Article Journal of Asian Geography, 2022, Volume 1 (Issue 1), 48-59.

Analysis of Observed Temperature Changes in The Northern Region of Sri Lanka Based on Climate Change Perspective

Piratheeparajah Nagamuthu[1,*]

[1]Department of Geography, University of Jaffna, Thirunelvely, Jaffna, Sri Lanka.

*Correspondence: npiratheeparajah@gmail.com

Received: 25 Aug 2022, Revised: 9 Sep 2022; Accepted: 15 Sep 2022; Published 21 Sep 2022

Abstract: Temperature is the primary weather element that determines the other weather element in a place. The Northern region of Sri Lanka has different climatic conditions that clearly define summer and winter because of its geographical setup. The area is categorized under the dry zone because of its climatic condition. However, the Northern region has unique characteristics compared with the other areas of the dry zone. This study aims to identify the changes in the temperature pattern of Northern Sri Lanka based on monthly, seasonal, and annual temperature data. The data were obtained from various sources, such as the meteorology department, the Department of Irrigation of Northern Province, and the Economic Development Department. The Mann Kendal (MK) trend and Sen's slope estimator analysis were employed to study the temperature data. According to the MK analysis, there is a positive trend in the annual temperature pattern in all six stations, such as Thirunelvely, Iranaimadu, Murungan, Akkarayankulam Vavuniya, and Kanukkerny, and Sen's values of these stations show the increase in temperature in the study area. The minimum and maximum temperature of the annual pattern indicate a significant increase of 0.35°C & 0.63°C, respectively, in the study area. Further compared to the 1930 to 1960 climatic period, the current climatic period (1990 to 2020) has a 0.84°C increase in the study area. The results show that the average temperature of every climatic period increases in the study area. Additionally, there are increases in the study area's monthly temperature pattern, especially in July, which significantly increases by 0.47°C in the study area. An appropriate mitigation and adaptation action would help the sustainable development of the Northern region of Sri Lanka.

Keywords: Climate change; Temperature; Northern Province; Sri Lanka; Global Warming.

1.0 Introduction

Many developing countries face severe climate change challenges (Grover et al., 2022). Researches and statistics reveal that the world economy is severely affected by climate change, where agriculture plays a significant role in the economy, which is more vulnerable to climate change. The agricultural system in every stage is affected by climate change. Precipitation, contrary to the regular pattern and extreme temperature, cause unexpected drought and floods, leading to crop failure in many countries worldwide (Mehta & Yadav, 2021). Most researches on climate change show that climate change is the leading cause of food shortage, poverty, and disease outbreak in several countries, especially developing countries. Compared to other weather elements, the temperature is the principal element influencing global climate change (Kuttippurath et al., 2021). It has been accepted that temperature is the primary indicator in studying climate change. Climate change has been accompanied by increased frequent, intense, and extreme weather occurrences, such as droughts, cyclones, floods, heatwaves, low rainfalls, and cold in the past. Similar phenomena are projected in several parts of Asia in the future (Kumar Guntu & Agarwal, 2020). The phenomenon of climate change is forecast for Asian countries. It indicates that there will be a 2-4 ° C increase in sea surface temperature and a 10-20% increase in tropical cyclone intensity from 2020 to 2050 (Grover et al., 2022). In recent decades, many countries have focused primarily on mitigating climate change impacts. Developed countries have already extended their valuable support to other countries vulnerable to climate change to adapt or minimize climate change impacts in their respective countries (Forootan, 2019). Further, the United Nations has listed climate action as one of the sustainable development goal number 13 and encourages all to reduce the temperature to achieve sustainable development in all sectors.

Climate change has created many burning issues in Sri Lanka, including severe water and food security threats. The government of Sri Lanka has been facing various challenges in mitigating the impacts of climate change on the water resources of Sri Lanka (Lacombe et al., 2019; Manawadu & Fernando, 2008). With its distinctive topographic characteristics and geographical location, Sri Lanka is liable for spatial and temporal climate variations in the tropical zone and the Indian Ocean (Naveendrakumar et al., 2018). It is a developing country located highly vulnerable to climate change impacts. According to the climate risk ranking of countries, the highest being the worst, Sri Lanka was ranked second in the climate risk index in 2019, after Puerto Rico (Paparizou et al., 2017).

Furthermore, being a developing country and its geographical location make Sri Lanka more vulnerable to climate-related risks. It is emphasized that climate change is a significant obstacle to achieving sustainable development goals in Sri Lanka (Thennakone, 2018). It poses severe threats and challenges to the agriculture sector, particularly to the war-affected North and East regions in Sri Lanka (Rajendram, 2019). The increasing unpredictable extreme weather due to climate change has become the biggest challenge for the Sri Lankan government to tackle. For instance, flood and drought hazards coincide in different parts of Sri Lanka in the same seasons (Alahacoon & Edirisinghe, 2021). More than 65% of the Sri Lankan people are involved in agricultural activities directly or indirectly. Since the temperature is the most influential weather factor in creating a climate pattern, increasing the temperature pattern influences the evaporation process, causing water bodies to diminish, which disrupts the farming system in the dry zone areas. Climate is the essential natural phenomenon responsible for all the activities that make human survival possible in Sri Lanka (Bonjean Stanton et al., 2016). Climate change creates several uncertainties concerning weather phenomena that affect many sectors, including agriculture, and jeopardize the progress of the socio-economic development of Sri Lanka (Weerasooriya, 2009).

The Northern region of Sri Lanka has a different geographical setting compared to other areas. Further to the physical characteristics vulnerable to climate change, the study area was under severe internal war for more than 30 years affecting social and economic development. More than 70% of people cultivate paddy, subsidiary crops, vegetables, and cash crops, and the study area has a long history of agricultural activities (Piratheeparajah, 2015). But recently, the farmers of the study area faced severe threats due to the prevailing unexpected climate variability due to climate change (De Silva & Hornberger, 2019). Temperature plays a crucial role in agricultural irrigation and water supply activities. Every year drought or water scarcity problem creates uncertainty not only in agriculture but also in the other economic sectors. In this

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/). E-ISSN: 2948-5231

context, this study aims to analyse the temperature changes in the Northern region of Sri Lanka from the climate change perspective. Hence, the studies about the study area's temperature would help to identify the significant changes in the prevailing temperature pattern of the Northern region of Sri Lanka and forecast the temperature anomalies to assist the farmers in sustaining their agriculture activities.

2.0 Study Area

The Northern Province of Sri Lanka is the study area for this research. It is located in the northernmost head of Sri Lanka (Figure 1). The Northern Region's northern boundary is the narrow Palk Strait, while the Bay of Bengal is in the eastern boundary. The Western and Southern boundaries are the North Central province and the Arabic sea. The northern region is between 80° 46' N and longitudes 80° 21'E and 80° 38'E and 22miles (35km) from India. It is connected with the Indian mainland by the mythical Adam's bridge. It has an area of 8,884 square kilometers (3,430 sq. miles). There are 3570 villages located in the Northern Province of Sri Lanka. The Northern Province has been alienated into central 05 administrative Districts such as Jaffna, Mullaitivu, Kilinochchi, Mannar, and Vavuniya, 34 Divisional Secretariat Divisions, and 921 Grama Niladhari Divisions. For Local Governance, the region is divided into one Municipal Council, 5 Urban Councils, and 28 Pradeshiya Sabhas. The total extent of the Northern Province is 8,848.58 sq. km.

The Northern region is a province with 24 rivers. All of these river basins belong to the category of seasonal rivers. There are 09 Major / Medium Irrigation schemes in the Northern region, including five significant tanks maintained by the Central Irrigation Department. These schemes primarily provide irrigation water to 45,551 acres. The Agrarian Development Department looks after two thousand seven hundred forty-four minor irrigation schemes in the Northern region. The Northern region can be divided into two distinct regions based on its water resources. The groundwater in the Limestone and sand aquifer is the prime water source for the Jaffna Peninsula and the surrounding islands. However, surface water bodies fed by 27 non-perineal rivers are the primary water sources in the other four districts. The population of Northern Province was 1109404, and about 36% of internal and external migration occurred after that, and the demographic pattern has changed. As a result, the total population of Northern Province was 1088537 in 2017 (Northern Provincial Council, 2018).

.

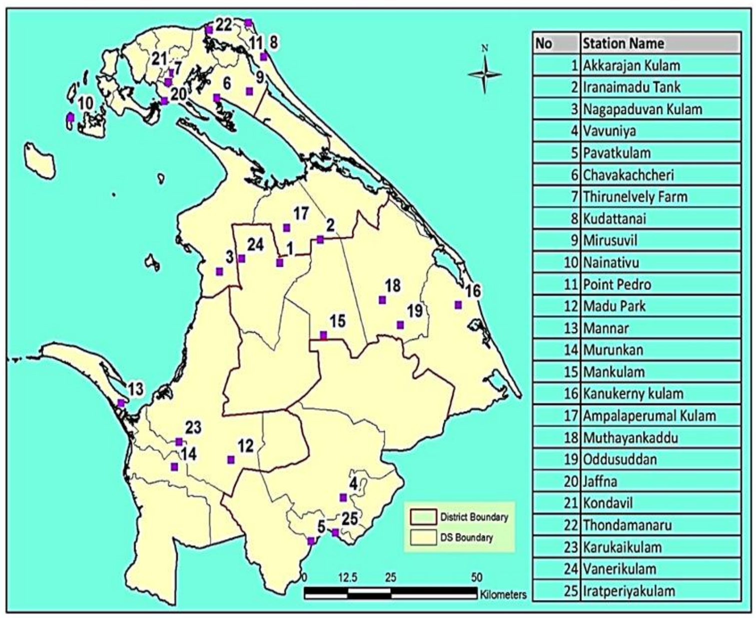


Figure 1: The Northern region of Sri Lanka.

3.0 Materials and Methodology

3.1 Materials

Necessary temperature data for the analysis were collected from the Department of Meteorology (DOM) in Colombo, and this institution functioned as a vital source to collect temperature data for this study (Table 1). Data regarding temperature such as Monthly maximum, Monthly average, and Monthly minimum data from 1901 to 2020 were collected to study the changes in temperature in Northern Sri Lanka. Further, data regarding the temperature of selected stations such as Iranaimadu, Mankulam, Thannimurippu, Akkarayankulam, Pallavarajankaddu, and Kanukkerny was obtained from the Reports of Economic Development Department (Tamil Eelam Porunmiya Mempaaddu Niruvanam- TPMN) of Liberation Tigers of Tamil Eelam (LTTE) for selected periods (1990 to 2008).

Table.1 Temperature details of stations and the source of data

Stations	T Mean	T Max	T Min	Source
Thirunelvely	28.7	30.3	26.2	DOM
Vavuniya	28.4	30.5	26.3	DOM
Iranaimadu	28.6	30.8	25.8	TPMN
Murungan	29.1	31.3	26.9	TPMN
Kanukkerny	28.7	30.9	25.6	TPMN
Akkarayankulam	28.5	30.7	26.4	TPMN

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231

3.2 Methodology

Mann-Kendall trend analysis is one of the essential statistical methods used widely in climate-related studies, especially to analyse rainfall and temperature-related long-term data (Alahacoon & Edirisinghe, 2021; Ogou, 2021). Sen's slope estimator and Mann- Kendal test were employed to study the observed temperature changes in the Northern Region of Sri Lanka. A climate typical is the arithmetic average of a climate element (e.g., temperature) over 30 years. 30 years is used as it is long enough to filter out any interannual variation or anomalies such as El Niño–Southern Oscillation, but also short enough to be able to show longer climatic trends (Kuttippurath et al., 2021; India Meteorological Department, 2013; Kumar Guntu & Agarwal, 2020; Katzenberger et al., 2021). The Mann-Kendall statistical test for trend is used to assess whether a set of data values increases over time or decreases over time and whether the trend in either direction is statistically significant. The Mann-Kendall test does not assess the magnitude of change. Sen's estimator quantified the magnitude of the trend, and positive and negative values showed increasing and decreasing trends, respectively. For this purpose, the years were classified into four significant climatic periods, namely 1901-1930 (first climatic period), 1931-1960 (second climatic period), 1961-1990 (third climatic period- Baseline period), and 1991-2019 (fourth climatic period).

The Mann- Kendall trend analysis test and Sen's slope analysis method were employed to study the temperature changes in the Northern Region of Sri Lanka. In this test, every data value in the time series is compared with all consequent values. Primarily, the Mann-Kendall statistics (S) are assumed to be zero (Saini et al., 2020). If a data value in subsequent periods is higher than in the prior period, S is incremented by 1, and vice-versa. The net result of all such increments and decrements gives the final value of S. The Mann-Kendall statistics (S) is given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sign\left(x_j - x_k\right) \quad (1)$$

Where, where, xi and xk are sequential data in the series and

$$\text{Sign } (X_i - X_k) = \begin{cases} +1 \text{ when } (X_i - X_k) > 0 \\ 0 \text{ when } (X_i - X_k) = 0 \\ -1 \text{ when } (X_i - X_k) < 0 \end{cases} \quad (2)$$

A positive value of 'S' indicates an increasing trend, and a negative value designates a decreasing trend. However, it is necessary to perform a statistical analysis of the meaning of the trend.

$$Var\ (S) = \frac{S(n-1)(2n+5) - \sum_{p-1}^{q} + p\left(t_p - 1\right)\left(2_p^t + 5\right)}{18} \quad (3)$$

where n is the number of data points, g is the number of tied groups and t_p is the number of data points in the p^{th} group.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}; & if\ S > 0 \\ 0; & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}; & if\ S < 0 \end{cases} \quad (4)$$

The direction is said to increase if the Z is positive, and the computed Z - statistics are more fabulous than the z-value corresponding to the 5% significance level. The trend decreases if Z is negative, and the computed Z-statistics are higher than the z-value corresponding to the 5% significance level. If the computed Z-statistics is less than the z-value corresponding to the 5% significance level, there is no trend (Chandubhai et al., 2017).

Sen's slope is a nonparametric statistical method used widely in climatological studies worldwide to identify the magnitude of changes in temperature and rainfall. Sen identified Sen's slope in 1968 to estimate the magnitude of trends in the data time series. The slope of 'n' pairs of data can be first calculated by using the following equation;

$$\beta_i = \text{Median} \left\{\frac{X_j - X_k}{j-k}\right\} \ \forall\ (k < j) \quad (5)$$

A negative βi value denotes a lessening tendency; a positive βi value epitomizes an increasing trend over time. The average 'n' values of βi are Sen's slope estimator test. If 'n' is an even number, then the slope of Sen's estimator is calculated using the following equation: In this equation, xj and xk represent values data at the period j and k, respectively, and period j is after time k (k ≤ j).

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231

$$\beta_{med=\frac{1}{2}} \ (\beta[{}^{n}/_{2}] + \beta\left[{}^{(n+2)}/_{2}\right] \quad (6)$$

If 'n' is an unknown number, then the estimated slope by using Sen's method can be computed as follows:

$$\beta_{med=\beta\left[{}^{(n+1)}/_{2}\right]} \quad (7)$$

Lastly, βmed is tested by a two-tailed test at a 100 (1−α) % confidence level, and the actual slope of the monotonic trend can be projected using a nonparametric test.

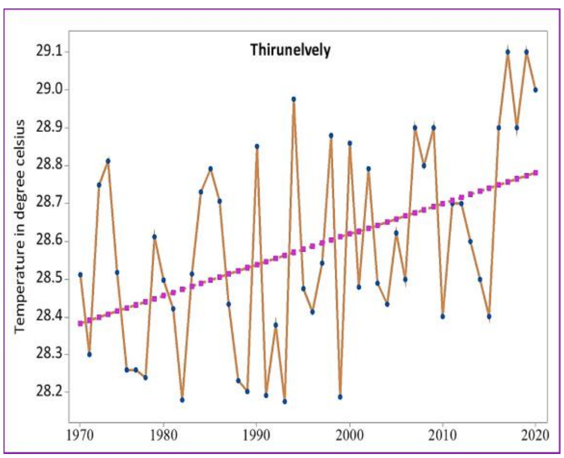
4.0 Results

4.1 The Mann Kendal trend analysis of temperature

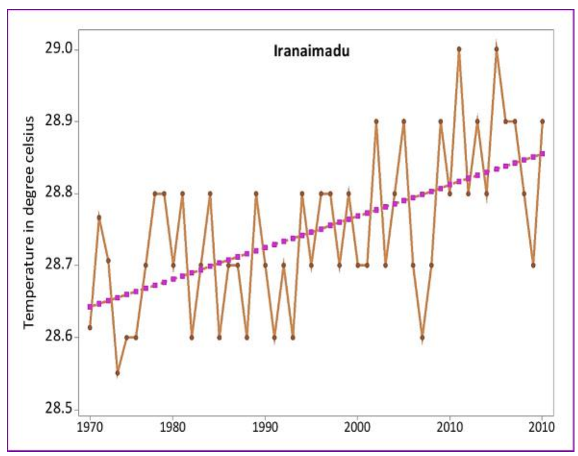
The Mann Kendal trend analysis portrays the annual temperature trend of all the study areas (Table 2). The Mann Kendal trend analysis of the temperature also indicates the data's trend pattern. P values of all temperature stations such as Thirunelvely (Figure 2 (a), Iranaimadu (Figure 2 (b), Murungan (Figure 2 (c), Kanukkerny (Figure 2 (d), and Vavuniya (Figure 2 (e), show more petite than the significant alba level (Table 1). Further, all results of the Mann Kendal analysis reject the null hypothesis. The following table indicates the p values of all temperature stations.

Table 2: The Mann Kendal trend analysis of temperature of the Northern region of Sri Lanka

Series\Test	Kendall's tau	p-value	alba	Test Interpretation
Thirunelvely	0.275	0.005	0.05	Reject H0
Vavuniya	0.443	<0.0001	0.05	Reject H0
Iranaimadu	0.467	<0.0001	0.05	Reject H0
Murungan	0.460	<0.0001	0.05	Reject H0
Kanukkerny	0.403	<0.0001	0.05	Reject H0
Akkarayankulam	0.432	<0.0001	0.05	Reject H0



(a)



(b)

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231

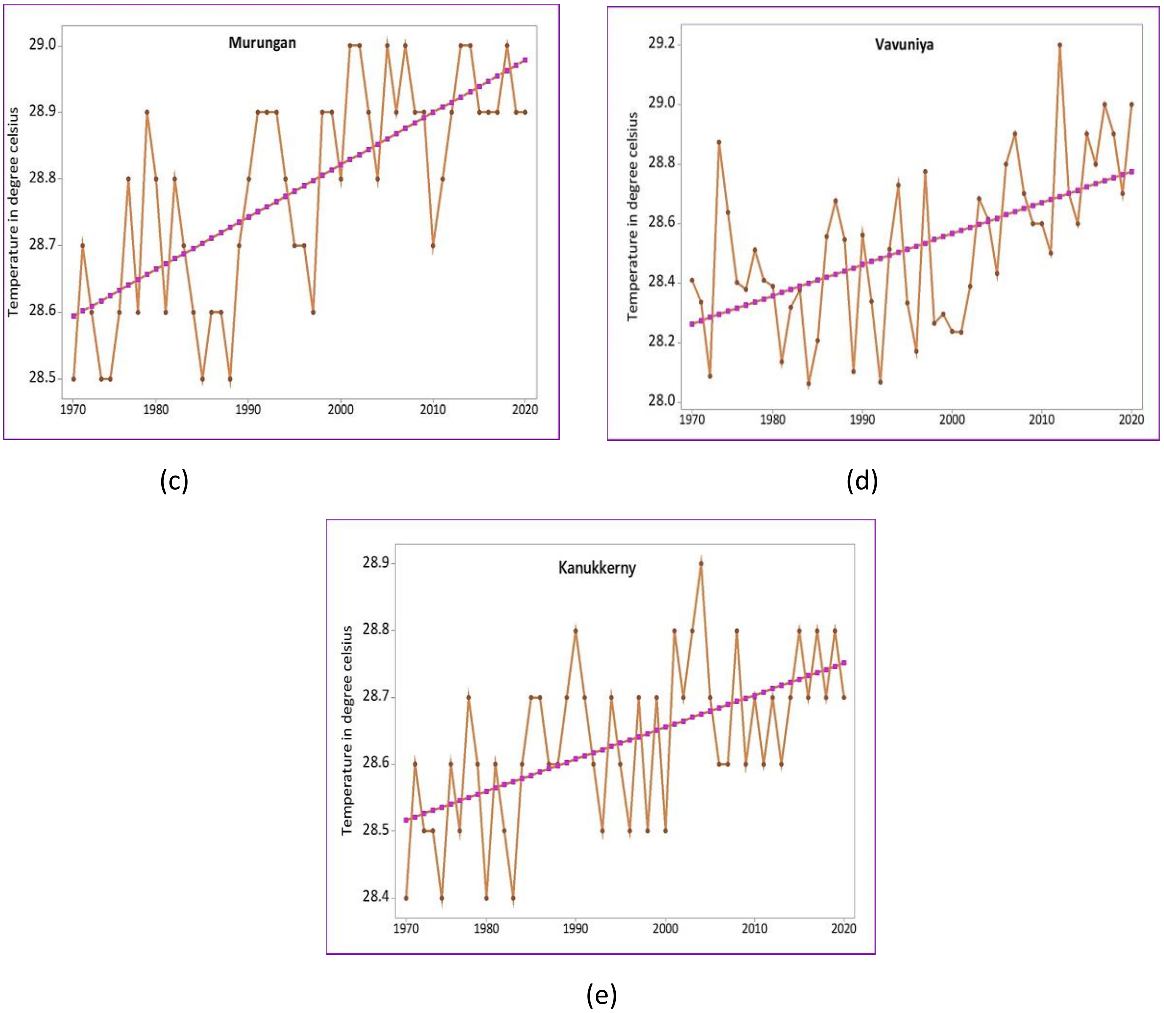


Figure 2: Average annual temperature trend of selected stations in the Northern Region of Sri Lanka

According to Sen's slope analysis, there is an increase in the temperature of the Northern region of Sri Lanka by 0.44 °C per decade from 1970 to 2019, but it varies spatially and temporally. The following table indicates Sen's various slope values regarding the temperature increase for the multiple stations of the study area (Table 3).

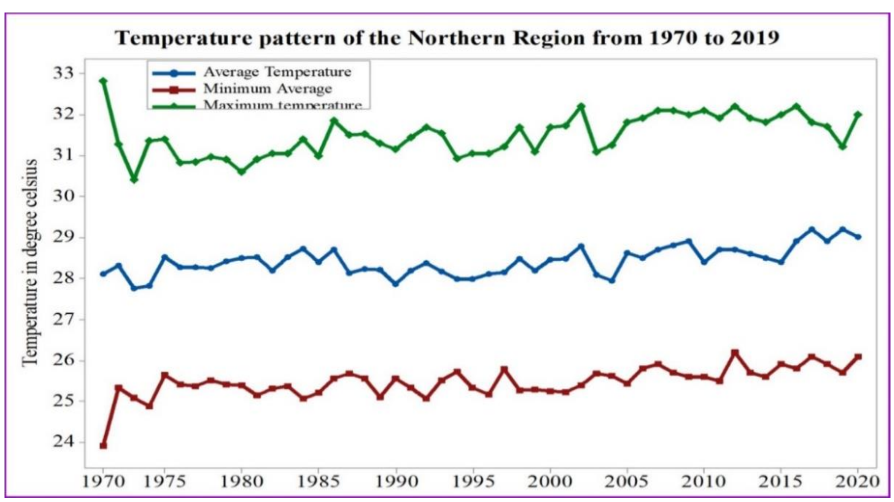


Figure 3: Annual mean, maximum, and minimum temperature changes in the Northern region of Sri Lanka.

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/). E-ISSN: 2948-5231

Article Journal of Asian Geography, 2022, Volume 1 (Issue 1), 48-59.

Table 3: Sen's slope values of temperature for different stations of the Northern region of Sri Lanka

Stations	Seasons	Sen's Slope Values/decade	Trend
Iranaimadu	North-East Monsoon	0.37	Rising
	South West Monsoon	0.32	Rising
	Annual	0.43	Rising
Murungan	North-East Monsoon	0.31	Rising
	South West Monsoon	0.39	Rising
	Annual	0.44	Rising
Kanukkerny	North-East Monsoon	0.35	Rising
	South West Monsoon	0.38	Rising
	Annual	0.41	Rising
Thirunelvely	North-East Monsoon	0.36	Rising
	South West Monsoon	0.39	Rising
	Annual	0.45	Rising
Vavuniya	North-East Monsoon	0.33	Rising
	South West Monsoon	0.44	Rising
	Annual	0.49	Rising

4.2 Monthly mean Temperature increases during the climatic periods

There was no considerable increase in temperature in the research region during the climatic periods of 1901-1930 and 1930-1960. However, a significant temperature rise can be observed in 1960-1990 compared to the previous two periods. The average temperature in the period from 1901 to 1930 is 27.25°C. From 1931 to 1960, it was 27.27°C, then a significant increase to 27.57°C in 1961-1990. Finally, it increased to 28.2°C from 1991-2019. No such difference can be seen between 1901-1930 and 1931-1960. The research region has started its significant deviation from 1960, with a 0.4°C change between 1960-1990 and 1991-2019. According to the analysis, the temperature increased in the 1990-2019 period compared to the 1901-1930 period. The temperature of the study area (including all stations) has risen by 0.84°C from 1901 to 2019. However, it has deviated between stations such as 0.84°C in Thirunelvely (Figure 4(a)), 0.86°C in Iranaimadu (Figure 4(b)), 0.87°C in Murungan (Figure 4(c)), 1.06°C in Kanukkreni (Figure 4(d)), 0.96°C in Mankulam (Figure 4(e)), and 0.74°C in Akkarayankulam (Figure 4(f)),). The Kanukkerny station has the highest increase in temperature in the study area, which is 1.06°C. Considering the months, the temperature increased by 1.01°C in January. It has increased between stations. For example, in January 1901-1930, it was 25.32°C, then the temperature rose to 26.33°C.

There is an increase in air temperature in February. The temperature increased to 0.9°C in February. Compared to the period of 1901-1930, the February factor increase of the 1991-2019 period in Vavuniya was 0.96°C, one °C in Pallavarayankaddu, 0.97°C in Iranaimadu, 0.95°C in Murungan, 0.98°C in Kanukkeni, 0.98°C in Thirunelvely, and 1.05°C in Mankulam. The month of March is significant, according to the analysis. The average temperature of 1.07°C has increased in the research area. Compared to 1901-1930, in every climate period, it is being raised. For example, March 1930-1960 seemed 27.5°C, then increased to 28.1°C in 1961-1990 and 28.57°C in 1991-2019. In all stations, March's average temperature has risen by more than one °C. Therefore, from 1991 to 2019, the climate has increased by 1.04°C in Vavuniya, 1.06°C in Palvarayankaddu, 1.05°C in Iranaimadu, 1.03°C in Murungan, 1.07 °C in Kanukkerni, 1.07 °C in Thirunelvely, and 1.04 °C in Mankulam. Only in Akkrayankulam and Thannimurippu areas was the increase 0.85 °C. March has the highest growth out of the monthly increase even though the rise between stations was from 0.7 °C to 0.85 °C.

The temperature of May, June, and July also increased. During these months, a temperature increase was observed, and a high temperature was felt in the research areas. Thus, the temperature rose by 0.83 °C in June, 0.85 °C in May, and 0.92 °C in July. However, the monthly temperature for July in Akkarayankulam stations for the climatic period from 1931 to 1960 shows significant variation from the other climatic period. Even the temperature felt in August and September is high. There was no such increase in the temperature of August and September from 1971 to 1990. The average temperature for September during the climatic period from 1901 to 1930 manifest significant in Mankulam station. The average climatic factor conclusion of October, November, and December changed in research areas. In November, the temperature increase is lesser than in December, the wettest month. Thus, the wettest month may be changed to November. In October, the temperature increase is 0.65 °C, and in December, it is 0.73 °C. The lowest temperature increase in the research area was in November. Although December has a slight increase, many differences can be area-wise.

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231

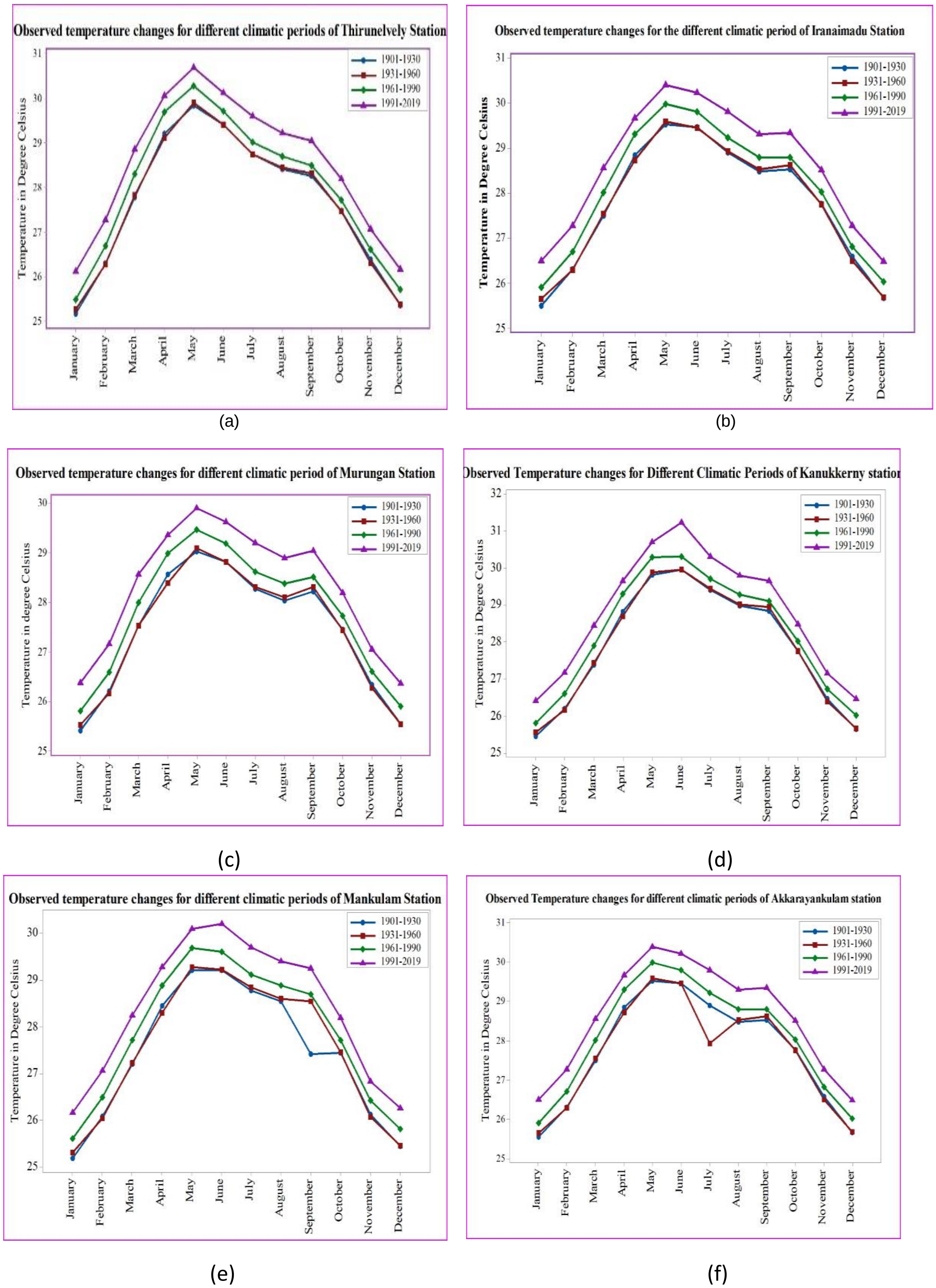


Figure 4: Observed monthly temperature changes in the different climatic periods at selected stations of the Northern Region of Sri Lanka

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).

4.3 The monthly mean temperature pattern of the Northern region of Sri Lanka.

Monthly temperature from January to April

The average temperature in January was 25.5°C from 1960 to 1990. Even though there was not much difference from 1990 to 2008, it sometimes fluctuated. However, it is in the range of 25 - 26°C. The average temperature in February of 1990 – 2008 was 26.5°C, while the average temperature in March from 1960 to 2015 was 28.7°C. The highest temperature was felt during mid of March to early April of 1972 – 1981 and 2008. In this period, high rainfall was recorded because of ionic inter convergence zone motion and Cumulus clouds' intensity- Cu in the Northern region sky. There was no temperature change in April. It was between 29 - 30°C. There was not much difference in temperature during the above four months. The northeast monsoon wind influences the Northern region by bringing rain during January and February, and the average temperature is low. This is because the condensation forms clouds and low compression in the weather.

Temperature changes from May to August

Next in line is the temperature of the Northern region from May to August. An increase in temperature can be observed from 1960 to 2007. The average temperature of May from 1960 to 1990 was 29.50°C. However, it was 31.30°C in 1999, 31.0°C in 2001, and the average temperature in May from 2000 – 2008 was 30.3°C. As far as the 1960 – 1990 period is considered, in June it was 29°C, 30.80°C in 2002, and 30°C in 2006. From July 1960 – 1990, it was 28.6°C, 31.3°C in 1999, 29.4°C in 2000, 29.3°C in 2001, 29.3°C in 2002, 30.1°C in 2003, and 29.9°C in 2009. The average temperature in August of 1960 – 1990 was 28.3°C. However, it was 31 °C in 1999, 28.9°C in 2001, 29.4°C in 2004, 29.5°C in 2005, and 29.5°C in 2006. The months mentioned above are dry in the Northern region of Sri Lanka. Eventually, high temperatures and a dry atmosphere give rainfall to the Northern region due to the Southwest monsoon that blows in the South and West parts of Sri Lanka. However, the temperature increased in these periods after the 1990s. Averagely it has increased to 0.28°C in May, to 0.21°C in June, to 0.28°C in July, and to 0.3°C in August. However, this increase cannot be taken as an advantage because it took place within a short period in the Northern region. July is the hottest month in the Northern, and the monthly temperature of July is higher than in the other adjoining region of the study area. Figure 5 shows the July temperature in the Northern and North Central regions of Sri Lanka.

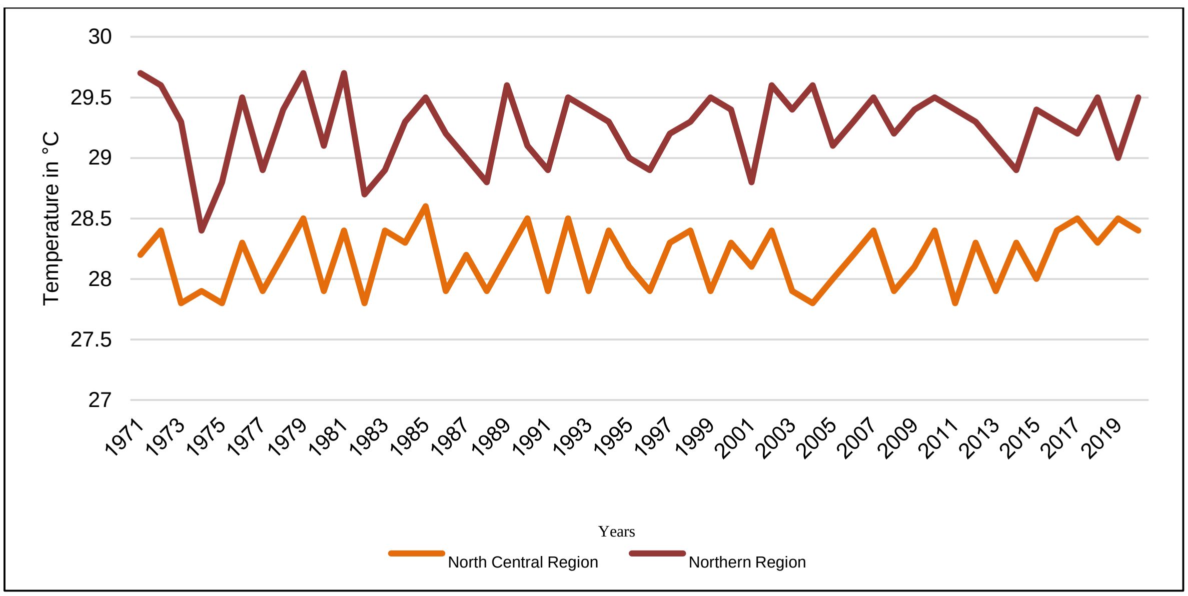


Figure: 5 Average temperature of July in the Northern and North Central Region of Sri Lanka from 1971 to 2020

Temperature pattern from September to December

There are not many differences in temperature between September and December. However, it increased from September – December in 1960. The temperature in September was 28.3°C, and it got increased afterward to 30.7°C in 1999, to 29.1°C in 2001, to 29.7°C in 2003, and 29.2°C in 2006. The average temperature from September 1961 – 1990 was 28.3°C, in 2000-2008, it was 28.8°C. From 1930 to the present, the temperature has averagely increased by 0.30°C. The temperature increased in October month. In 1960 – 1990 it was 27.7°C, and 28°C in 2000 – 2007. In these months, it has risen to 30.03°C. From 1960 to 1970 it was 26.7°C, and in 2000 – 2007 it was 26.4°C. Considering December, the temperature was 25.8°C from 1960 – 1990 and 25.8°C from 2000 – 2008. It has increased by 0.02°C.

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).

High temperature during the Convectional Period

Analysis results show that the average monthly temperature in Northern Sri Lanka for the convectional months is higher than during the other months. Moreover, the hottest month of the study area falls under the convectional period. For example, July was the hottest month in the Northern region, but the convectional process is the main reason for July's highest temperature. However, spatially, all Northern areas have the highest monthly rainfall during the convectional periods. Therefore, spatially, there are some variations in the temperature between the places, as illustrated in Figure 6. However, coastal areas have low temperatures than other places due to the changes in evaporation rate in the study area's coastal parts.

The day-night air temperature variations in the study area impact the comfort weather system. Generally, variations can be seen in the temperature range between the day and night temperature in the Northern region of Sri Lanka, which creates extreme weather variations between day and night. These temperature variations create wind speed variations in the coastal parts, which disrupt the standard land-sea breeze directions and velocity. Furthermore, these conditions affect fishing activities as well as agricultural activities.

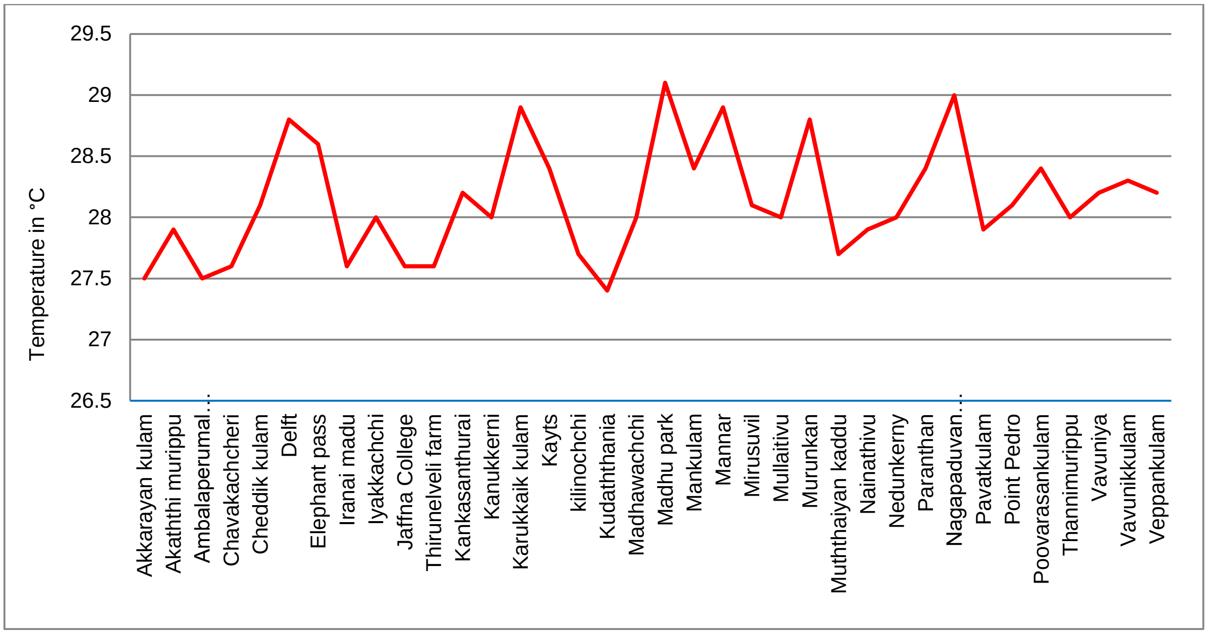


Figure 6: Annual Average Temperature of convectional months for the Selected Places in Northern Sri Lanka

5.0 Discussion

Temperature trend analysis indicates significant results in this study. Some important changes have been identified in the study area. However, various studies also revealed the same pattern of climate change in multiple places (Silva, 2014; Shanthi De Silva, 2016; Premalal, 2009; Basnayake, Fernando, & Vithanage, 2002; Suppaiah, 1996). As per the report of the national-level agencies about climate change, there are temperature changes by 0.81 °C from 1901 to 2019 all over the country. It is considered the baseline and acceptable climate change in Sri Lanka (Eriyagama et al., 2010). However, the current study indicates that the temperature change in the Northern region of Sri Lanka is 0.84 °C, similar to the national level studies. Seasonal temperature changes are also identical to the studies from other areas. The current study explained an increase in temperature in the SouthWestMonsoonSeason by 0.96 °C, and the other studies also have a similar scale of expansion for this season (Zubair, 2002; Eriyagama & Smakhtin, 2009; Basnayake, Fernando & Vithanage, 2002). Based on the monthly pattern of studies, observed temperature changes in the study area do not tally with other studies because other studies indicate different values in the monthly increasing temperature pattern (De Costa, 2010; Silva, 2006). However, there are significant differences between June, July, August, and September. Many studies indicate an increase in the monthly temperature changes, but the increased value of the current study differs from previous studies (Eriyagama et al., 2010). Studies such as by Basnayake, 2007; Chandrapala, 2007; De Costa, 2008 explain that the temperature had increased significantly. However, there are some variations among the studies regarding the daily mean, maximum, and minimum temperature in Sri Lanka. Certain studies show variations in the monthly and annual mean temperatures in many parts of Sri Lanka.

According to the Mann Kendal trend analysis, temperature increases by 0.84° C in the Northern region of Sri Lanka. However, it varies spatially in the study area. According to the findings, from 1901 to 1930 and from 1931 to 1960, there were no significant changes in the annual or seasonal pattern of temperature. However, substantial temperature changes are found between 1961-1990 and 1991-2019. The temperature has increased rapidly by 0.61° C in the Northern region of Sri Lanka. Compared with other countries studies on temperature anomalies, they also indicate an increase in temperature. Kuttippurath et al., 2021; India Meteorological Department, 2013; Kumar Guntu & Agarwal, 2020; Katzenberger et al., 2021 elaborated that there is an increase in the annual temperature pattern of India. Further analysis of other South Asian countries also revealed the same results in temperature changes (Xu et al., 2017; Lacombe et al., 2019; Raswan, 2017). Temperature is the most crucial factor influencing a region's evaporation pattern. The evaporation rate of the Northern region has increased by 17% in the study area. The temperature increase could contribute to the study area's evaporation increase.

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231

6.0 Conclusions

There are increasing trends in the annual, seasonal, and monthly temperature patterns of the Northern region of Sri Lanka. The Mann Kendal trend analysis shows a significant trend in increasing temperature in every station. Sen's slope estimator also indicates the rising temperature pattern in all the stations of the Northern region of Sri Lanka. Further, the temperature of the Northern part has increased in every climatic period compared with previous climatic periods. In conclusion, climate change dramatically impacts many socio-economic sectors of the Northern region of Sri Lanka. The surface water resources of the study area are prone to the severe threat of climate change.

Geographically the Northern region has a different setting compared to other parts. The study area has much been influenced by the sea surface temperature changes from the Bay of Bengal and the Arabic Sea. The observed temperature has shown a significant increase in Northern Sri Lanka. If the temperature increases continuously, the Northern region will face a severe threat in many socio-economic sectors. The immediate and essential mitigation or adaptation measures would reduce the severe impact due to dramatically increased temperature in the Northern region.

Acknowledgement: The authors would like to acknowledge editors and reviewers for their constructive comments to improve this article.

Conflicts of Interest: There is no conflict of interest in this study

References

Alahacoon, N., & Edirisinghe, M. (2021). Spatial variability of rainfall trends in Sri Lanka from 1989 to 2019 as an indication of climate change. ISPRS *International Journal of Geo-Information*, *10*(2), 84.

Basnayake, BRSB, Fernando, T.K. and Vithanage, J. C. (2002). Variation of Air Temperature and Rainfall during Yala and Maha Agricultural Seasons. *Proceedings of the 58th Annual Session of Sri Lanka Association for the Advancement of Science (SLASS), Section E1*, 212.

Bonjean Stanton, M. C., Dessai, S., Paavola, J., Miu, L. M., Hennessey, R., Pittman, J., Morand, A., Douglas, A., UNDP, Ciscar, J. C., Dowling, P., Lise, W., van der Laan, J., Duan, H., Wang, S., Dowling, P., Lehner, B., Czisch, G., Vassolo, S., … Dutra, R. M. (2016). Coping with Climate Change and Variability: Lessons from Sri Lankan Communities. In *Energy Policy* (Vol. 1, Issue 5).

Chandubhai, P. C., Chandrawanshi, S. K., Nehru, J., Vishwavidyalaya, K., & Thanki, J. D. (2017). *Analysis of rainfall using Mann-Kendall trend, Sen's slope and variability at five districts of south Gujarat, India Analysis of rainfall using Mann-Kendall trend, Sen's slope and variability at five districts of south Gujarat, India*. *May*.

De Costa, W. A. J. M. (2010). Adaptation of agricultural crop production to climate change: A policy framework for Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, *38*(2), 79–89. https://doi.org/10.4038/jnsfsr.v38i2.2032

De Silva M., T., & Hornberger, G. M. (2019). Assessing water management alternatives in a multipurpose reservoir cascade system in Sri Lanka. *Journal of Hydrology: Regional Studies*, *25*(April), 100624. https://doi.org/10.1016/j.ejrh.2019.100624

Eriyagama, N., & Smakhtin, V. (2009). Observed and projected climatic changes, their impacts and adaptation options for Sri Lanka: A review. *National Conference on Water, Food Security and Climate Change*, *October 2015*, 99–117. http://publications.iwmi.org/pdf/H042863.pdf

Eriyagama, N., Smakhtin, V., Chandrapala, L., & Fernando, K. (2010). *Report 135*.

Grover, S., Tayal, S., Sharma, R., & Beldring, S. (2022). Effect of changes in climate variables on the hydrological regime of Chenab basin, western Himalaya. *Journal of Water and Climate Change*, *13*(1), 357–371. https://doi.org/10.2166/wcc.2021.003

India Meteorological Department. (2013). *State Level Climate Change Trends L S Rathore, S D Attri, and A K Jaswal*. 156.

Katzenberger, A., Schewe, J., Pongratz, J., & Levermann, A. (2021). Robust increase of Indian monsoon rainfall and its variability under future warming in CMIP6 models. *Earth System Dynamics*, *12*(2), 367–386. https://doi.org/10.5194/esd-12-367-2021

Kumar Guntu, R., & Agarwal, A. (2020). Investigation of Precipitation Variability and Extremes Using Information Theory. In *Sciforum Electronic Conference Series* (Vol. 3).

Kuttippurath, J., Murasingh, S., Stott, P. A., Balan Sarojini, B., Jha, M. K., Kumar, P., Nair, P. J., Varikoden, H., Raj, S., Francis, P. A., & Pandey, P. C. (2021). Observed rainfall changes in the past century (1901–2019) over the wettest place on Earth. *Environmental Research Letters*, *16*(2). https://doi.org/10.1088/1748-9326/abcf78

Lacombe, G., Chinnasamy, P., & Nicol, A. (2019). Review of climate change science, knowledge, and impacts on water resources in South Asia. Background Paper 1. In *International Water Management Institute*. https://doi.org/10.5337/2019.202

Manawadu, L., & Fernando, N. (2008). Climate Change in Sri Lanka. *Review-Journal of the University of Colombo*, *1*(2), 1–28.

Mehta, D., & Yadav, S. M. (2021). An analysis of rainfall variability and drought over Barmer District of Rajasthan, Northwest India. *Water Supply*, *21*(5), 2505–2517. https://doi.org/10.2166/ws.2021.053

Naveendrakumar, G., Vithanage, M., Kwon, H. H., Iqbal, M. C. M., Pathmarajah, S., & Obeysekera, J. (2018). Five decadal trends in averages and extremes of rainfall and temperature in Sri Lanka. *Advances in Meteorology*, *2018*. https://doi.org/10.1155/2018/4217917

Ogou, F. K. (2021). *Vegetation Cover Change Associated With Changes in Hydro-Climatic Variables in Northern Sub-Saharan Africa in Recent Decades.*

Paparizou, S., & Dirk Schindler Simeon Poturdis Andres Matzarkis. (2017). Spatio-temporal analysis present and future precipitation responses over South Germany. *Journal of Water and Climate Change*, *9*(3), 490–498.

Piratheeparajah, N. (2015). Spatial and Temporal Variations of Rainfall in the Northern Province of Sri Lanka. *Journal of Environment and Earth Science*, *5*(15), 179-189.

Premalal, K. H. M. . (2009). Weather and Climate Trends, Climate Controls & Risks in Sri Lanka. *Presentation Made at the Sri Lanka Monsoon Forum, April 2009. Department of Meteorology, Sri Lanka.*

Purnadurga, G., Lakshmi Kumar, T. V., Koteswara Rao, K., Rajasekhar, M., & Narayanan, M. S. (2018). Investigation of temperature changes over India in association with meteorological parameters in a warming climate. *International Journal of Climatology*, *38*(2), 867–877. https://doi.org/10.1002/joc.5216

Rajendram, D. K. (2019). An Assessment of Drought in Mannar District, Sri Lanka. *International Journal of Humanities and Applied Social Science*, *November* 1–13. https://doi.org/10.33642/ijhass.v4n11p1

Raswan, G. (2017). Climate change Impact on Agriculture in the South Asian Countries. *Journal of Applied Studies*, *4*(2), 32–39.

Ross, R. S., Krishnamurti, T. N., Pattnaik, S., & Pai, D. S. (2018). Decadal surface temperature trends in India based on a new high-resolution data set. *Scientific Reports*, *8*(1), 2–11. https://doi.org/10.1038/s41598-018-25347-2

Saini, A., Sahu, N., Kumar, P., Nayak, S., Duan, W., Avtar, R., & Behera, S. (2020). Advanced rainfall trend analysis of 117 years over west coast plain and hill agro-climatic region of India. *Atmosphere*, *11*(11), 1–25. https://doi.org/10.3390/atmos11111225

Shanthi De Silva. (2016). *Impacts of Climate Change on Water Resources in Sri Lanka Impacts of Climate Change on Water Resources in Sri*

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).

Lanka. *July*.
Silva, S. de. (2014). Impacts of climate change on water resources in Turkey. *Environmental Engineering and Management Journal*, *13*(4), 881–889. https://doi.org/10.30638/eemj.2014.092
Silva, S. De. (2006). Impacts of Climate Change on Water Resources in Sri Lanka. *23nd WECD. International Conference*, 45–55.
Suppaiah, R. (1996). Spatial and Temporal Variations in the relationships between the Southern Oscillation Phenomenon and the Rainfall of Sri Lanka. *International Journal of Climatology*, *16*, 1–17.
Thennakone, V. (2018). Impact of Climate change on the water flow of the Kalu Ganga river in Sri Lanka. *International Journal of Hydraulic Engineering*, *3*(4), 38–51.
Weerasooriya, G. (2009). Economic Development problems of Sri Lanka in the postwar context. *International Journal of Economic Development*, 90–98.
Xu, Y., Zhou, B. T., Wu, J., Han, Z. Y., Zhang, Y. X., & Wu, J. (2017). Asian climate change under 1.5–4 °C warming targets. *Advances in Climate Change Research*, *8*(2), 99–107. https://doi.org/10.1016/j.accre.2017.05.004
Zubair, L. (2002). El Niño-Southern oscillation influences on rice production in Sri Lanka. *International Journal of Climatology*, *22*(2), 249–260. https://doi.org/10.1002/joc.714

This work is licensed by the Creative Commons Attribution 4.0 International (CC By 4.0) (http://creativecommons.org/licenses/by/4.0/).
E-ISSN: 2948-5231