Research Paper

Spatial and Temporal Trends in Rainfall in the Dry and Wet Seasons in Sri Lanka from 1994 to 2020

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Abstract

Climate change is a global crisis impacting the entire world. In July 2023, the severity of this crisis became clearly evident, as it marked the hottest month ever recorded in history. Sri Lanka in particular, faces a critical situation, with temperatures soaring to unprecedented levels, surpassing the global average by about 1.8 °C per decade. These changes have important implications for the country's food security, particularly during the two main cultivating seasons, Dry (March-September) and Wet (October-February), especially in terms of crop production. This study employed the Mann-Kendall Trend test, Sen's slope estimator, Coefficient of Variations (CV), and Z statistics to examine the trends in rainfall in the Dry and Wet seasons using data from 13 rain guage stations encompassing all three climatic zones (Wet, Intermediate and Dry) from 1994 to 2020. Notably, In the Dry season, two rain gauge stations Anuradhapura and Mahailluppallama in the Dry Zone (DZ), exhibited a significant increasing trend, and a majority of the stations showed an increasing trend potentially linked to the growing occurrence of extreme rainfall events. Conversely, none of the rain gauge stations showed a notable trend, but a majority of the stations showed a decreasing trend in the Wet seasons. While a North-South gradient is discernible, the diversity of trends observed in different regions highlighted the need for localized climate studies bolstered by cutting-edge climate models that peer into Sri Lanka's climate future. Such knowledge would better support climate change adaptation and mitigation efforts, securing a sustainable future for Sri Lanka.

Keywords: Coefficient of variations (CV), Mann-Kendall test, Sen's slope estimator, Dry and Wet, Z statistics

Introduction

Sri Lanka, like many other nations, is confronting escalating risks of climate change. The country has witnessed a significant rise in temperatures, soaring to approximately 36 degrees Celsius during heat-stress periods (Jayawardena *et al.*, 2018). Sri Lanka was frequently ranked among the top ten high-risk nations, e.g. 4th in 2016, 2nd in 2017 and 6th in 2018 by the Global Climate Risk Index 2021 (Eckstein *et al.*, 2021), however, was ranked at the 30th position in 2019. In 2023, Sri Lanka faced undeniable consequences of climate change. The temperature of the country has increased at a rate about 1.8 °C per decade, which is a faster rate than the global average. Increased heat stress is an indication of climate change (FECT, 2023). The impacts of the changing climate could be greater along the borders of the country's climatic zones (Prof. Devaka Weerakoon – Personal Communication), thus highlighting the need for more research to analyse possible impacts of heat stress and the overall impacts of climate change in Sri Lanka (Rodrigo, 2023).

Moreover, climate extremes have already led to irrevocable consequences, disproportionately affecting vulnerable communities and systems across several sectors and regions (IPCC, 2022).The effects of climate change on agriculture and other sectors are of great concern, necessitating the identification and quantification of long-term climate variables for effective mitigation and adaptation (Manawadu *et al*., 2019). One of the key impacts of climate change in Sri Lanka is the alteration of rainfall patterns, particularly during the two main crop seasons, Dry and Wet (Basnayake *et al*., 2002). These seasons, which are crucial for agricultural production, are heavily reliant on specific rainfall patterns. Wijewardena *et al*. (2018) observed that alterations in precipitation patterns have severe implications for the two main crop cultivation seasons.

The Dry season spans from March to September and receives rainfall from the First Inter-monsoon (FIM) and Southwest Monsoon (SWM), traditionally receiving ample rainfall required for paddy cultivation in the Wet Zone (WZ). However, changing rainfall patterns may reduce precipitation during this season, negatively impacting crop yields and food security. Similarly, the Wet season receives rainfall from both the Second Inter-monsoon (SIM) and Northeast Monsoon (NEM) and usually starts in October, relying on sufficient rainfall for successful cultivation in the Dry Zone (DZ). Changes in rainfall patterns, such as delays or decreases in monsoonal rainfall, can significantly impact crop growth and agricultural productivity during the Wet season (Marambe & Wijesundara, 2021).

Given these challenges, it is crucial to properly examine the long-term meteorological data to understand the extent of climate change impacts on rainfall in the Dry and Wet cultivation seasons. By analyzing historical rainfall data, we can assess changes in rainfall patterns during these seasons and quantify the extent of these changes. This will provide valuable evidence to support the claim that climate change is significantly impacting Sri Lanka's two main crop seasons by altering rainfall patterns. Many studies on rainfall trends have been conducted in Sri Lanka over the past three decades, identifying different localized variabilities in the country. An exclusive recent study showed that all climatic zones in Sri Lanka have shown a significant increase in annual rainfall from 1989 to 2019 by using CHIRPS data instead of a traditional location-based approach (Alahakoon & Edirisinghe, 2021). However, Nissanka *et al*. (2011) observed the absence of a significant alteration within the annual rainfall series as well as those specific to the two cultivating seasons in Sri Lanka.

This study investigated whether climate change has impacted the Dry and Wet crop seasons in Sri Lanka by analyzing rainfall trends and their magnitude using long-term data. Quantification of changes in rainfall patterns during these seasons would enhance our understanding of how climate change affects the agricultural productivity and food security in the country. This knowledge will be vital in developing targeted adaptation strategies and sustainable practices to mitigate the adverse effects of climate change on agriculture production in Sri Lanka.

Materials and methods

Study area

Location-specific daily data from 13 rain-gauge stations representing the climatic zones (CZ), agroclimatic zones (ACZ) and agro-ecological regions (AER) were used for this study (Figure 1 and Table 1). The data were converted into seasonal (In this study, Yala Season was considered as Dry Season and the Maha Season as Wet Season), annual and monsoonal accumulation concerning the climatic zone. Daily rainfall data from March to September were considered the Dry season including rainfall from the First Inter-monsoon (FIM; from March to April) and South-west Monsoon (SWM; from May to September), while those from October to February for the Wet season corising the Second Inter-monsoon (SIM; from October to November) and Northeast Monsoon (NEM; from December to February).

(a) (b)

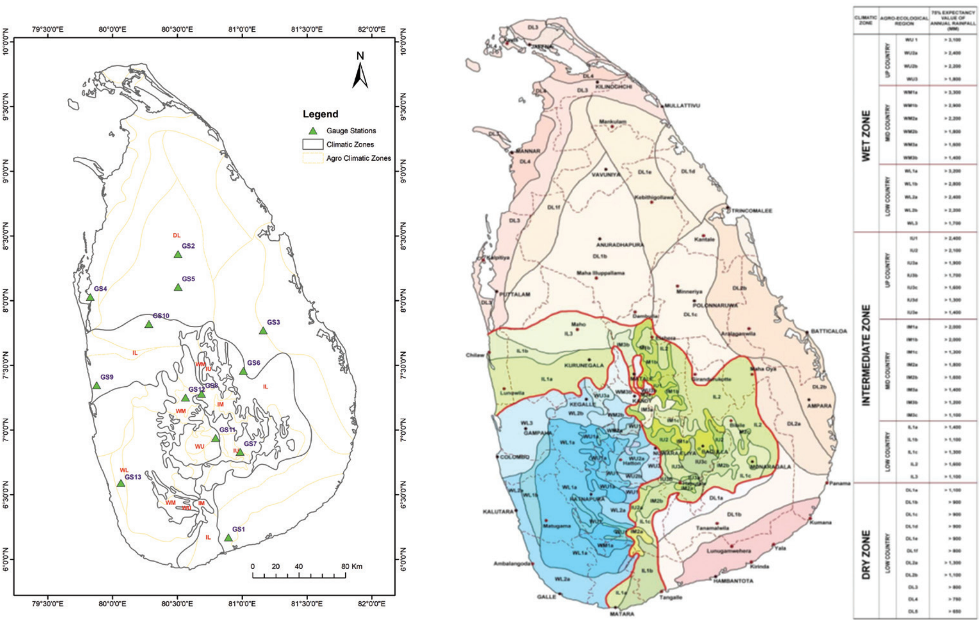


Figure 1. Locations of the selected rain gauge stations (a) and the Climatic zones, Agroclimatic Zones and Agro-ecological regions of Sri Lanka (b) (Punyawardene, 2009)

Table 1. Selected rain-gauge stations, and their geographical information

No	Code	Location (gauge station)	District	Climatic Zone	Agro-climatic zone (AEZs) and agro-ecological regions (AERs*)	Expected annual rainfall* (mm)
1	GS1	Angunakolapelessa	Hambantota	Dry zone	Low-Country Dry Zone (DL1b)	>900
2	GS2	Anuradhapura	Anuradhapura	Dry zone	Low-Country Dry Zone (DL1b)	>900
3	GS3	Aralaganwila	Polonnaruwa	Dry zone	Low-Country Dry Zone (DL2b)	>1100
4	GS4	Kalpitiya	Puttalama	Dry zone	Low-Country Dry Zone (DL3)	>800
5	GS5	Mahailluppallama	Anuradhapura	Dry zone	Low-Country Dry Zone (DL1b)	>900
6	GS6	Girandurukotte	Badulla	Intermediate Zone	Low-Country Intermediate Zone (IL2)	>1600
7	GS7	Bandarawela	Badulla	Intermediate Zone	Up-Country Intermediate Zone (IU3c)	>2000
8	GS8	Kundasale	Kandy	Intermediate Zone	Mid-Country Intermediate Zone (IM3a)	>1400
9	GS9	Lunuwila	Puttalama	Intermediate Zone	Low-Country Intermediate Zone (IL1a)	>1100
10	GS10	Maho	Kurunegala	Intermediate Zone	Low-Country Intermediate Zone (IL3)	>1100
11	GS11	Sitaeliya	Nuwara Eliya	Wet Zone	Up -Country Wet Zone (WU3)	>1800
12	GS12	Peradeniya	Kandy	Wet zone	Mid-Country Wet Zone (WM2b)	>1800
13	GS13	Bombuwela	Kalutara	Wet zone	Low Country Wet Zone (WL1b)	>2800

Punyawardena (2009)

All rain-gauge stations had only a few missing records during the chosen periods (1994-2020) except that Kalpitiya rain gauge station had one missing year (2018) of rainfall data, where the linear interpolation technique was used to fill gap. No attempt was made to re-construct the missing daily rainfall records, which may lead to erroneous results. To simplify the analysis, rainfall observed once in four years on the 366th day of the leap years, was also not considered. The non-parametric statistical test, Mann-Kendall (MK) (Mann, 1945; Kendall, 1975) test, was used to detect trends in meteorological variables, as it can be used without specifying whether the trend is linear or non–linear (Yue & Wang, 2002; Seleshi & Zanke, 2004; Mekonnen & Woldeamlak, 2014; Tabari *et al*., 2015; Kiros *et al*., 2016).

Preliminary and exploratory analyses following the Mann-Kendall trend test were done on non-auto correlated rainfall series to identify trends in the annual cumulative rainfall as well as Dry season (FIM+SWM) and Wet season (SIM+NEM) cumulative rainfall series. The magnitude of the trend was determined using Theil and Sen's slope estimator and the abrupt changes or the structural breaks were identified using Pettit's test as part of the Mann-Kendall test. Further, Z statistics and the percentage change in rainfall relative to the mean based on the change year were computed for the Dry and Wet cumulative rainfall series along with the annual and monsoonal rainfall series. Rainfall anomalies were also examined to detect the unusual variations from the climate–normal. Subsequently, the Inverse Distance Weighting (IDW) technique was employed to spatially investigate the rainfall trends over AERs with the help of Arc GIS software.

Preliminary analysis

The 'trend' package and the 'cat ()' function were used in R software for visualizing the time series data. The CV of rainfall data obtained from the selected rain gauge stations was considered as important statistical parameters to study the rainfall variability.

Exploratory analysis

The running mean is not resistant to (robust) local fluctuations. Therefore, to reduce the local fluctuations, annual and seasonal data series were fitted with Locally Weighted Scatterplot Smoothing (LOWESS) (Cleveland, 1984; Helsel & Hirsch, 2002) regression curves to identify patterns over time. It is a non-parametric regression method used to fit a smooth curve to a scatter plot of data points. This study adjusted the smoothness of the LOWESS curve by specifying the f parameter in the 'LOWESS ()' function in R by assigning 0.5 (default value) to it, which means that each local regression will use approximately 50% of data points.

Rainfall anomaly

A rainfall anomaly boxplot provides a visual representation of the distribution of rainfall data and helps identify significant deviations from the normal trend. This study employed rainfall anomaly analysis using boxplots on the 13 rain-gauge stations for the Dry and Wet seasons. The 'ggplot2 ()' package and 'data_long' function in R software were used to create a boxplot representing 13 rain-gauge stations.

The Mann–Kendall trend analysis

The Mann-Kendall test is based on the assumptions that the data are independent, identically distributed (IID), continuous and is not affected by serial correlation (*i.e.* auto-correlation) (Gilbert, 1987; Helsel & Hirsch, 2002; Yue & Wang, 2002). The analysis was carried out using the 'Kendal' and 'trend' packages in R statistical software. Subsequently, the Mann-Kendall analysis for the Dry and Wet rainfall data for the rainfall data from 13 rain-gauge stations was carried out to see if any significant monotonic increasing or decreasing trend could be evidenced in the historical data sets. The Mann-Kendall analysis on seasonal rainfall during the two major growing seasons was further extended to the annual rainfall series for the two monsoons and two inter-monsoons. The results illustrated the spatial distribution of the Z statistics using IDW interpolation in Arc Map 10.7.1.

Results & Discussion

Preliminary Analysis

Dry Season: In the Dry Zone (DZ), CVs of rainfall data except for the rain gauge station GS1 (23%), were high suggesting that the dataset had a relatively higher dispersion of values. A greater erratic behavior was observed in the rainfall (52%) was recorded at the GS4 station. Rainfall in the Intermediate Zone (IZ) and WZ showed a relatively low CV except for higher values recorded in GS6 (31%) and GS10 (34%). Rainfall recorded in GS13 showed the lowest CV (18%) suggesting a higher dependability and a relatively constant rainfall pattern recorded by this rain gauge station during the dry season (Figure 2).

Wet Season: The year to year fluctuation in the seasonal rainfall was lower in the DZ regions with a lower CV (e.g. GS1 25%). The GS9 and GS10 rain gauge stations in the IZ showed a more erratic behaviour showing a larger CV (42% and 40%, respectively). The GS11 and GS13 rain gauge stations in the WZ, showing a similar behaviour of rainfall recorded in these two stations in the Dry season, had a lower CV indicating dependability in their respective rainfall patterns (Figure 3).

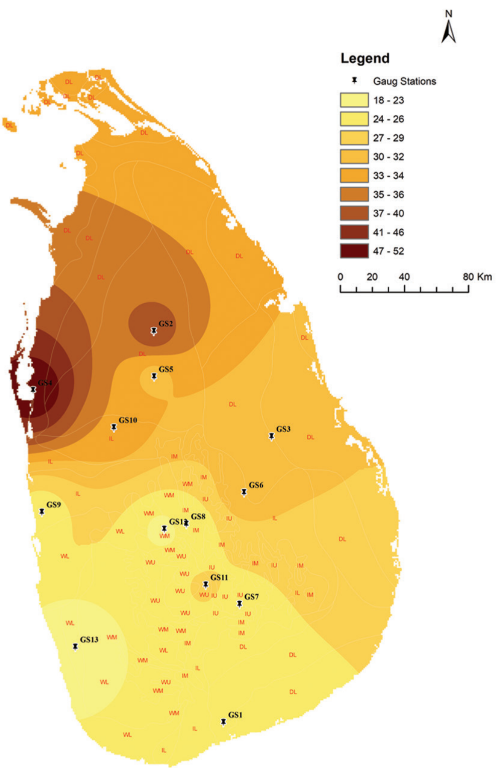


Figure 2. CV % of the rainfall data recorded in the selected rain gauge stations in Dry Seasons from 1994-2020

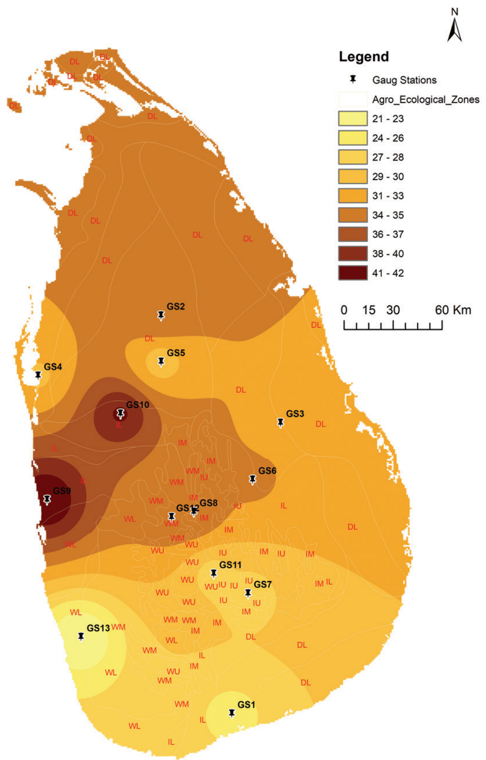


Figure 3. CV % of the rainfall data recorded in the selected rain gauge stations in Wet Seasons from 1994-2020

The leeward side of the central highlands typically experiences limited rainfall due to the adiabatic warming of descending monsoon winds (Punyawardena, 2010). During the Wet season, the dry conditions in the DZ has persisted, corresponding to the NEM experiencing high variability. The IZ has experienced a mix of wet and dry conditions. During the Dry season, IZ has received a moderate rainfall from SWM. The WZ on the windward side, typically had a more consistent and abundant rainfall throughout the year, resulting in lower rainfall variability compared to the other zones.

Table 2 provides an overview of the rainfall data observed in the study.

Rainfall Anomaly

Rainfall data recorded in GS4, GS7 and GS11 showed more instances of below-normal rainfall during the Dry season and GS1, GS2, GS12 and GS13 showed a relatively balanced distribution of above and below-normal rainfall. The rainfall data and their spread in GS3, GS5, GS6 and the Wet season than in the Dry Season. Extreme anomalies were reported from some rain gauge stations in both seasons (Figure 4). Rajendram (2021) observed that in the Wet Zone area , three extreme drought occurred in 2016, 1983 and 1980 and in the years of 2001,1976,1974, 1950 and 1890 severe drought recorded. Catastrophic droughts in the Dry Zone areas in the years 2020, 2019, 2018, 2017, 2016, 2004, 2001, 1997,1995-96,1992,1988,1980-1983,1974-76,1960 and 1950.And during the period of 2015-2017, Sri Lanka has received heavy rainfall as well as severe droughts (Alahakoon *et al*., 2018)

Table 2. Basic statistics of the rainfall data recorded in the selected rain gauge stations: Dry and Wet seasons from 1994-2020

Rain Gauge Station		Dry Season					Wet Season				
Code	Name	Min.	Max.	Mean	SD	CV (%)	Min.	Max.	Mean	SD	CV (%)
Dry Zone											
GS1	Angunakolapelessa	266.5	795.7	540.3	122.0	23	421.0	1116.3	682.1	167.9	25
GS2	Anuradhapura	260.8	916.3	497.6	188.7	38	427.1	1627.1	901.9	312.3	35
GS3	Aralaganwila	187.0	740.6	450.1	138.0	31	620.1	2582.0	1423.3	456.1	32
GS4	Kalpitiya	67.5	696.1	297.1	154.8	52	256.6	937.4	636.7	188.8	30
GS5	Mahailluppallama	278.5	871.8	540.5	166.9	31	442.6	1296.8	917.6	265.1	29
Intermediate Zone											
GS6	Girandurukotte	176.5	799.1	510.6	159.0	31	467.5	2554.3	1510.9	499.8	33
GS7	Bandarawela	479.3	1116.4	746.2	186.9	25	427.3	1410.7	958.9	262.6	27
GS8	Kundasale	333.6	1007.9	667.6	161.8	24	111.0	1279.0	785.5	275.2	35
GS9	Lunuwila	561.8	1403.9	936.8	225.7	24	22.3	1459.9	745.2	319.9	42
GS10	Maho	87.0	1116.0	670.3	228.2	34	153.4	1463.2	786.1	314.7	40
Wet Zone											
GS11	Sitaeliya	517.5	1515.3	979.2	249.8	26	392.6	1542.8	957.3	253.8	27
GS12	Peradeniya	614.0	1583.3	1084.9	229.4	21	150.0	1504.7	993.2	311.8	34
GS13	Bombuwela	990.0	2412.4	1788.2	316.8	18	811.4	1599.5	1184.5	246.3	21

(Note:Min.-Minimum Value,Max.-Maximum Value,CV-Coefficient of Variation)

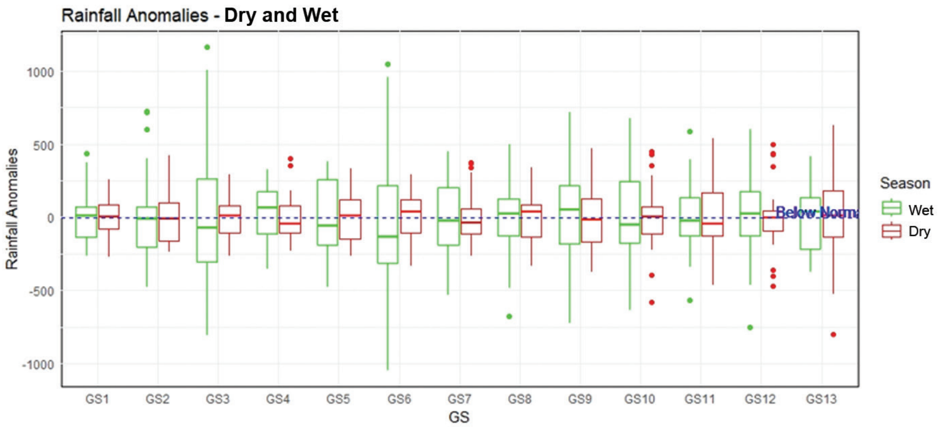


Figure 4. Rainfall anomaly boxplots for 13 rain-gauge stations in the Dry and Wet seasons from 1994-2020

Exploratory Analysis

Figures 5, 6 and 7 illustrate the LOWESS curves of all 13 rain guage stations in the Dry, Intermediate and Wet Zones.

Dry Zone: The LOWESS regression curve (Figure 5) illustrates that the rainfall in GS2 in the Dry season has gradually increased, while GS3 had an increase at the end of the series. The GS5 depicted similar rainfall patterns throughout in both seasons, but with a steep increase towards the end of the series. The rainfall in the Wet seasons in GS2, GS3 and GS5 showed a steep decrease at the end of the series. All other rainfall stations recorded complex rainfall patterns without any noteworthy trend at the end portion of the series in both the Dry and Wet seasons.

Intermediate Zone: Most of the rainfall data series in both the Dry and Wet seasons showed a cyclic pattern. The GS6, GS8 and GS9 data series in the Dry season showed an increasing trend, while GS9 showed a steep decreasing trend at the end part of the series in the Wet season compared to the data series from other stations, which showed complex patterns (Figure 6).

Wet Zone: Conversely, all rainfall data series from all rain guage stations showed a cyclic pattern and a decreasing trend at the end of both seasons (Figure 7)

The Mann-Kendall test

The MK p-value, Tau value, Pettit test k value and Theil Sen's slope estimator (Sen, 1968) are shown in Table 3 and the outcome of the MK test us illustrated spatially in Figure 8, showing the trends (labels) and the magnitude of the trends using Sen's slope (Color gradient) on seasonal rainfall in the Dry and Wet Seasons.

The p-value associated with Mann-Kendall trend analysis is a crucial component in determining the statistical significance of the detected test and the Tau value is a rank–based measure of correlation that assesses the monotonic relationship between two data points (Mann, 1945; Kendall,1975). In a time series, the Tau value is often used to evaluate the trend or directionality of a series. The magnitude of the Tau value indicates the strength of the trend. The closer the Tau value is -1 to +1, the stronger the trend.

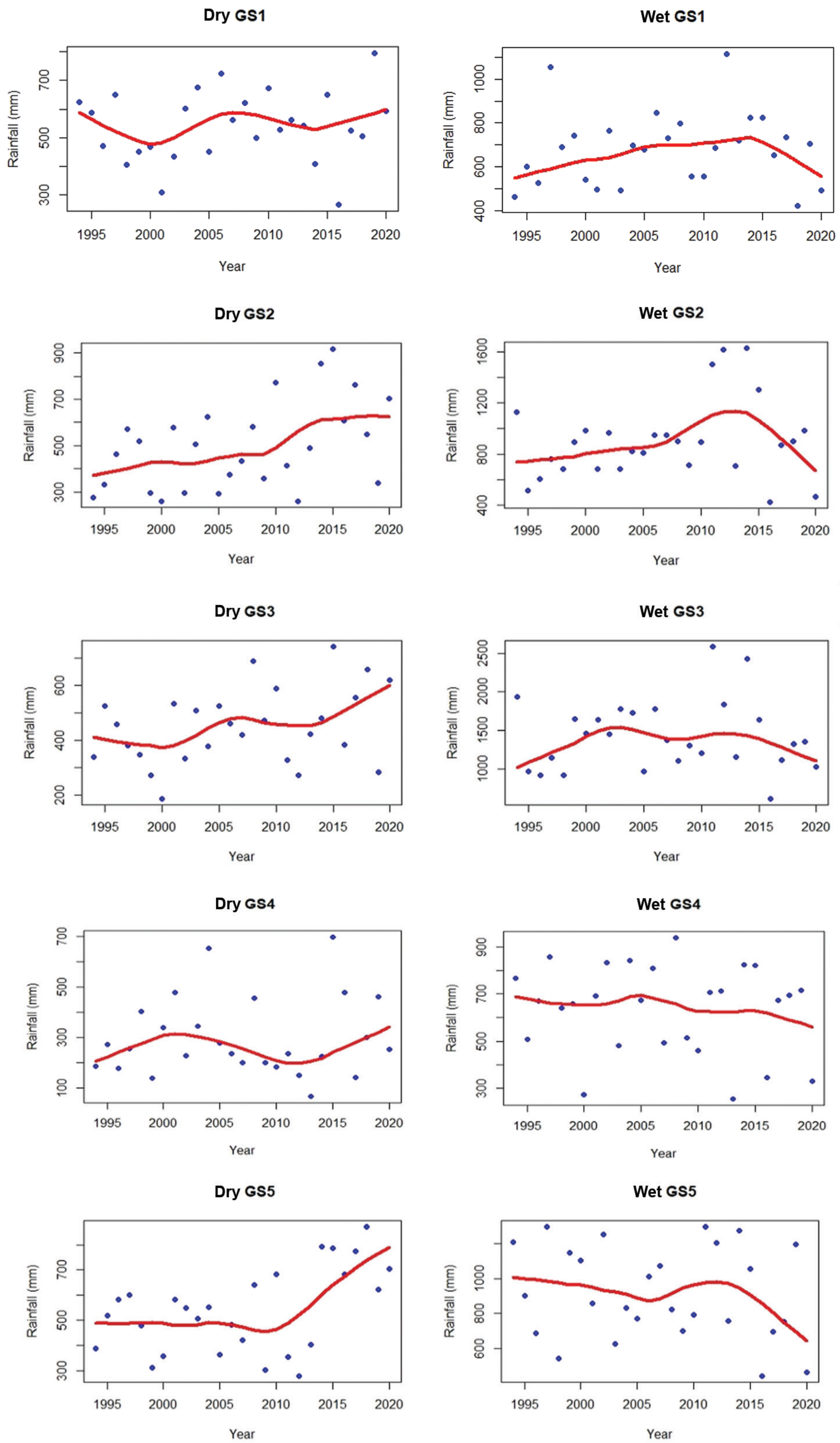


Figure 5. LOWESS regression lines for the Dry Zone rain gauge stations in the Dry and Wet seasons from 1994-2020

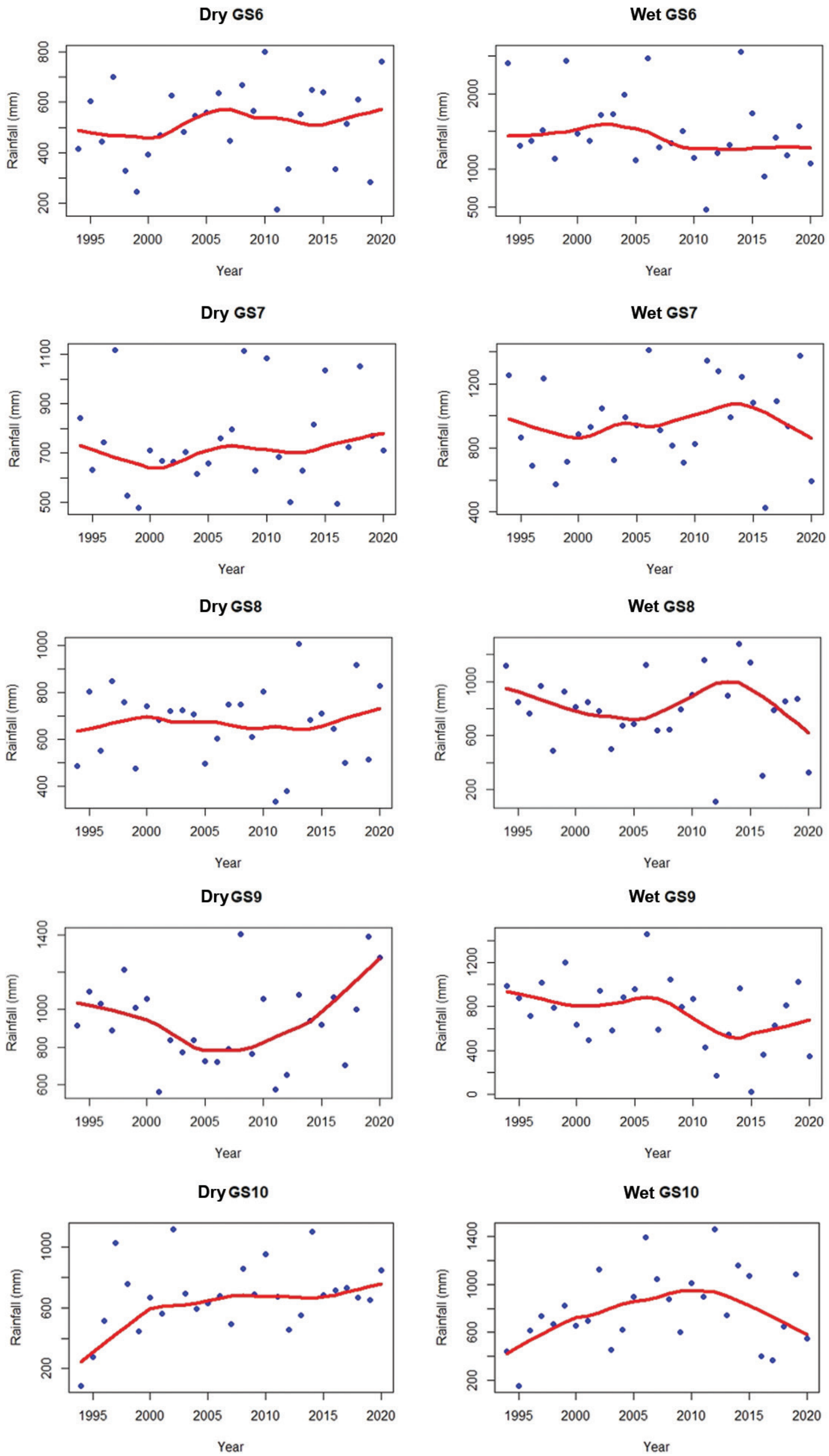


Figure 6. LOWESS regression lines for the Intermediate Zone rain gauge stations in the Dry and Wet seasons from 1994-2020

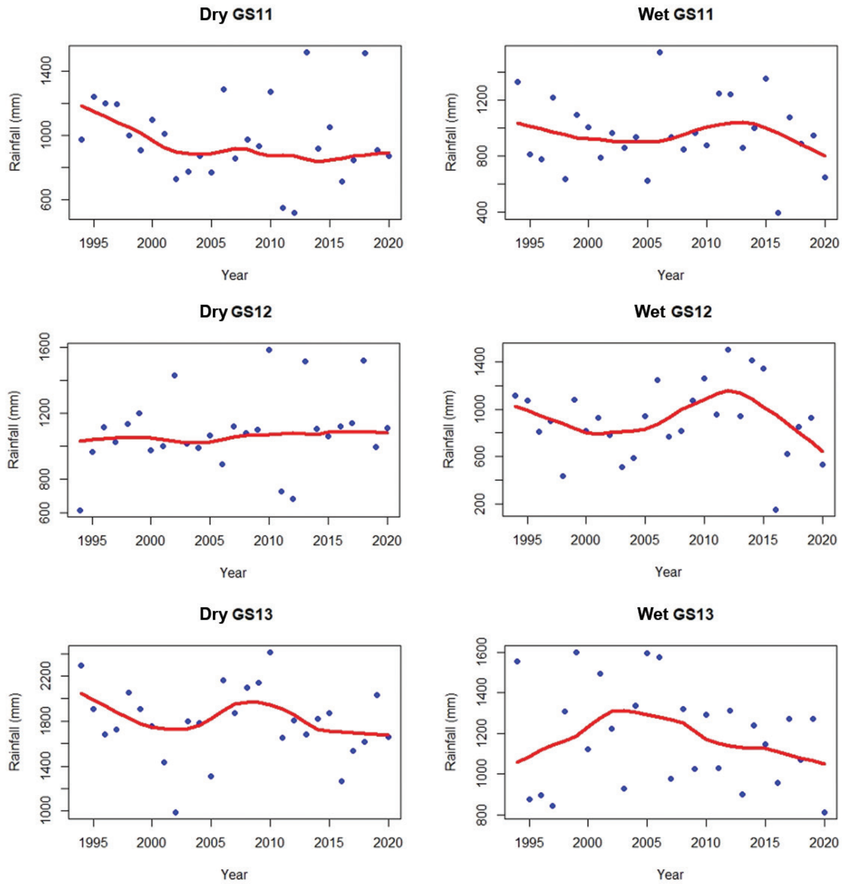


Figure 7. LOWESS regression lines for the Wet Zone rain gauge stations in the Dry and Wet seasons from 1994-2020

The Tau value close to 0 suggests a weak or no trend. Combining the parameters of the Mann-Kendall test, Tau, p-value and Sen's slope, a decision can be made to whether the rainfall trend is a significant monotonic increase or decrease or not.

Dry Season: At the GS2 rain gauge station from the DZ with a moderate slope of 11.19 mm/year, p-value of 0.03, Tau of 0.30 and GS5 from the IZ with a moderate slope of 10.24 mm/year, p-value of 0.05, Tau of 0.27 demonstrated a significant monotonic increasing trend of rainfall while the other stations exhibited a non-significant trend, indicating no significant change in the rainfall pattern over time. However, in the Wet Season, there was no evidence of a significant trend of rainfall in all the stations used in this study.

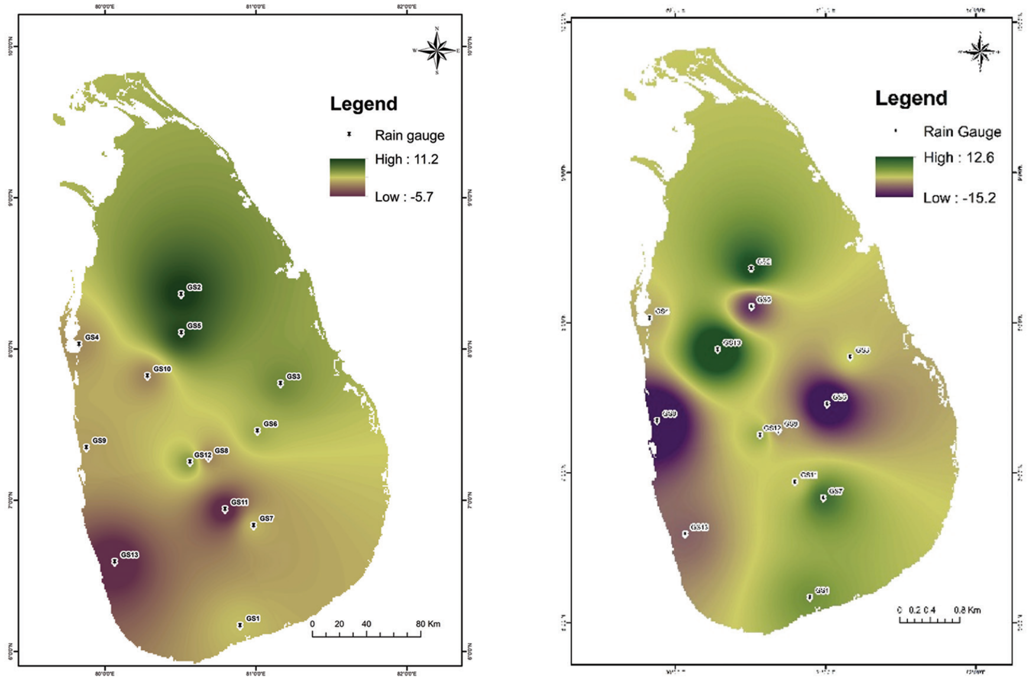
The Z statistics and percentage change of the Mann-Kendall analysis rainfall series of the Dry and Wet, annual and monsoon seasons

Building upon the temporal and spatial analyses, we further enriched the study by conducting an in-depth assessment of percentage change and Z statistics associated with the observed rainfall trends for both annual and two monsoons and two inter monsoons from the 13 rain gauge stations.

Table 3. Summary of Trend on Dry and Wet seasonal rainfall at the 13 rain gauge stations.

Code	Location Name	Dry Season							Wet Season						
		Mann Kendal Test		Theil & Sen's slope estimator		Pettitt Test		Trend (Significance)	Mann Kendal Test		Theil & Sen's slope estimator		Pettitt Test		Trend (Significance)
		P Value	Tau Value	Z statistics	Slope (mm/year)	p Value	K		p Value	Tau Value	Z statistics	Slope (mm/year)	p Value	K	
GS1	Angunakolapelessa	0.60	0.07	0.46	2.50	0.60	9	NSP	0.50	0.09	0.70	2.60	0.80	12	NSP
GS2	Anuradhapura	**0.03**	0.30	2.21	11.19	0.13	19	**S**	0.28	0.15	1.08	7.68	0.65	12	NSP
GS3	Aralaganwila	0.12	0.21	1.54	6.36	0.40	11	NSP	0.95	-0.01	-0.06	-0.56	0.80	22	NSN
GS4	Kalpitiya	0.93	0.01	0.08	0.41	0.90	21	NSP	0.71	-0.05	-0.38	-1.98	1.00	15	NSN
GS5	Maha Illuppallama	**0.05**	0.27	1.96	10.24	**0.01**	**20**	**S**	0.24	-0.16	-1.17	-6.80	0.60	22	NSN
GS6	Girandurukotte	0.28	0.15	1.08	4.70	0.80	8	NSP	0.23	-0.17	-1.21	-12.63	0.40	13	NSN
GS7	Bandarawela	0.60	0.07	0.52	2.44	0.88	12	NSP	0.38	0.12	0.88	5.06	0.65	17	NSP
GS8	Kundasale	1.0	0.002	0.00	0.01	1.00	19	NSP	0.80	-0.04	-0.25	-2.63	1.00	22	NSN
GS9	Lunuwila	0.93	0.01	0.08	1.22	0.65	19	NSP	0.08	-0.24	-1.75	-15.23	0.13	17	NSN
GS10	Maho	0.10	0.23	1.67	9.03	0.51	8	NSP	0.21	0.18	1.25	12.62	0.40	11	NSP
GS11	Sitaeliya	0.21	-0.17	-1.25	-5.68	0.40	8	NSN	0.97	-0.01	-0.04	-0.33	1.00	12	NSN
GS12	Peradeniya	0.13	0.21	1.50	5.73	0.51	19	NSP	0.90	0.02	0.12	1.18	0.60	22	NSP
GS13	Bombuwela	0.40	-0.12	-0.83	-5.73	0.31	17	NSN	0.43	-0.11	-0.79	-4.44	0.85	19	NSN

*Note: *S-Significant, NSP-Non-significant positive, NSN-Non-significant nega*



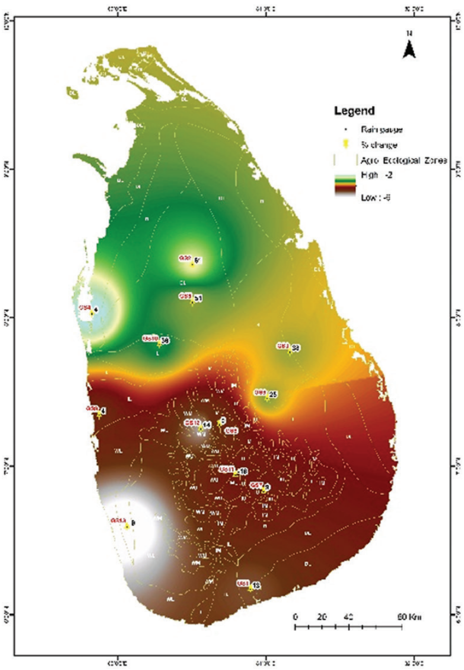
a) b)

Figure 8. Spatial distribution of Sen's slope (colour gradient) and significance (Label) of the Mann-Kendall analysis of the rainfall series from the selected rain gauge stations; a). Dry season and b). Wet season

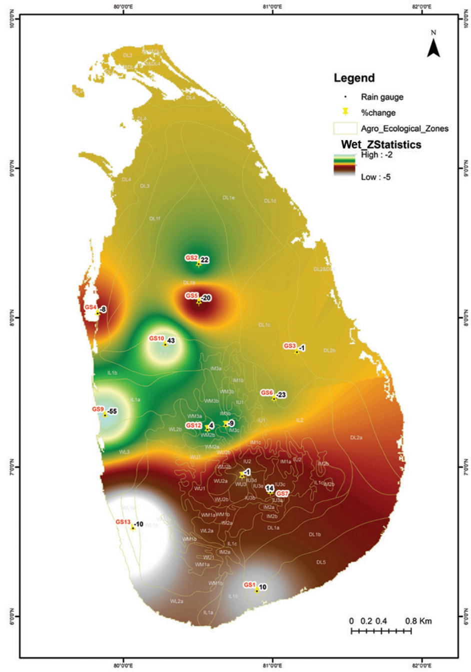
Figure 9 illustrates the spatial distribution of Z statistics in the Dry, Wet seasons and annual rainfall series, and rainfall series of FIM, SWM, SIM and NEM. The Z statistics related to lower altitudes tend to have values, while the higher altitudes had higher values. Altitudes can influence rainfall patterns. However, in this data series rainfall data from all rain guage stations shows negative Z statistics irrespective of the altitudes, suggesting predominantly decreasing trends in rainfall across the analyzed periods.

These negative values are consistent with the Mann-Kendall test's providing an interpretation of a declining trend in the rainfall data. The combined analysis of Z statistics reaffirms a distinct north-south gradient in rainfall patterns across Sri Lanka. This results confirmed the findings of the Manawadu,(2008) which water volume of the watershed showed increasing trends in the North while decreasing trends in the south.

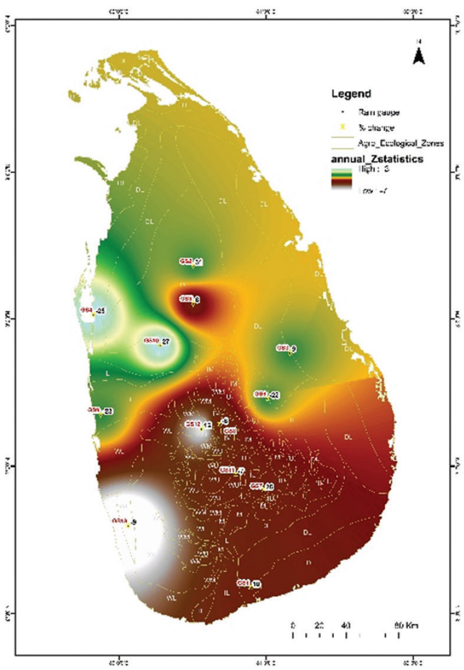
The percentage change detection, however, should also be considered when the trend results of rainfall are interpreted. Moreover, rain gauge stations in the DZ such as "GS2", showed substantial positive values, indicating a notable increase in the rainfall. Rain gauges in the coastal areas such as "GS4," exhibited mixed trends with some negative and positive values, indicating varying impacts of coastal influence on rainfall. Some higher-altitude stations like "GS12" showed positive values all the time, indicating increased rainfall over time.


Legend
Rain gauge
% change
Agro Ecological Zones
0 20 40 80 Km

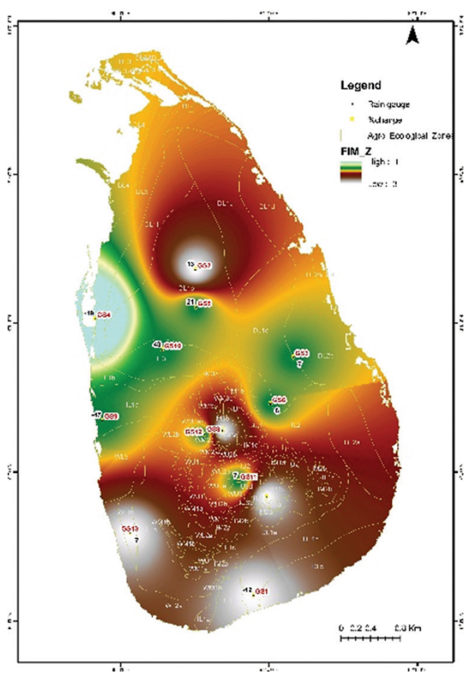
a)


Legend
Rain gauge
%change
Agro_Ecological_Zones
Wet_ZStatistics
High : -2
Low : -5
0 0.2 0.4 0.8 Km

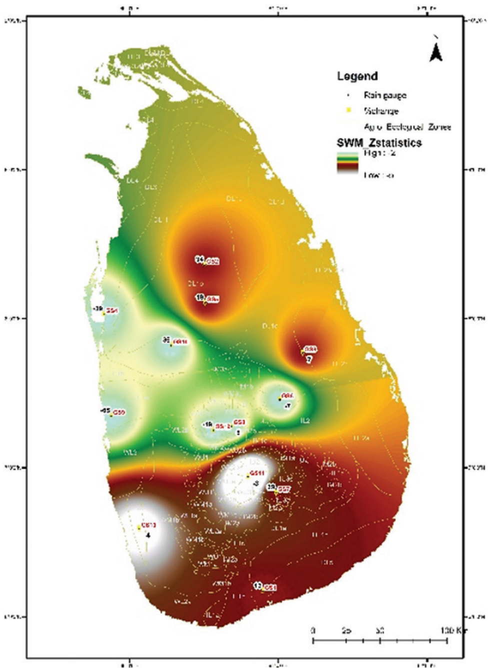
b)


Legend
Rain gauge
% change
Agro_Ecological_Zones
annual_Zstatistics
0 20 40 80 Km

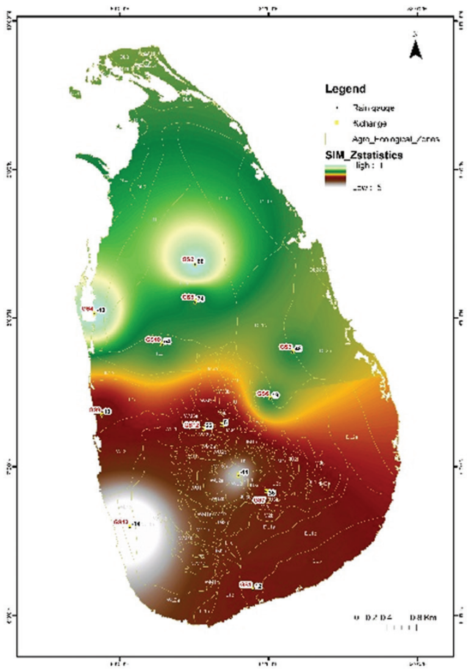
c)


Legend
Rain gauge
%change
FIM_Z

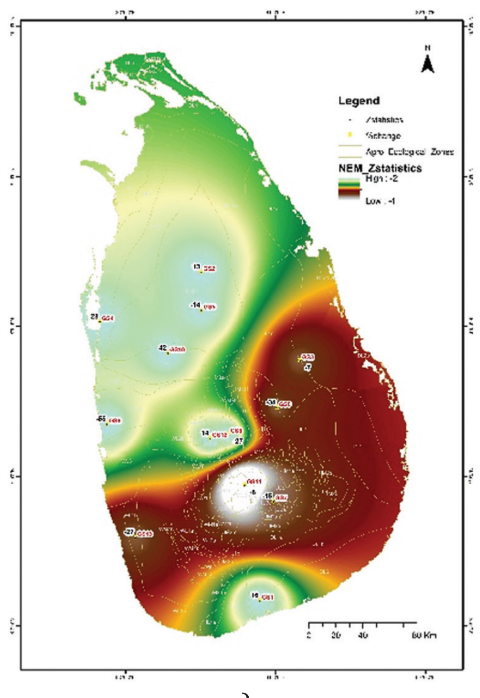
d)



e)



f)



g)

Figure 9. Spatial distribution of Z statistics (colour gradient) and % change (numbers) for a). Dry and b). Wet, and c). Annual, and d). FIM, and e). SWM, and f). SIM, and g). NEM monsoon rainfall series of Sri Lanka

The broader patterns in rainfall as described above display the diversity due to the influence of various meteorological factors. The findings of the study revealed the existence of outliers in multiple stations for both crop seasons, indicating an increase in the occurrence of extreme weather events.

When comparing our results to existing literature, it becomes evident that our findings align with the observations of (Nissanka *et al*., 2011) who similarly reported no alteration of the trend in rainfall during Dry and Wet in Sri Lanka. This conformity underscores the consistency of our results with prior research and strengthens the robustness of the observed trend.

Furthermore, in the Wet season, our study did not detect any significant increasing or decreasing trends, which suggests that the Wet season in our study area is characterized by climatic stability rather than a discernible trend. These findings echo the heterogeneous nature of climate systems and highlight the importance of incorporating local contextual factors in the interpretation of rainfall trends.

Conclusion

This study employed a Mann-Kendall non-parametric trend test along with other statistical analyses to investigate the impact of changing climate on cumulative rainfall of Dry and Wet crop seasons in the three major climatic zones in Sri Lanka from 1994-2020. The data series collected from the 13 rain-gauge stations at Anuradhapura and Mahailluppallama showed a significant monotonic trend in the Dry crop season and none of the stations showed any discernible trend in the Wet Season. The combined analysis highlights the complexity of rainfall trends. While a north-south gradient is discernible, the influence of altitude, proximity to the ocean, and other geographical factors add layers of variability to the country's climate.

The findings of the study underscore the importance of considering local climatic factors when interpreting rainfall patterns. Further research is recommended to gain a comprehensive understanding of the rainfall dynamics for a longer time period in the Dry and Wet seasons encompassing all agro-ecological regions in comparison with global grided-historical data and the local point-data.

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