960	56.2	0.1		1946	1.2	-0.3		1885	-34.5	0.5	E
1954	55.2	0.0		1966	-2.8	0.8	E	1998	-35.2	2.8	E
1892	51.8	-0.1		1941	-3.2	2.0	E	1872	-35.8	-0.5	L
1947	51.5	0.1		1975	-3.8	-0.3		1945	-36.2	-0.5	L
1994	47.8	0.1		1950	-3.8	-1.1	L	1911	-36.2	-0.7	L
1937	44.2	0.2		1896	-5.5	0.4		1906	-36.8	0.9	E
1952	38.2	0.4		1881	-7.2	0.3		1887	-37.5	-0.8	L
1990	36.2	0.0		1909	-7.2	-0.7	L	1905	-38.2	1.0	E
1878	35.5	2.4	E	1886	-9.2	-0.2		1979	-38.5	0.0	
1970	35.5	0.7	E	1920	-10.8	1.1	E	1959	-38.8	0.0	
1961	32.2	-0.1		1922	-10.8	0.0		1916	-39.5	-0.6	L
1870	32.2	-0.7	L	1935	-11.8	-0.5	L	1895	-40.2	-0.2	
1924	23.5	0.7	E	1907	-12.5	-0.3		1877	-41.2	0.7	E
1930	22.5	0.1		1874	-12.5	-1.0	L	1884	-41.5	-0.1	
1964	22.2	0.1		1873	-13.5	-0.8	L	1989	-44.2	-0.9	L
1936	20.8	0.2		1988	-13.8	0.5	E	1876	-45.8	-1.0	L
1891	20.8	0.1		1978	-14.8	0.3		1974	-48.2	-1.0	L
1921	20.8	-0.7	L	1926	-16.8	1.3	E	1973	-49.2	1.2	E
1953	19.5	0.3		1890	-16.8	-1.0	L	1982	-51.8	0.2	
1985	18.2	-0.8	L	1996	-17.2	-0.4		1912	-53.5	1.1	E
1901	17.5	0.1		1919	-18.2	1.5	E	1993	-55.8	0.3	
1904	17.5	-0.4		1942	-18.8	0.5	E	1997	-59.2	-0.2	
1991	16.8	0.2		1948	-18.8	0.2		1940	-60.2	1.2	E
1931	16.2	1.6	E	1957	-19.2	0.1		1972	-64.2	-0.2	
1902	16.2	0.4		1897	-21.2	1.4	E	1888	-65.2	0.6	E
1971	15.8	-1.3	L	1977	-22.5	0.8	E	1980	-70.5	0.3	
1883	15.2	-0.4		1898	-22.5	-0.4		1983	-74.8	2.8	E
1880	15.2	-0.6	L	1889	-23.5	1.7	E	1992	-79.2	1.5	E
				1939	-23.5	-0.7	L				
Total	**43**	**E- 4**	**L-9**	**Total**	**44**	**E- 14**	**L-10**	**Total**	**43**	**E- 16**	**L-15**

Table 3c: April to June. (EC - ENSO Condition, E – El Niño, L – La Niña)

Rainfall Anomalies, NINO3 anomalies											
Wettest Tercile				Normal Seasons				Driest Seasons			
Year	Anomaly	NIN03		Year	Anomaly	NIN03		Year	Anomaly	NIN03	
1995	82.9	-0.03		1984	16.6	-0.26		1924	-17.4	-0.36	
1940	79.9	1.27	E	1962	15.6	-0.45		1937	-18.4	-0.03	
1933	75.6	-0.21		1903	14.6	-0.03		1898	-19.1	-0.18	
1959	74.9	0.23		1975	14.3	-0.45		1967	-19.1	-0.23	
1930	72.3	0.50	E	1988	13.6	-0.93	L	1956	-19.4	-0.32	
1891	70.6	0.60	E	1961	13.3	0.50	E	1948	-21.1	0.08	
1943	62.9	0.13		1901	12.9	-0.11		1981	-22.1	-0.18	
1888	57.9	0.74	E	1997	11.9	1.34	E	1994	-23.4	0.21	
1878	50.6	1.41	E	1897	9.9	0.25		1928	-25.4	0.20	
1877	49.9	1.33	E	1996	8.6	-0.31		1968	-25.4	-0.37	
1951	46.9	0.38		1969	8.3	0.87	E	1973	-25.7	-0.58	L
1939	43.9	0.04		1957	4.9	0.80	E	1980	-27.1	0.42	
1889	42.6	0.64	E	1944	3.9	0.18		1869	-28.1	-0.02	
1899	41.9	0.48		1978	2.3	-0.47		1987	-28.4	1.40	E
1993	40.9	1.13	E	1949	1.6	0.06		1921	-30.7	-0.31	
1883	39.6	0.15		1932	0.6	0.60	E	1909	-30.7	-0.39	
1875	38.9	-0.65	L	1985	-0.1	-0.53	L	1881	-31.7	0.28	
1927	36.9	0.07		1963	-0.7	0.44		1938	-32.7	-0.54	L
1926	35.9	0.87	E	1922	-1.4	0.10		1913	-33.4	-0.10	
1920	35.6	0.91	E	1902	-2.4	0.90	E	1918	-35.1	0.50	E
1876	33.9	-0.56	L	1925	-3.7	0.45		1935	-36.4	-0.19	
1905	31.9	1.43	E	1904	-4.1	0.20		1979	-37.1	0.50	E
1929	31.3	0.37		1954	-4.1	-0.74	L	1880	-37.1	-0.15	
1982	30.9	0.90	E	1989	-4.4	-0.24		1894	-38.4	-0.45	
1955	30.3	-0.73	L	1896	-5.1	0.41		1946	-38.7	-0.27	
1942	29.3	-0.05		1970	-5.4	-0.24		1884	-39.1	0.41	
1916	27.3	-0.79	L	1998	-5.7	1.22	E	1945	-39.1	0.07	
1974	26.3	0.03		1965	-6.1	0.70	E	1947	-40.1	0.13	
1952	25.3	0.10		1890	-6.4	-0.52	L	1964	-40.1	-0.95	L
1900	24.6	0.94	E	1971	-6.7	-0.57	L	1923	-41.1	0.59	E
1885	24.6	0.23		1871	-7.4	-0.27		1906	-43.1	0.27	
1887	23.9	-0.24		1934	-7.7	0.22		1914	-44.4	0.77	E
1873	22.9	-0.49		1892	-8.4	-0.49		1910	-44.4	-0.94	L
1972	22.3	0.77	E	1990	-9.7	0.47		1870	-45.7	-0.37	
1912	21.6	0.47		1895	-11.1	0.13		1986	-51.4	0.03	
1977	21.6	0.13		1915	-11.4	1.29	E	1911	-51.4	-0.25	
1886	21.3	-0.61	L	1960	-12.1	-0.09		1953	-52.1	0.57	E
1941	20.6	1.86	E	1907	-12.4	0.22		1950	-52.1	-0.77	L
1931	19.9	0.69	E	1872	-13.1	-0.61	L	1966	-53.4	-0.06	
1893	17.6	-1.11	L	1879	-13.4	-0.11		1976	-57.1	0.29	
1958	17.3	0.43		1874	-13.4	-0.78	L	1983	-59.1	2.12	E
1991	16.9	0.79	E	1919	-13.7	0.88	E	1908	-59.4	-0.50	L
1992	16.6	1.32	E	1936	-14.7	0.03		1917	-63.7	-0.27	
				1882	-15.1	-0.42					
Total	43	E-18	L-6	Total	44	E-10	L-7	Total	43	E- 7	L- 6

Table 3d: May.. (EC - ENSO Condition, E – El Niño, L – La Niña)

Wettest				Normal				Driest			
Year	Anomaly	NIN03	EC	Year	Anomaly	NIN03	EC	Year	Anomaly	NIN03	EC
1933	250.6	-0.3		1994	23.6	0.4		1973	-45.4	-0.9	L
1930	219.6	0.4		1959	19.6	0.4		1897	-46.4	0.2	
1891	200.6	0.7	E	1974	19.6	0.1		1935	-46.4	-0.2	
1943	193.6	0.4		1912	16.6	0.5	E	1875	-48.4	-0.6	L
1926	179.6	0.9	E	1924	16.6	-0.5	L	1909	-48.4	-0.3	
1940	145.6	1.4	E	1882	15.6	-0.3		1947	-48.4	0.1	
1936	140.6	0.1		1879	13.6	-0.1		1906	-49.4	0.2	
1883	125.6	0.1		1965	12.6	1.0	E	1900	-51.4	1.0	E
1972	120.6	0.8	E	1937	11.6	-0.2		1914	-51.4	0.8	E
1993	117.6	1.4	E	1904	6.6	0.2		1890	-54.4	-0.4	
1916	115.6	-0.8	L	1939	2.6	0.1		1971	-56.4	-0.7	L
1978	108.6	-0.3		1984	2.6	-0.2		1980	-56.4	0.4	
1995	104.6	-0.1		1922	-0.4	0.2		1871	-57.4	-0.3	
1927	101.6	0.2		1970	-2.4	-0.2		1986	-59.4	0.0	
1977	101.6	0.3		1967	-4.4	-0.2		1908	-62.4	-0.5	L
1962	96.6	-0.5	L	1985	-4.4	-0.5	L	1988	-67.4	-1.0	L
1903	95.6	0.0		1963	-7.4	0.5	E	1892	-68.4	-0.4	
1886	80.6	-0.5	L	1915	-9.4	1.3	E	1979	-68.4	0.6	E
1941	80.6	1.9	E	1949	-9.4	0.3		1920	-69.4	1.0	E
1877	77.6	1.1	E	1954	-9.4	-0.8	L	1934	-71.4	0.2	
1932	74.6	0.7	E	1981	-10.4	0.0		1948	-72.4	0.1	
1888	65.6	0.9	E	1885	-11.4	0.2		1907	-74.4	0.2	
1952	64.6	0.1		1893	-12.4	-1.2	L	1872	-75.4	-0.7	L
1969	63.6	1.1		1918	-14.4	0.6	E	1869	-77.4	0.0	
1876	61.6	-0.5	L	1942	-14.4	0.1		1968	-77.4	-0.6	L
1998	61.6	1.6	E	1989	-14.4	-0.2		1870	-78.4	-0.4	
1997	60.6	1.4	E	1874	-15.4	-0.7	L	1911	-80.4	-0.2	
1889	58.6	0.7	E	1880	-16.4	-0.1		1928	-84.4	0.4	
1873	52.6	-0.4		1884	-18.4	0.5	E	1945	-85.4	0.2	
1992	51.6	1.7	E	1964	-19.4	-1.1	L	1917	-86.4	-0.3	
1961	46.6	0.3		1960	-20.4	0.0		1881	-87.4	0.3	
1919	39.6	0.9	E	1975	-20.4	-0.4		1895	-87.4	0.2	
1951	39.6	0.3		1901	-24.4	-0.1		1921	-88.4	-0.3	
1957	39.6	0.8	E	1983	-24.4	2.3	E	1910	-91.4	-1.0	L
1990	39.6	0.6	E	1896	-26.4	0.4		1976	-96.4	0.2	
1899	37.6	0.5	E	1929	-27.4	0.4		1946	-97.4	-0.1	
1955	37.6	-1.0	L	1987	-27.4	1.5	E	1938	-103.4	-0.5	L
1878	35.6	1.4	E	1925	-28.4	0.3		1956	-107.4	-0.3	
1944	34.6	0.2		1931	-28.4	0.7	E	1996	-112.4	-0.3	
1958	34.6	0.6	E	1887	-30.4	-0.1		1923	-114.4	0.7	E
1982	34.6	1.0	E	1898	-31.4	-0.2		1966	-125.4	-0.4	
1991	29.6	0.9	E	1902	-31.4	0.9	E	1894	-137.4	-0.6	L
1905	28.6	1.5	E	1950	-34.4	-1.1	L	1953	-151.4	0.5	E
				1913	-45.4	-0.2					
Total	43	E- 22	L-5	**Total**	44	E-10	L-7	**Total**	43	E- 6	L-10

Table 3e: The ranked rainfall departures for July-August. (EC-ENSO Condition, E-El Niño, L-La Niña)

Wettest Tercile				Normal Seasons				Driest Seasons			
Year	Anomaly	NIN03	EC	Year	Anomaly	NIN03	EC	Year	Anomaly	NIN03	EC
1878	110.5	0.7	E	1917	9.5	0.0		1958	-22.0	0.2	
1882	87.0	-0.8	L	1907	6.0	0.3		1991	-22.0	0.9	E
1947	80.5	-0.1		1975	6.0	-0.7	L	1898	-23.0	-0.5	L
1998	76.0	0.0		1939	5.5	0.2		1987	-23.5	1.6	E
1909	67.0	-0.4		1959	5.5	-0.5	L	1993	-23.5	0.3	
1933	66.0	-0.7	L	1946	4.0	-0.7	L	1896	-24.0	1.1	E
1953	64.0	0.4		1881	3.0	0.0		1983	-25.0	1.3	E
1949	63.5	-0.7	L	1904	3.0	0.7	E	1872	-25.5	-0.6	L
1886	62.5	-0.9	L	1950	1.5	-0.4		1976	-25.5	0.9	E
1916	59.5	-1.1	L	1954	1.5	-0.8	L	1884	-26.0	0.4	
1988	58.0	-1.6	L	1938	1.0	-1.0	L	1913	-26.5	0.3	
1900	56.0	0.7	E	1871	0.5	-0.3		1977	-26.5	-0.1	
1915	45.0	0.8	E	1874	0.5	-1.0	L	1979	-26.5	0.3	
1931	44.0	-0.2		1984	0.5	-0.4		1982	-26.5	1.1	E
1923	43.0	0.7	E	1919	-0.5	0.5	E	1891	-27.0	0.4	
1989	43.0	-0.2		1870	-1.5	-0.7	L	1957	-27.0	1.3	E
1910	41.0	-0.8	L	1967	-2.0	-0.5	L	1894	-28.0	-0.2	
1928	41.0	0.0		1902	-2.5	1.6	E	1936	-28.0	-0.1	
1924	40.5	-0.8	L	1876	-3.5	0.0		1890	-28.5	-0.7	L
1996	40.5	-0.1		1941	-4.0	0.6		1922	-29.0	-1.0	L
1883	37.5	0.2		1970	-4.0	-1.7	L	1978	-29.0	-0.7	L
1964	35.5	-0.9	L	1995	-4.0	-0.2		1951	-29.5	0.9	E
1869	33.5	-0.5	L	1880	-5.0	-0.3		1914	-33.0	0.9	E
1932	33.5	0.1		1981	-6.0	-0.5		1945	-33.5	-0.3	
1906	32.0	-0.5	L	1912	-8.0	-0.2		1972	-34.0	1.7	E
1892	30.0	-0.9	L	1973	-9.0	-1.2		1927	-34.5	-0.2	
1897	29.0	-0.1		1873	-11.0	-0.3		1966	-34.5	0.1	
1960	28.0	0.0		1877	-11.0	2.0	E	1925	-35.0	0.9	E
1879	26.0	-0.6	L	1968	-13.0	0.5	E	1952	-35.0	-0.4	
1942	24.5	-1.2	L	1887	-13.5	-0.2		1920	-35.5	0.2	
1971	24.0	-0.5	L	1948	-13.5	-0.3		1901	-37.0	-0.4	
1903	21.0	-0.5	L	1985	-13.5	-0.7	L	1986	-37.5	0.2	
1974	20.5	0.0		1885	-14.0	0.1		1930	-38.5	1.2	E
1963	19.5	1.0	E	1955	-14.5	-0.5	L	1918	-39.0	1.1	E
1921	19.0	-0.1		1895	-15.0	0.1		1980	-39.5	0.0	
1937	19.0	-0.4		1994	-16.0	-0.2		1940	-41.0	0.7	E
1997	17.0	2.7	E	1969	-17.0	0.5	E	1908	-43.5	-0.5	L
1962	15.5	-0.1		1893	-18.0	-0.8	L	1911	-45.5	0.5	E
1926	14.0	0.5	E	1943	-18.0	0.1		1929	-46.0	0.4	
1961	14.0	-0.5	L	1875	-18.5	-0.6	L	1899	-48.5	0.9	E
1992	14.0	0.1		1990	-18.5	0.1		1905	-50.0	1.5	E
1965	13.5	1.1	E	1944	-19.5	0.1		1888	-57.5	0.9	E
1889	10.5	-0.6	L	1956	-20.0	-0.4		1934	-63.0	0.2	
				1935	-20.5	0.1					
Total	43	E- 8	L-17	Total	43	E- 6	L-13	Total	43	E-18	L-6