

RESEARCH ARTICLE

Trends in extreme rainfall events in Sri Lanka, 1961–2010

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Submitted: 31 May 2018; Revised: 11 February 2019; Accepted: 28 March 2019

Abstract: Many parts of Sri Lanka are vulnerable to extreme rainfall events leading to floods and droughts. This study was focused on a trend analysis of climate extremes derived from daily rainfall records. The daily rainfall data from 13 meteorological stations representing different geographical regions in Sri Lanka for the period 1961–2010 were chosen. The analysis was carried out separately for summer half year (March-August) and winter half year (September-February) to capture the possible changes in two growing seasons, Yala and Maha. Magnitudes of trends were derived using linear regression analysis while the statistical significance was determined using the Mann-Kendall test. Spatial maps were used to study the regional differences in climate extremes. Extreme rainfall events were found to be isolated events without coherent increasing or decreasing trends. However, statistically significant increasing (decreasing) trends were observed for number of dry days (wet days) ranging from 1.1 to 3.1 days/decade in most parts of the island during the summer half year, except for the coastal areas of the dry zone. No increasing or decreasing trends in extremes were observed for the winter half year. Based on the analysis, it was concluded that there is widespread climate change leading to increasing (decreasing) dry days (wet days) during the summer half year receiving rainfall predominantly from the South-West monsoon. However, mixed results were obtained for the winter half year.


Keywords: Dry days, extreme events, monsoons, seasonal rainfall, wet days.

INTRODUCTION

An understanding of the characteristics of extreme rainfall events is important, as these events cause

extensive damages to the ecology, infrastructure, agriculture, economy, environment, human settlements, etc. (Coates, 1996). Studies conducted on extreme rainfall events worldwide demonstrate that changes in extreme events can result in significant impacts on the planning of physical infrastructure (Zin *et al.*, 2012). Investigating changes in intensity (amount) and duration (time span) of extreme rainfall events can assist in reducing risks associated with floods, droughts, hydropower generation etc. for Sri Lanka, as the country primarily depends on rainfall for agriculture and electricity generation.

Sri Lanka is an island located close to the equator. It is influenced by two monsoons and weather systems that originate within the inter-tropical convergence zone (ITCZ). The western, central and southern parts of the country experience wet and humid conditions throughout the year with the mean temperature ranging from 27 °C in coastal areas to 16 °C in the central highlands. The two monsoon seasons are the southwest monsoon (SWM - summer monsoon) from May to September and the northeast monsoon (NEM - winter monsoon) from December to February. During the SWM season, heavy rainfall is received by the low land areas in the south-western part of Sri Lanka and the western slopes of the hill country. The NEM brings rainfall to the northern and eastern parts of the country. The two inter monsoon seasons are from March to April (FIM - first inter monsoon season) and from October to November (SIM - second inter monsoon season). Weather systems such as convergence, convection and depressions bring intense rain during the inter-monsoon seasons. Extreme

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rainfall events are caused by tropical cyclones, slow-moving tropical lows from the Bay of Bengal, active and onset phases of the SWM and the NEM seasons and by local-scale thunderstorms during the inter-monsoon seasons. Linked to the two monsoons, there are two cultivation seasons, namely, Maha and Yala. The onset and retreat of the Maha season is defined from September to March of the following year while the Yala season is defined from May to August.

Many parts of Sri Lanka are vulnerable to extreme rainfall events such as floods and droughts during the monsoon seasons (SWM and NEM) and occasionally due to tropical depressions in the Bay of Bengal, particularly during the SIM season and the early part of the NEM season. The Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship reveals that droughts and floods affect up to 4 million people a year (Disaster Management Centre, 2009). Another study (Karunathilaka *et al.*, 2017) reported that the occurrence of extreme wind events connected to the rainfall seasons is on the rise especially from 2000 onwards. Extreme wind events experienced in 1978 and 2000 affected many people. The district of Batticaloa, which is located on the east coast of Sri Lanka, recorded a large number of casualties due to extreme wind events. In particular, the tropical cyclone of November 1978 caused extensive damage to human settlements, agriculture, ecology and infrastructure (Suppiah, 1982). Fatalities due to extreme weather conditions are more frequent in Sri Lanka during the SIM season and the loss of life is highest during the month of November due to extreme winds. Heavy rainfall can also result in inundation in low lying areas and landslides, especially in highland areas of Sri Lanka. Comparatively, higher loss of life per month is also experienced during the months of May and June, which is attributed to landslides and floods caused by heavy rainfall during the SWM season (Disaster Management Centre, 2009). The opposite of wet extremes is the occurrence of long dry spells. The Dry Zone, which occupies about two thirds of the country and encompasses lowlands of north, east, north central and southeast of Sri Lanka, receives less rainfall during the SWM season, compared to the Wet Zone which occupies the southwestern part of the country. Extended periods of dry spells during the growing seasons particularly impact rain fed agricultural crops and other related economic activities. Heavy agricultural losses due to drought conditions were reported in the Northwestern, Northcentral and Eastern provinces during the years 1965, 1974, 1981, 1985, 1993 and 2000 (Disaster Management Centre, 2005).

A number of studies have focused on climate variability and its possible impact on Sri Lankan climate during the instrumental period. The influence of extreme phases of the southern oscillation phenomenon on Sri Lankan rainfall anomalies was studied by Suppiah (1997), and a significant relationship has been found between the SWM and SIM rainfall and the Southern Oscillation Index (SOI). Punyawardena and Cherry (1999) demonstrated a link between seasonal rainfall in Ratnapura and the SOI and their extremes, which are associated with El Niño and La Niña events. Malmgren *et al.* (2003) examined long term (>100 years) precipitation trends in Sri Lanka and their relationship to El Niño events. Their analysis revealed statistically significant trends (both positive and negative) in some stations during the SWM season. Herath and Ratnayake (2004) studied short term (30 years) trends in rainfall in the central mountain region of Sri Lanka. They found a decreasing trend in the first inter-monsoonal rainfall and an increasing trend in the return period of extreme events. Niroshinie *et al.* (2012) investigated extreme flooding conditions around Colombo using data from a global circulation model (GCM). They found no significant differences in the characteristics of extreme events in the future compared to the present.

While most of the previous studies have focused on annual or seasonal rainfall variability over Sri Lanka (Rasmusson & Carpenter 1983; Zubair *et al.*, 2003; Jayawardene *et al.*, 2014; Karunathilaka *et al.*, 2017), only a few recent studies have focused on extreme rainfall events (Stolbova *et al.*, 2014; Sheikh *et al.*, 2015). The main objective of the present work is to investigate whether there is any deviation in the temporal and spatial characteristics of extreme rainfall events in Sri Lanka adversely affecting the two cultivation seasons, Yala and Maha, using daily rainfall data.

METHODOLOGY

Daily rainfall data were obtained from the Meteorological Department of Sri Lanka for 13 selected stations to cover different geographical regions. The stations are; Anuradhapura, Badulla, Batticaloa, Colombo, Galle, Hambantota, Jaffna, Kandy, Mannar, Nuwara Eliya, Puttalam, Ratnapura and Trincomalee. The topography of the country and the locations of the selected stations are shown in Figure 1. Except for Jaffna, Batticaloa and Mannar, all the other stations had only a few missing records during the period 1961 to 2010. For Jaffna, data are unavailable during the period from 1991 – 2001 (11 years), Batticaloa from 1966 – 1971 (6 years) and Mannar from 1989–1994 (6 years). Since the study

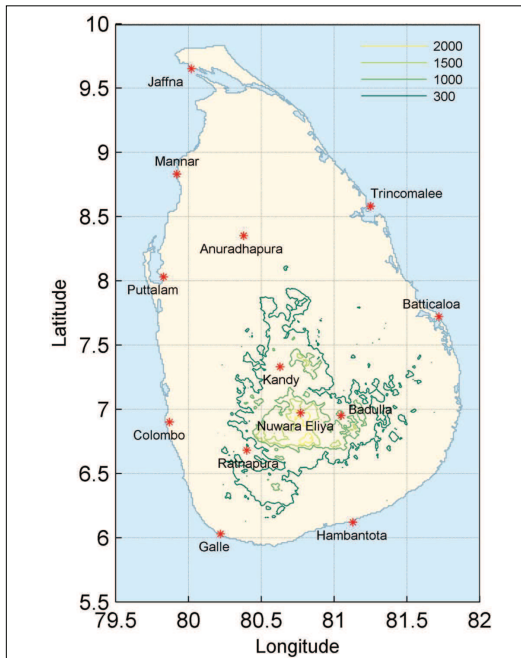


Figure 1: Geographical distribution of stations used in this study. The legends indicate the surface height in meters represented by the contour lines.

deals with extreme events, no attempt was carried out to reconstruct the missing daily rainfall records, which may lead to erroneous results. In order to simplify the analysis, rainfall observed once in four years on the 366th day of leap years was also not considered. Thus, the data were arranged in an array of dimension 50×365 where the columns and rows represent the day of the year and the individual years, respectively.

In recent years, studies focused on the characteristics of extreme events have adopted different definitions for extreme rainfall events around the world (Fowler & Kilsby, 2003; Rajeevan *et al.*, 2008). Varathan *et al.* (2010) defined extreme rainfall events by two different methods; (1) the annual maximum of daily rainfall, and (2) daily rainfall that exceeds a threshold value. Zin *et al.* (2012) used eight different indices to represent extreme events. They were: extreme dry spells; extreme sum of rainfall; extreme wet-day intensities at 95th and 99th percentiles; proportion of extreme rainfall amount to the total rainfall amount at 95th and 99th percentiles; and frequency of extreme wet-days at the 95th and 99th percentiles. Suppiah and Hennessy (1998) used the Kendall-Tau test to calculate the statistical significance of trends in total rainfall, heavy rainfall and number of dry days in Australia. They defined heavy rainfall events as the 90th and the 95th percentiles of daily rainfall in each half year. Different threshold values have been used by different researchers to define wet and dry conditions depending on the area of interest and the season. Singh and Ranade (2010) studied wet and dry spells across India. They defined a wet spell as a continuous period with daily rainfall equal to or greater than the daily mean rainfall of the monsoon period over the area of interest. Martin-Vide and Gomez (1999) regionalised the peninsular Spain based on the length of dry spells. They used 0.1 mm, 1 mm and 10 mm daily rainfall values as threshold values to calculate the mean length of dry spells and wet spells. In the present study, the 99th percentile of daily rainfall is defined as an extreme rainfall event. To calculate the number of dry days and the length of dry spells, 1 mm of daily rainfall was used as the threshold (Sonnadara & Jayewardene, 2014), which is the minimum requirement for crop-water demand.

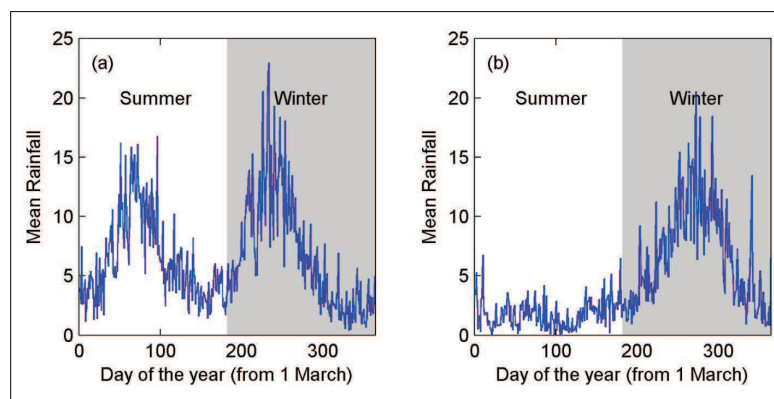


Figure 2: Distribution of mean rainfall in (a) Colombo and (b) Trincomalee. Days are shown from 1st March. Shaded region separates the summer half of the year from winter half of the year showing two cultivation seasons Yala and Maha.

The extreme rainfall index for the 99th percentile was calculated for each year from 1961 to 2010 from daily rainfall records of 13 stations. Since regional differences cannot be taken into account with a fixed higher threshold, heavy rainfall events were defined as days having more than 10 mm of rainfall. The number of dry days, number of dry spells and the 99th percentile of the length of dry spells were investigated for each individual station. The spatial patterns of extreme events were estimated by using the triangle-based cubic interpolation method (Nielson, 1980; Watson, 1992). The analysis was carried out separately for two crop seasons. For this analysis, the calendar year was defined as March 1st being the day one. In Figure 2, mean rainfall is shown for (a) Colombo - a station in the western part of the island, which receives rainfall during both Yala and Maha seasons and (b) Trincomalee - a station in the eastern part of the island, which receives rainfall mostly during the Maha season. The grey area separates the summer half year from the winter half year. The figure clearly shows the dominance of monsoons' rainfall during the two cropping seasons in the western (Wet Zone) and eastern (Dry Zone) parts of the island.

From the generated indices, trend analysis was performed to detect any statistically significant trends.

The statistical significance of the results was tested using the Mann-Kendall trend test. This method is widely used for testing statistical significance in climatological and hydrological time series because it is a non-parametric test and does not require the data to be normally distributed (Mann, 1945; Kendall, 1975).

RESULTS AND DISCUSSION

Wet indices

Temporal variations

Time series of 99th percentile daily rainfall values of each station for the two halves of the year were computed to examine trends in extreme rainfall events. The results derived from the linear regression analysis and the Mann-Kendall test are given in Table 1. Linear trends for each station are shown separately for the summer half and the winter half of the year. A positive value indicates an increasing trend while a negative value shows a decreasing trend. Statistical significance of trends were evaluated at the 90 % confidence level. For the 99th percentile, statistically significant decreasing trend was detected at Colombo and a statistically significant

Table 1: Results of trend analysis for extreme rainfall, number of days with heavy rainfall and rain per rainy day. For each station linear trend values are shown separately for summer half year (March-August) and winter half year (September-February). Highlighted values with asterisks show statistically significant values at 90 % confidence level.

Station	Summer half year			Winter half year		
	Extreme rainfall	Heavy rainfall	Rain per rainy day	Extreme rainfall	Heavy rainfall	Rain per rainy day
Colombo	- 0.54*	- 0.11	- 0.04*	- 0.23	- 0.09	- 0.03
Galle	0.09	- 0.01	0.00	- 0.07	- 0.07	- 0.02
Nuwara Eliya	- 0.08	- 0.03	- 0.02	- 0.01	0.01	- 0.02
Ratnapura	0.08	- 0.04	0.01	- 0.09	- 0.06	0.00
Badulla	- 0.07	- 0.06	- 0.01	0.08	0.04	0.01
Kandy	0.18	0.02	0.01	- 0.07	0.05	- 0.02
Hambantota	- 0.17	- 0.05	- 0.03	0.14	- 0.03	0.01
Batticaloa	0.18	- 0.01	0.05	0.49	0.12	0.09
Trincomalee	0.08	- 0.03	0.02	- 0.48	0.00	- 0.03
Anuradhapura	0.14	0.01	0.06*	- 0.10	0.02	0.02
Mannar	0.03	0.01	0.03	- 0.07	0.05	0.04
Jaffna	0.38*	0.07*	0.10*	0.25	0.07	0.05
Puttalam	0.17	0.00	0.03	- 0.01	- 0.05	- 0.01

increasing trend was detected at Jaffna during the summer half of the year. This may be connected to the northward propagation of cloud bands associated with the Madden-Julian Oscillation, particularly during the active and onset phases of the SWM. However, further analysis is required to explore this view. Although extreme events fluctuate between years, any widespread trend was not detected. The strongest decreasing trend of 5.4 mm per decade was seen for Colombo, which is situated in the southwestern coastal area of the country. During the summer half of the year, Colombo receives most of its rainfall during the SWM season. However, Galle which is located in the southern coast and also receives most of its rain from the SWM during the summer half year, does not show a statistically significant decreasing trend. Table 1 also shows trends calculated for number of heavy rainfall events (defined as daily rainfall exceeding 10 mm) and rain per rainy day. For heavy rainfall, only Jaffna showed a statistically significant positive trend during the summer half year. For rain per rainy day, during the summer half year, Colombo showed a negative trend while stations in the Dry Zone, Anuradhapura and Jaffna showed statistically significant positive trends at 90 % confidence level. Jaffna receives most of its rain during the NEM during the winter half year, and its results show statistically significant increasing trends for all three indices. When rainfall values exceeding 250 mm/day at individual stations were investigated, it was found that 264 mm/day rainfall was recorded in Kandy during November 1978. During the same year and the same month, another station, Nuwara Eliya which is in close proximity but at a higher elevation, recorded 343 mm/day rainfall. These events were caused by a severe tropical cyclone in November 1978 (Suppiah, 1982). Although 276 mm/day of rainfall was recorded at Puttalam during April 1984, no other extreme values were recorded in stations in close proximity, such as Mannar. Therefore, it was not possible to estimate the probability of occurrence of these events due to the relatively short period of observational data used in this study.

Spatial variations

The spatial patterns of mean extreme rainfall for summer and winter halves of the year and signs of their trends (positive or negative) are shown in Figure 3. The spatial distribution of seasonal rainfall reveals that the southwestern parts of the country reaching up to the slope of the central mountain region receives ample rainfall during the summer half year compared to other areas of Sri Lanka. The atmospheric circulation patterns during

the summer half year provide favourable conditions for thunderstorm activity, and hence, for extreme rainfall amounts in the southwestern part of the country. The mid altitude of the western slopes of the mountain region receives heavy rainfall during the summer half year, which is strongly influenced by uplifting of air in the mountain slopes. The amount of rainfall decreases as the altitude increases due to reduced water vapour content in the air. Therefore, the top of the mountain and leeward side of the mountain region receive relatively less rainfall compared to the windward side. Comparatively much less rainfall is received by the coastal areas in northern and eastern parts of the country. The northern and eastern regions of Sri Lanka show positive trends in extreme rainfall events. During the winter half year, tropical cyclones and depressions, which form in the Bay of Bengal especially during the months of October and November, provide intense rainfall all over the country, particularly concentrated on eastern and northern regions. Furthermore, eastern slopes of the central highlands and the eastern coastal region receive maximum rainfall during the winter half year. Interestingly, the western coastal region also receives a similar amount of rainfall during this period. However, for the winter half year, most of the regions in Sri Lanka show negative trends for extreme rainfall events.

A recent study demonstrated a declining trend in annual counts of days with heavy rainfall in Southern India and Sri Lanka based on a different definition of extreme events (Sheikh *et al.*, 2015). The spatial patterns of the number of days with heavy rainfall for summer and winter halves of the year for the present analysis are shown in Figure 4. The spatial distribution pattern of trends shows a declining trend in the northwestern region of Sri Lanka, while the remaining regions show an increasing trend during the summer half year. Similar to extreme rainfall, heavy rainfall events are high in the western region up to the highlands and show an increase when moving towards northern and eastern regions. For the winter half of the year, heavy rainfall events are also high in the western part of Sri Lanka but show a declining trend. In general, the NEM is weaker compared to the SWM in terms of winds, and hence, gives widespread light rainfall to the entire country, but more for the Dry Zone. Depressions and occasional tropical cyclones contribute to heavy rainfall to this zone. Therefore, trends in extreme or heavy rainfall largely depend on the occurrences of these weather phenomena, but overall trends in rainfall could be different as these are controlled by a number of meteorological phenomena.

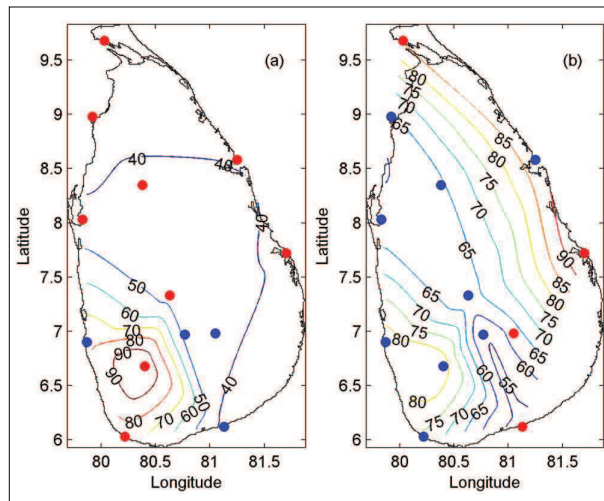


Figure 3: Spatial patterns of the 99th percentile rainfall over Sri Lanka for (a) summer half of the year and (b) winter half of the year. Blue dots denote a decreasing linear trend while red dots denote an increasing linear trend. Contour lines indicate the 99th percentile rainfall values.

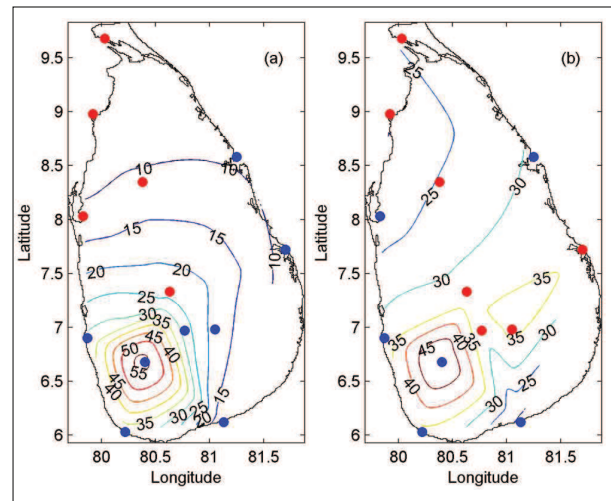


Figure 4: Spatial patterns of the number of heavy rainfall events over Sri Lanka for (a) summer half of the year and (b) winter half of the year. Blue dots denote a decreasing linear trend while red dots denote an increasing linear trend. Contour lines indicate the number of heavy rainfall events.

Dry indices

Temporal variations

Number of dry days, number of dry spells and the 99th percentile values of the length of dry spells during each half year and their trends were also analysed. Results obtained from the trend analysis are shown in Table 2. The analysis shows that most of the stations considered in this work (9 out of 13) reveal statistically significant increasing trends for the number of dry days during the summer half year. The positive trend at Nuwara Eliya, which is at an altitude of 1,895 m, is not statistically significant at the 90 % confidence level. However, Kandy, which is at an altitude of 477 m and has rainfall climatology closely linked to Nuwara Eliya, shows a statistically significant increasing trend of 2.5 days/decade. Jaffna, Mannar, and Batticaloa located in the northern, northwestern and eastern coast respectively, do not show statistically significant trends. However, Trincomalee, which is on the northeastern coast, shows a statistically significant increasing trend (1.1 days/decade). For the winter half year, none of the stations show statistically significant increasing or decreasing trends in number of dry days. Results obtained from this study indicate clear widespread increases in the number of dry days during the summer half year, which is linked to the Yala season. When number of dry spells are considered, two stations in the Dry Zone, Hambantota

and Anuradhapura showed a statistically significant declining trend during summer half year. For extreme length of dry spells (99th percentile), Badulla, Kandy, Hambantota and Anuradhapura showed increasing trends, while Jaffna showed a declining trend. For the winter half year, only Trincomalee showed a statistically significant declining trend for the number of dry spells. Anuradhapura located in the northcentral region of the country, showed statistically significant trends in all three indices.

Since the number of dry days showed a widespread increasing trend, the statistical significance in differences in mean values for two time periods, 1961–1985 and 1986–2010, were calculated for stations in the Wet Zone. The results are shown in Table 3 for corresponding means with p values. These results show that differences in means for many stations in the Wet Zone are significant at the 90 % confidence level during the summer half year. From the stations in the Dry Zone, Trincomalee and Anuradhapura showed a statistically significant difference. As expected, differences in means are not statistically significant for the winter half year.

Spatial variations

The spatial patterns of indices such as number of dry days, number of dry spells and the 99th percentile of the length of dry spells and signs of their linear trends are shown in Figures 5 and 6 for summer and winter halves of the year,

Table 2: Results of trend analysis for number of dry days, number of dry spells and length of extreme dry spells. For each station linear trends are shown separately for summer half year (March-August) and winter half year (September-February). Highlighted values with asterisks show statistically significant values at the 90 % confidence level.

Station	Summer half year			Winter half year		
	Dry days	Dry spells	Extreme spells	Dry days	Dry spells	Extreme spells
Colombo	0.31*	- 0.02	0.10	0.16	0.03	0.06
Galle	0.21*	0.03	0.04	0.20	- 0.01	0.09
Nuwara Eliya	0.10	0.01	- 0.02	- 0.05	- 0.07	- 0.01
Ratnapura	0.18*	0.00	0.04	0.12	- 0.01	- 0.03
Badulla	0.17*	- 0.02	0.13*	0.07	0.00	- 0.06
Kandy	0.25*	- 0.05	0.10*	0.10	0.02	- 0.06
Hambantota	0.21*	- 0.08*	0.12*	0.11	- 0.05	- 0.03
Batticaloa	0.09	0.01	- 0.26	- 0.07	- 0.03	- 0.18
Trincomalee	0.11*	- 0.05	- 0.08	0.11	- 0.13*	0.27
Anuradhapura	0.15*	- 0.10*	0.37*	0.13	- 0.06	0.11
Mannar	- 0.02	- 0.02	- 0.05	0.05	- 0.02	0.00
Jaffna	- 0.07	0.03	- 0.37*	- 0.12	0.00	0.06
Puttalam	0.15*	- 0.05	- 0.04	0.03	0.03	- 0.08

Table 3: Mean number of dry days for two periods 1961–1985 and 1986–2010 and their statistical significance denoted by p value. For each station values are shown separately for summer half year (March-August) and winter half year (September-February). Highlighted values with asterisks show statistically significant values at the 90 % confidence level.

Station	Summer half year			Winter half year		
	Mean	Mean	p value	Mean	Mean	p value
	1961–1985	1986–2010		1961–1985	1986–2010	
Colombo	102.6	110.7	0.01*	115.0	117.5	0.49
Galle	96.0	101.0	0.09*	104.9	109.0	0.22
Nuwara Eliya	99.0	101.2	0.44	103.3	99.4	0.27
Ratnapura	67.1	73.2	0.03*	92.0	94.8	0.36
Badulla	131.4	135.2	0.13	103.2	104.0	0.81
Kandy	105.4	112.4	0.03*	109.8	111.3	0.65
Hambantota	143.6	148.4	0.03*	133.6	137.0	0.27
Batticaloa	160.3	161.9	0.43	120.8	118.2	0.55
Trincomalee	157.7	161.1	0.04*	121.3	124.6	0.40
Anuradhapura	150.4	154.7	0.01*	124.4	128.0	0.32
Mannar	166.2	165.3	0.58	139.5	142.3	0.32
Jaffna	166.2	163.6	0.10	135.3	135.4	0.97
Puttalam	149.6	153.0	0.16	131.1	133.1	0.54

respectively. As expected, Figure 5 indicates that during the summer half year, comparatively, number of dry days and lengths of extreme dry spells are generally lower in the southwestern part of the country and the values tend to increase towards the northern and eastern parts of the

country. Most of the stations indicate increasing trends for number of dry days except for the northern region of Sri Lanka. The length of extreme dry spells shows negative trends for stations in the north and east coastal areas, while the number of dry spells shows negative

trends for most of the stations considered in this work. The mean length of extreme dry spells is about 50-60 days in the northwestern, northern and northeastern parts of the country. The length of dry spells are below 10 days

in the southwestern part of the country, which is located in the Wet Zone. The number of dry spells varies from 12 to 32 in the summer half year and increases towards north and west.

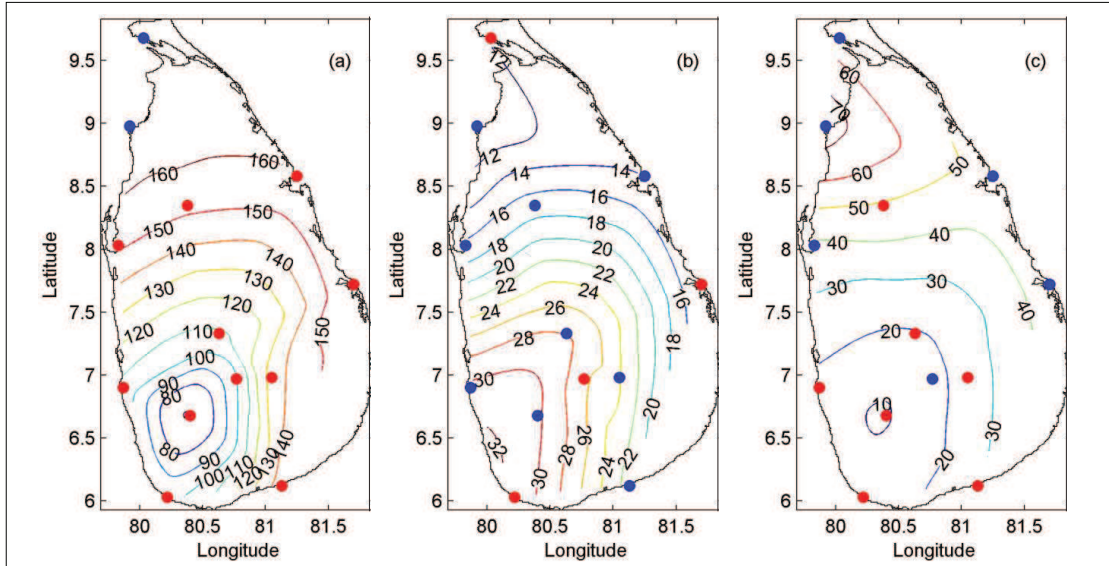


Figure 5: Spatial patterns of trends of (a) number of dry days; (b) number of dry spells and (c) the 99th percentile of length of dry spells during summer half of the year. Blue dots denote decreasing trends while red dots denote increasing trends. Contour lines indicate the number of day values.

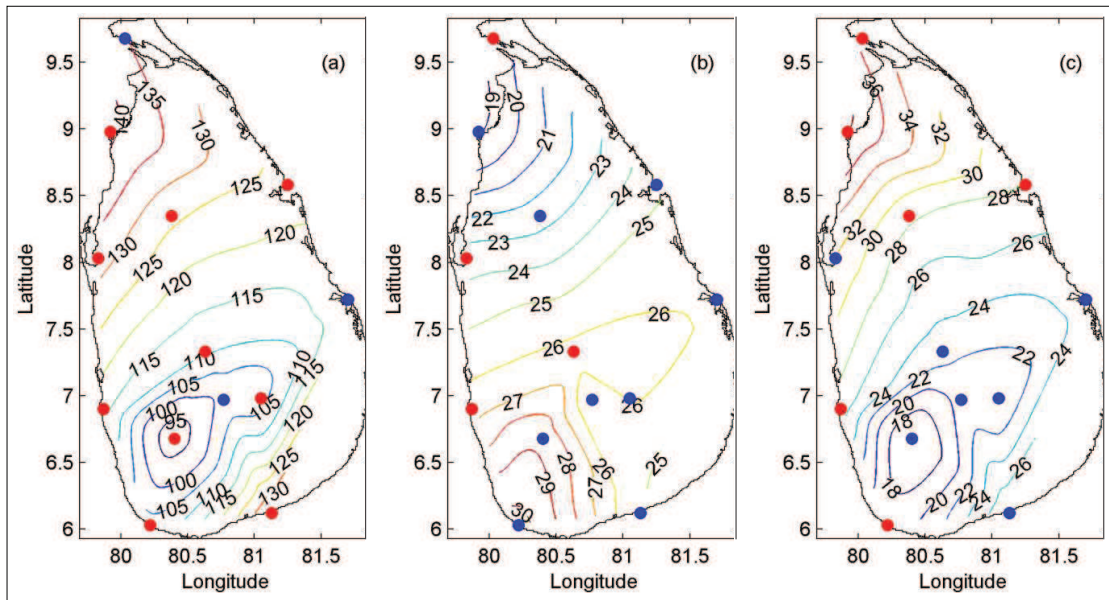


Figure 6: Spatial patterns of trends of (a) number of dry days; (b) number of dry spells and (c) the 99th percentile of length of dry spells during winter half of the year. Blue dots denote decreasing trends while red dots denote increasing linear trends. Contour lines indicate the number of day values.

Figure 6 shows that during the winter half year, the number of dry days varies between 100 and 130. The mean number of dry spells in the summer and winter halves of the year reveals similar frequencies in the western part of the country. When the number of dry days increases, dry spells with shorter duration such as single day spells tend to decrease. Although more rainfall is received during the winter half year compared to the summer half year in northern and eastern regions of the country, higher numbers of dry spells are also detected in these regions during the winter half year. While the patterns of extreme length of dry spells are same for summer and winter halves of the year, shorter lengths of dry spells were observed during the winter half year.

The present study shows that trends in the 99th percentile rainfall reveal increases in eight out of twelve stations during the summer half year. This may be due to warmer atmosphere, which contains higher moisture levels, and hence, produces intense rainfall. Condensation releases more thermal energy from latent heat, which creates additional convective current and enhances the extreme rainfall events. Most of the global climate models (GCMs) project an increase in heavy rainfall and a decrease in light rainfall under enhanced greenhouse conditions (Suppiah & Hennessy, 1998). An increasing number of dry days during the summer half year found in this study is consistent with GCMs simulated changes in the future.

CONCLUSIONS

This study shows that there are no coherent statistically significant increases or decreases in extreme rainfall events or number of heavy rainfall events in two cropping seasons in Sri Lanka during the period from 1961 to 2010. Extreme rainfall event, which was defined as the 99th percentile value of daily rainfall, showed a statistically significant decreasing trend of 5.4 mm/decade at Colombo and an increasing trend of 3.8 mm/decade at Jaffna for the summer half year. Heavy rainfall event, which was defined as the daily rainfall amount exceeding 10 mm/day, showed a statistically significant increasing trend of 0.7 days/decade only at Jaffna. A statistically significant decreasing trend of 0.4 mm/decade and an increasing trend of 1.0 mm/decade were observed at Colombo and Jaffna for rain per rainy days for the same season, respectively. No statistically significant trends were obtained for the winter half year. Spatial patterns of extreme events show that they occur in the southwestern

part of the country reaching up to the slopes of the central mountain region.

The number of dry days showed statistically significant increasing trends at stations located in the Wet Zone of Sri Lanka during the summer half year, except for Nuwara Eliya, which is situated in the highlands and has the highest elevation among the selected stations. Most of the stations in the north and east coast of Sri Lanka in the Dry Zone did not show any trends, except for Trincomalee. Trincomalee experiences different weather conditions compared to other Dry Zone stations especially during the southwest monsoon season. One notable example is that, during the active phase of the southwest monsoon, winds are more westerlies and higher temperatures are observed in the east coast centred Batticaloa. When the southwest monsoon is on normal condition, winds are south westerlies and higher temperatures are observed around Trincomalee. Rainfall events do change according to changes in wind patterns. However, further investigation is necessary in this regard.

The highest increase has been observed at Colombo in the west coast with a trend of 3.1 days/decade followed by Kandy in the hill country with 2.5 days/decade. Results of dry spells showed statistically significant decreasing trends at two stations for the summer half year. While four stations showed statistically significant increasing trends in extreme events defined as the 99th percentile value of length of dry spells, one station showed a decreasing trend. Statistically significant trends were absent for the winter half year for all three dry indices except for Trincomalee, which showed a decreasing trend in the number of dry spells.

Results from this study suggest that during the last 50 years, there has been a wide spread or large scale climate change resulting in increasing (decreasing) trends in the number of dry days (wet days) in the Wet Zone during the Yala season, which receives rainfall predominantly from the southwest monsoon. Such large-scale changes may not be easily detectable at local scales during the 50-year period and may be possibly detectable over a large area with longer time series analysis. Moreover, this study sets a basis with some encouraging results particularly for the number of dry days and dry spells, and for extreme events at some stations. Such interim results have implications for agricultural, ecological, water resources and infrastructure planning of the country. However, as an initial step, an investigation into changes in extreme events using longer datasets is recommended.

Acknowledgements

Financial support for this study was provided by the Higher Education for the Twenty First Century (HETC) Project assisted by the World Bank (IDA Credit 49190-LK). The work was carried out at the CSIRO Marine and Atmospheric Research, Melbourne, Australia.

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