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Long Term Microscale Decadal Analysis of Coastal Rainfall Pattern: An Indication of Microclimatic Variation in South India

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Abstract: There are drastic variations in the intensity and the pattern of rainfall and temperature globally. The variations thus reflect the variation in the microclimatic signatures. The current study aims to assess the climatic changes in the coastal region of Ramanathapuram using the monthly rainfall and temperature average along the coastal region. The microscale rainfall and temperature trend have been analysed for three decades (30 years), representing 1990 to 2019. The study was divided into three different periods: first (1990-1999), second (2000-2009), and the third decade (2010-2020). The study infers that 467 km^2 of the area receives an average of 676 mm of rain in decade-I. In decade-II, 39 km^2 of the area is noted with 637.6 mm rainfall, 48 km^2 of the study area is reported to have 821 mm rainfall, and only 29 km^2 area receives normal rainfall of 992 mm, but 351 km^2 receives "excess" rainfall of above 1000 mm. In decade-III, less than 750 mm rainfall is recorded at 202 km^2, with 43 km^2 recorded "deficit" rainfall, and 24 km^2 area received an "excess" rainfall. The variation in the amount of rain during the recent period was observed. Similarly, the temperature was comparatively elevated during the Ist Decade (1990-1999). The intensity of rain events, number of rainy days and frequency of rainfall reflected variations. The land surface temperatures also indicated minor variations and increased inter-monsoonal periods. The variation in the rainfall amount, the shift in monsoonal periods and the change in temperature indicate the microclimatic variation in the region.

Keywords: Rainfall; Monsoon; Intensity; Microclimate.

Introduction

The coastal region is vulnerable to environmental changes, especially during storms and rising sea levels. According to a study conducted by Kodzo et al. (2013), 70% of the world's coasts have significant dangers. Apart from natural reasons, the human endeavour is one of the triggering variables influencing climate changes along the coastal zone. The coastal environment changes day by day due to anthropogenic activity, creating a severe problem for the coastal ecosystem. The National Disaster Management Authority (NDMA), Government of India, has classified the study area as a moderate cyclone-hitting region and a high drought zone. The average annual rainfall in the district is 827 mm, with the largest concentration along the coast and decreasing inland.

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As a result of climate change, variations in rainfall and temperature rise have been observed globally (Ramesh et al., 2019). Studies on the possibility of global climate change in India by the IPCC (2007) forecasted significant climatic variation in specific regions. Several studies show that as a result of global warming, rainfall patterns have shifted, resulting in an increase in extreme weather events (Briffa et al., 2009; Vasiliades et al., 2009; Zhang et al., 2008; Ghahraman et al., 2007; Thilagavathi et al., 2019). Warming in the Asian area decreases the movement of southern gradients, which negatively impacts the distribution of the Indian monsoon (Ueda et al., 2006). In this regard, nonparametric approaches are frequently utilised (Nasri et al., 2009; Sonali et al., 2013).

Therefore, climate analysts and water resource management need to know rainfall outcomes' spatial and temporal trends (Meshram et al., 2017; Sayemuzzaman et al., 2013; da Silva et al., 2015; Tabari et al., 2012; Udo et al., 2012). Rainfall spatial mapping is useful in understanding the spatial pattern and its concentration variations (Gurugnanam et al., 2010; Vijayakumar et al., 2015). The number of rainy days and rainfall intensity are vital to comprehending climate vulnerability (Suhatharahima et al., 2013).

Asharaf et al. (2015) used forecasting studies to analyse changes in the Asian and Indian summer monsoons, emphasizing the expected rise in greenhouse gas emissions. Ueda et al. (2006); Stowasser et al. (2009); Annamalai et al. (2007); Turner et al. (2007); Kripalani et al. (2007); Douville et al. (2000); Hu et al. (2000); Meehl et al. (1993) revealed that the loss of the summer monsoon has an impact on the amount of monsoon rainfall and could intensify the Indian summer monsoon, seasonal and systematic changes in rainfall time series. Few authors used the GIS techniques to address the extreme climatic conditions by assessing the rainfall patterns and the temperature variations for a few decades (Thilagavathi et al., 2019). GIS techniques help to enable an easy understanding of the rainfall trend, their spatial distribution and variation concerning time (Venkatraman et al., 2012). On the other hand, the interpretation of the rainfall trend necessitates more caution (Rahman et al., 2017; Elouissi et al., 2016). Suhatharahima et al. (2013) inferred that the temporal variations of the rainfall show the sign of climate change in Tamilnadu. Boobalan et al. (2018) studied the rainfall data concerning season and annual average spatial variation maps with respect to the quartile statistical method to develop the spatial mapping of rainfall patterns. Geochemical variations in groundwater concerning the climatic changes were also noted by Thivya et al. (2018); Sivasubramanian et al. (2013); Kom et al.(2021); Balasubramanian et al. (2019); Kumar et al. (2020). Detailed knowledge and understanding of rainfall variability across various time measurements can help risk management.

This study aims to determine the microclimatic variation in the study area by integrating the decadal analysis of monthly rainfall and temperature pattern for three decades.

Study Area

The study area is a coastal region which extends a total area of 467 km^2 located in south India. The region was experiencing an average rainfall of 826 mm, with the highest concentration along the shore and decreasing inland. The land surface temperature in the location is around 28°C on average. The region experiences four different seasons in a year, viz., North-East Monsoon (NEM), South-West Monsoon (SWM), Pre-monsoon, and Post-monsoon. NEM represents October to December, SWM from June to September and Post monsoon during January and February. The northern side of the study area is Palk Bay, and the southern side is the Gulf of Mannar. The entire region is in contact with the sea; therefore, the study area is highly susceptible to radical changes. Figure 1 represents the eight rain gauge stations in the study area and Table 1 shows the average rainfall and temperature for 30 years (1990-2019). The study area was observed with consistent temperature values for all the locations, except Valinockam. The particular region is 14 m above mean sea level. Hence the temperature of the region is comparatively high.

Materials and Methods

The monthly rainfall data were collected from the Indian Meteorological Department (IMD), and Temperature data was collected from the NASA power data access portal (https://power.larc.nasa.gov/data-access-viewer/). A brief on the analytical procedure is depicted in Figure 2, enlisting the detailed methods used to process numerical data at different time series to achieve the objectives. There are mainly three methods of calculating the average precipitation depth upon an area. These are (1) Arithmetic Mean, (2) Theissen Polygon Method, and (3) Iso-Hyetal Method. The Arithmetic Mean method gives accurate results only if the stations are uniformly distributed over the area.

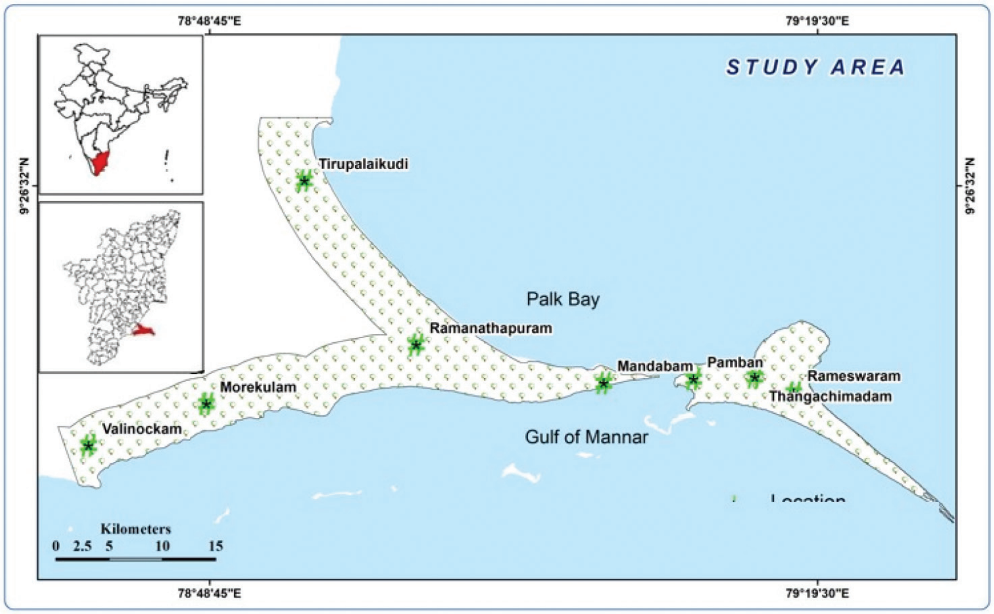


Figure 1: Rain gauge locations of Ramanathapuram.

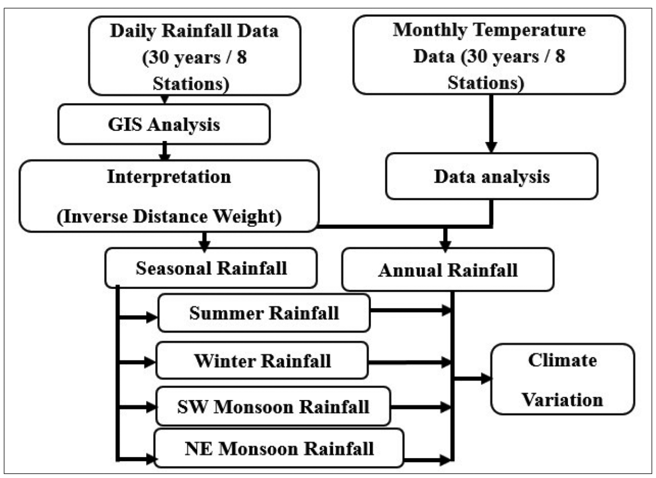


Figure 2: Methodology adopted for rainfall and temperature analyses.

Theissen Polygon method is accurate if the study area is between 500-5000 km^2. The Iso-Hyetal Method is comparatively more accurate if the rain gauge stations are large in number. The present study is concentrated in a highly sensitive coastal region with a total extent of 465 km^2. The number of rain gauge stations is less in the study area, and the distance between each rain gauge station is not uniform. Hence, nonparametric methods are usually preferred for analysing precipitation trends (Nasri et al., 2009; Sonali et al., 2013). In this method, the data can be collected from a sample location that does not follow a specific distribution. The trends provide systematic information for precise modelling, prediction, and control (Mohorji et al., 2017). In this study, daily observations at each location were used to calculate the monthly average rainfall. The formula adopted to calculate the average monthly rainfall is as follows:

Table 1: Study area rainfall and temperature

Station	*Station name*	*Latitude*	*Longitude*	*Elevation (AMSL)*	*Rainfall (mm)*		*Temperatures (°C)*	
					Max	*Min*	*Max*	*Min*
1	Ramanathapuram	9°18′N	78°59′E	8 m	179	34	28	27
2	Morekulam	9°15′N	78°48′E	6 m	162	31	28	27
3	Valinockam	9°13′N	78°42′E	14 m	133	14	29	27
4	Mandabam	9°16′N	79°08′E	7 m	165	28	28	27
5	Pamban	9°16′N	79°13′E	5 m	105	40	28	27
6	Thangachimadam	9°16′N	79°16′E	6 m	122	29	28	27
7	Rameswaram	9°18′N	79°18′E	2 m	189	30	28	27
8	Tirupalaikudi	9°26′N	78°53′E	4 m	164	19	28	28

$$y_m(t) = \sum_{j=t+1-M}^{t} y_j$$

here y is a monthly rainfall measured at the time (t) and rain for the months M. The time series derived from y_m (t) is divided into monthly subsets for each month of the year

$$y_{M^n}(T) = y_m(12(T-1)+n)^M$$

where T is taken as the year index for the whole year (i.e. from 1 to N, and N is the total number of years given in the rainfall series), n is the month index, i.e., n = 1, 2, ... 12 as of January, February, ... and December, respectively. Hence, the $y_{M^n}(T)$ series represents the accumulated rainfall for a similar month but different years in the record.

The seasonal and yearly mean precipitation was calculated based on the average monthly rainfall. From the rain gauge station, the precipitation values were collected and interpreted. The weighted average of the values was considered for assigning values to the unknown nearby regions (Kalaivanan et al., 2018, 2019). The spatial maps were prepared for mean precipitation values representing the period 1990 to 2019. The maps were created using a multivariate interpolation technique called Inverse Distance Weighting (IDW) in GIS. Because of its low processing cost and ease of implementation, the inverse distance weighting (IDW) approach is regarded as one of the most popular deterministic methods and is frequently applied to various sectors (Paul et al., 2019; Arulbalaji et al., 2017; Chen et al., 015; Gorai et al., 2013). The accuracy of the IDW classification is satisfactory, and the computation time is fair (Maleika et al., 2020; Lyra et al., 2018; Golian et al., 2010; Kundu et al., 2019; Xihua et al., 2015) have been used to achieve a similar objective in several tropical regions.

The study period was divided into three different decades, from 1990-to 2019. The first decade referred to in the study ranges from 1990 to 1999, the second from 2000 to 2009 and the third from 2010 to 2019.

Hence, the current study focusses on assessing the decadal variation of rainfall in this drought-prone region to develop water management strategies in the near future.

Results

The first decade of the study signifies the period from 1990 to 1999. During the winter season (Figure 3-a), the Tiruplaikudi rain gauge station recorded the lowest rainfall among other locations, with an average rainfall rate of 31.6 mm. In the summer (Figure 3-b), all the rain gauge locations recorded an average rainfall rate of 60 mm. The rainfall of SWM (Figure 3-c) is comparatively lower than in the other season. The average rate of rain in SW Monsoon is 43.7 mm. The Tiruplaikudi rain gauge station received the highest rainfall rate of 84 mm among other stations. The study area receives higher rainfall during NEM (Figure 3-d). The Ramanathapuram rain gauge station observed the highest precipitation rate of 594.4 mm. The lowest rainfall was recorded in Valinockam station and is 440.76 mm. The seasonal changes in rainfall are shown in Table 2. In the second decade of the study (2000-2009), the rainfall is comparatively higher than in the previous decade, in the winter season (Figure 3-a). The Ramanathapuram and Rameswaram rain gauge station recorded the most increased precipitation of 98.04 mm. The lowest amount was recorded in the Valinockam station with 57.4 mm. In this decade, the average rainfall in the summer season has increased compared to the previous years (Figure 3-b). Tiruplaikudi station observed the highest rainfall rate of 225.6 mm and the lowest of 128.7 mm rainfall recorded in Valinockam station. During SW Monsoon (Figure 3-c), the Ramanathapuram and Rameswaram rain gauge stations observed higher precipitation of 138.17 mm and 198 mm. The lowest rainfall was recorded in Morekulam station and Valinockam station with an average of 27 mm. While in NE Monsoon (Figure 3-d), the Ramanathapuram and Rameswaram rain gauge station observed average precipitation of 937.39 mm and 1039 mm, respectively. Valinockam station recorded the lowest rainfall rate of 424.07 mm. The seasonal changes in rainfall are shown in Table 3.

In the third decade of the study (2010 – 2019), there was a decline in the winter rainfall pattern compared to the previous decade. The lowest rainfall of 10.2 mm was recorded in Valinockam, and the highest of 64 mm was recorded in Mandapam. There was also a minor decline in the summer rainfall pattern (Figure 3-b); the highest rainfall of 141 mm was recorded in the Thangachimadam rain gauge station, and the lowest was recorded in Morekulam, Mandapam station, with an average rate of 68 mm. During SW Monsoon (Figure 3-c), there was a hike in the rainfall pattern in all the locations compared with the previous decades. The Ramanathapuram rain gauge station received the highest precipitation of 138.4 mm, and the Morekulam station observed the lowest rate of 40.3 mm. Whereas in NE monsoon (Figure 3-d), Thangachimadam station

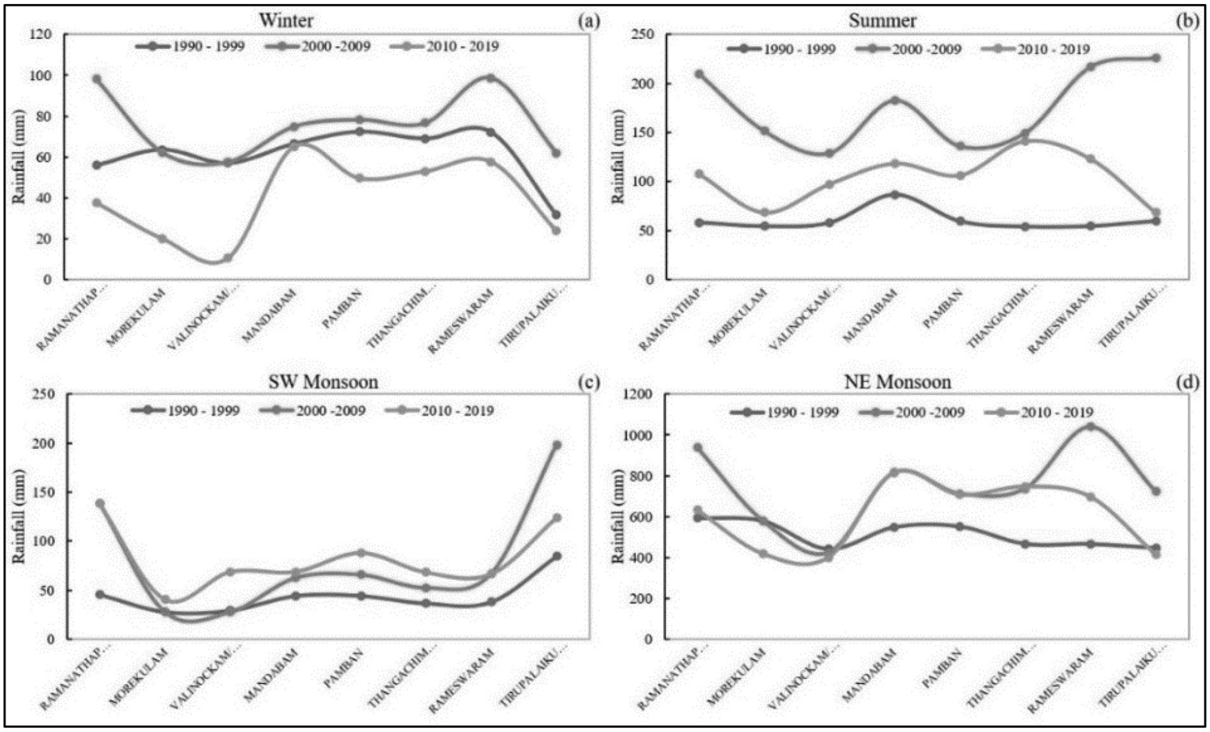


Figure 3: (a-d) Seasonal rainfall pattern of winter, summer, SWM and NEM (3 decades).

Table 2: Seasonal average rainfall in mm (1990-1999)

Stations	*Winter*	*Summer*	*SW Monsoon*	*NE Monsoon*
Ramanathapuram	55.86	58.11	45.72	594.42
Morekulam	63.54	54.39	27.8	579.8
Valinockam	56.91	57.84	29.22	440.76
Mandapam	66.31	86.31	44.15	548.29
Pamban	72.27	59.32	44.3	552.73
Thangachimadam	68.88	53.95	36.56	466.53
Rameswaram	72.07	54.47	37.99	465.79
Tirupalaikudi	31.65	59.58	84.52	445.63

Table 3: Seasonal rainfall in mm (2000-2009)

Stations	*Winter*	*Summer*	*SW Monsoon*	*NE Monsoon*
Ramanathapuram	98.04	209.78	138.17	937.39
Morekulam	62.2	151.3	27.8	579.8
Valinockam	57.4	128.7	27.45	424.07
Mandapam	74.7	182.5	62.4	815.8
Pamban	78.2	135.7	65.7	713.2
Thangachimadam	76.5	149.4	52.3	736.5
Rameswaram	98.7	216.6	66.9	1039.8
Tirupalaikudi	61.9	225.6	198.1	722.4

has observed the highest rainfall rate of 747.4 mm. The lowest rainfall rate of 400 mm was recorded in Valinockam. The seasonal changes in rainfall are shown in Table 4.

Groundwater is highly dependent on rainfall. It is a significant component that influences local ecological habitats, hydrological cycle and vegetation dynamics (Peng et al., 2021). Vegetation highly influences atmospheric temperature and climate change (Wang et al., 2021; Kouakou et al., 2014; Nunez et al.,2021; Materia et al., 2021; Zeng et al., 2021). The region is normally getting rainfall during the northeast monsoon and southwest monsoon. The precipitation predominantly occurs as cyclonic storms due to the

Table 4: Seasonal rainfall in mm (2010-2019)

Stations	*Winter*	*Summer*	*SW Monsoon*	*NE Monsoon*
Ramanathapuram	37.6	107.9	138.4	632.2
Morekulam	20.1	68.3	40.3	419
Valinockam	10.51	97.3	68.5	400.6
Mandabam	64.8	118.5	68.6	715.1
Pamban	49.5	106.3	88	708
Thangachimadam	52.9	141.4	68	747.4
Rameswaram	57.6	123.1	66.4	697.3
Tirupalaikudi	23.8	68	124	412.6

depressions in Bengal (Sivasubramanian et al., 2013). The region has undergone significant climate change over the past five decades (Sivajothi et al., 2018).

In decade-I, 25 rainy days occurred in the winter season, 35 rainy days occurred in summer, 72 rainy days in the southwest monsoon, and 289 rainy days in the northeast monsoon. From the four-season stations, Ramanathapuram, Morekulam, Valinockam, Mandapam, Pamban, Thangachimadam, Rameswaram, Trupalaikudi rain gauge were recorded with an average rainfall of less than 750 mm. Based on the regional average rainfall, the whole region was coming under scanty rainfall conditions in that decade. The decadal average rainfall is shown in Table 5.

In decade-II, 44 rainy days occurred in the winter season, 92 rainy days occurred in summer, 89 rainy days in the southwest monsoon, and 311 rainy days in the northeast monsoon. From the four different seasons, Ramanathapuram station recorded an average of 1383.4 mm rainfall (excess). Morekulam was recorded with an average of 821.1 mm (deficit) rainfall. Valinockam station recorded an average rate of 637.7 mm (scanty). Mandapam station recorded an average of 1135.4 mm (excess). Pamban rainfall station recorded an average rate of 992.8 mm (normal). Thangachimadam, Rameswaram, and Tirupalaikudi rain gauge stations with average rainfall between 850 mm to 1000 mm (excess).

In decade-III, 33 rainy days occurred in the winter season, 75 rainy days occurred in summer, 93 rainy days in the southwest monsoon, and 305 rainy days in the northeast monsoon. Ramanathapuram station recorded an average of 916 mm rainfall (normal). Morekulam and Valinockam recoded less than 750 mm. Hence it came under scanty rainfall class. Mandapam station recorded 1067 mm (excess) rainfall in the decade. Pamban station has recorded 952 mm rainfall (normal). Thangachimadam station has recorded an average of 1010 mm (excess) rainfall. Rameswaram station recorded 944 mm (normal) rain, and Tirupalaikudi noted an average of 628 mm (scanty) rainfall.

Discussion

During the three decades, the Valinockam region had scanty rainfall in all three decades. This region has no change in its rainfall condition. Similarly, the Mandabam and Thangachimadam regions have had excess rainfall for decades-II and decade-III. Spatially, 467 km^2 of the study area was under scanty rainfall in decade-I. While in decade-II, there was a variation in the spatial distribution of rainfall. Compared to the other two decades, the second decade reported a significant excess of rain among the three decades. Spatially, 39 km^2 study area got scanty rainfall, 48 km^2 area got a deficit, 29 km^2 got normal, and 351 km^2 area got excess rain. There was a similar variation in the spatial distribution of rainfall during decade-III. Spatially, 202 km^2 study area got scanty rainfall, 43 km^2 area got a deficit, 200 km^2 got normal, and 24 km^2 area got excess rain. The decadal spatial changes are given in Table 6 and spatially shown in Figure 4.

Table 5: Decadal average rainfall changes (mm)

Stations	*Decadal-I (1990-1999)*	*Decadal-II (2000-2009)*	*Decadal-III (2010-2019)*
Ramanathapuram	754	1383.4	916
Morekulam	725.6	821.1	548
Valinockam	584.8	637.62	577
Mandabam	745	1135.4	1067
Pamban	728.7	992.8	952
Thangachimadam	626	1014.7	1010
Rameswaram	630.3	1422	944
Tirupalaikudi	621.4	1208	628

Table 6: Spatial distribution of rainfall

Class	*Decadal-I Area km^2*	*Decadal-II Area km^2*	*Decadal-III Area km^2*
< 750: Scanty	467	39	202
750 - 850: Deficit	-	48	43
850 - 1000: Normal	-	29	200
1000 >: Excess	-	351	24

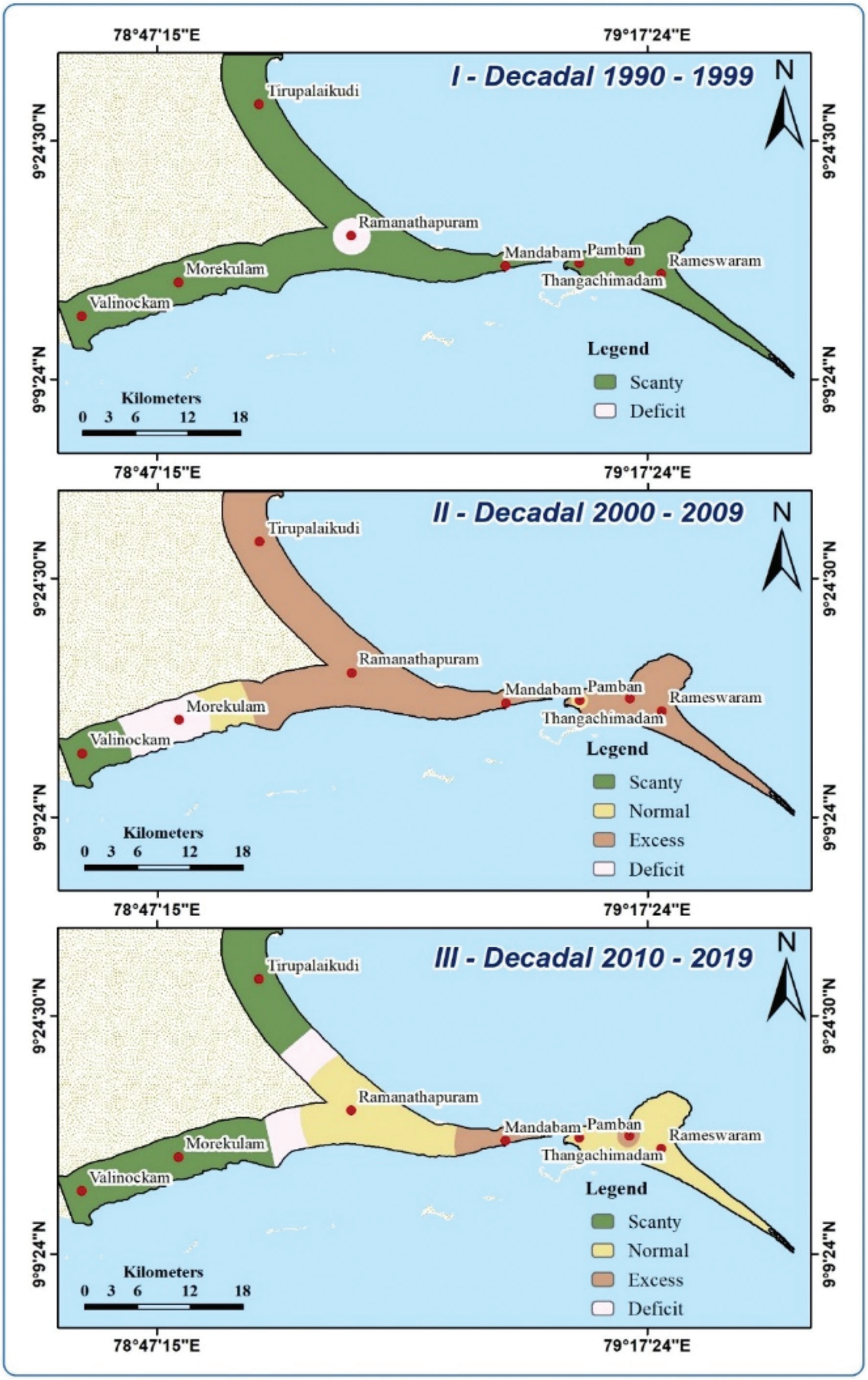


Figure 4: Spatial variation for the annual rainfall during the past three decades.

This coastal region received the maximum rainfall during the North-East Monsoon and radiated maximum temperature during the summer season. In the year 1990 of the I-Decade study period, 391 mm of highest rainfall was recorded in November and 26°C, the lowest atmospheric temperature recorded in December. The rain has raised the water table and enriched the healthy vegetation, decreasing the region's surface temperature.

March to May months represent the summer season of the year, which does not receive significant rainfall. Consequently, the healthy vegetation of the region decreased, and the regional land surface temperature reached a maximum of 32°C. During 1991-1992, a shift was recorded in the average rainfall and temperature. The moderate rain decreases throughout the year. Consequently, the surface temperature seems to increase in the year. In 1993 & 1994, the study found that a minor rise in the rainfall was recorded during the North-East Monsoon, reducing the surface temperature to 24.3°C. In other seasons, the temperature remains at an average of 30°C. During 1995 & 1996, the region recorded a lesser amount of rainfall. From 1997 to 1999, a minor increase in winter and summer rainfall was observed. Consequently, it decreases the surface temperature to an average of 27°C.

In the years 2000 & 2001 of the II-decade study, a minor increase in rainfall was recorded. The surface temperature of the region was also comparatively decreased at this time. The rain in the northeast monsoon increased compared to the previous year, and the surface temperature came down to 27.6°C. During the years 2002 & 2003, there was a decrease in rainfall pattern. Consequently, the average temperature also increased to 28°C. There was a drastic increase in rainfall recorded between 2004 to 2009. The region received rainfall during all seasons. In the second decade, 1383 mm of average rain was recorded in this station.

In the III-decade, the average rainfall recorded was high between 2010 to 2015. The atmospheric temperature was noted at an average of 28°C. From 2016 to 2019, a declining change was pointed out in the seasonal rainfall, and the location exhibits a surface temperature of 29°C.

In this location, the highest rainfall and lowest atmospheric temperature were recorded in decade-II, and the most insufficient rain and increased atmospheric temperature were noted in decade-I.

The decade-wise seasonal changes in the rainfall and temperature of the Ramanathapuram region illustrate that the rainfall distribution in decade-I is very low compared to decade-II and decade-III (Figure 5-A). Observation of the seasonal rainfall distribution indicates that there were changes noted in the seasonal cycle. In decade-I, during April month (summer season) received less rainfall. But in decade-II, a drastic increase in the rain during the summer was observed, and in decade-III, a slight decrease in the amount of rainfall was observed.

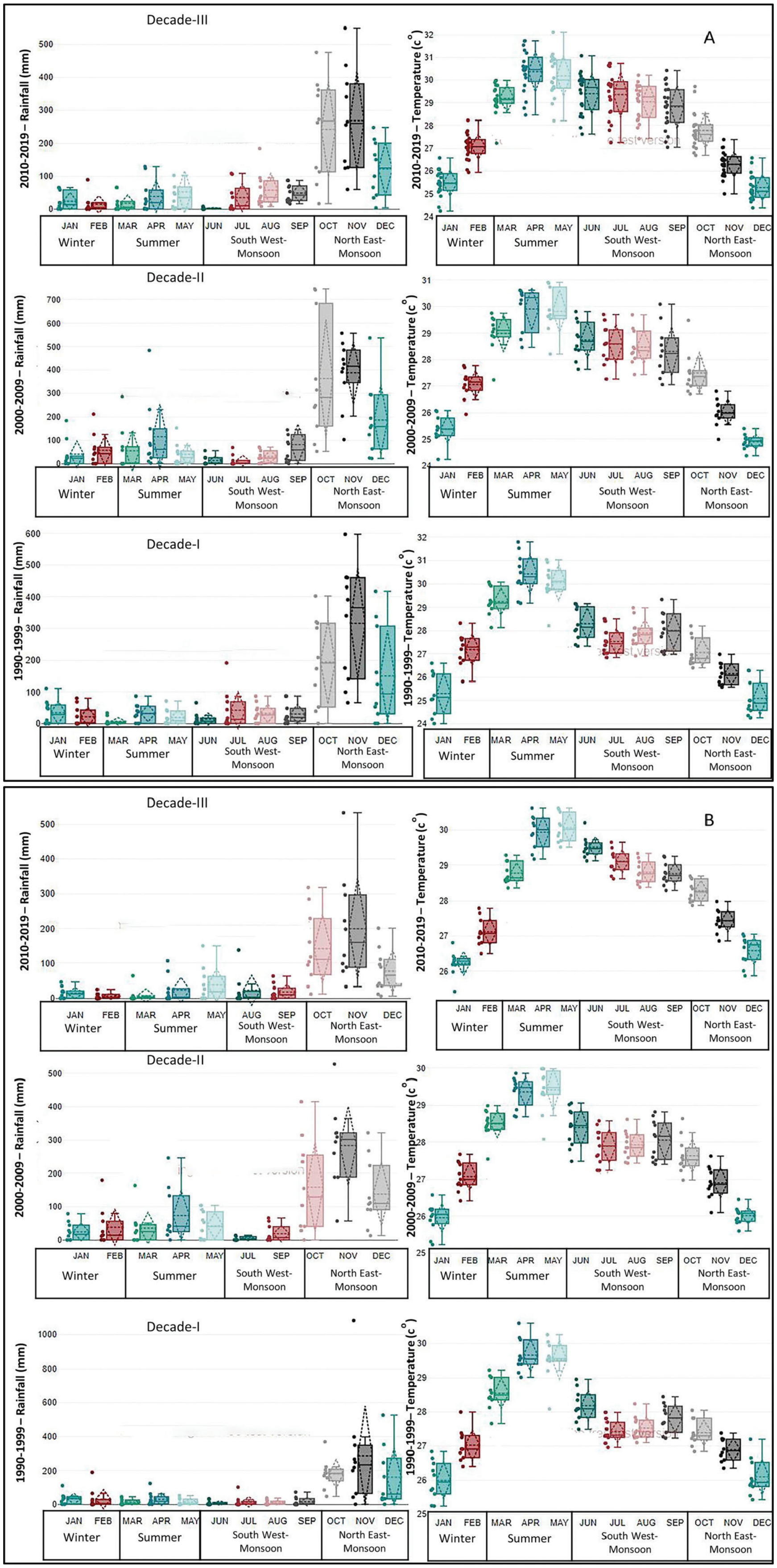
The variations in rainfall were also noticed in the southwest monsoon. From decade-I to decade-III, a decreasing rainfall trend was seen during June, July, and August southwest monsoon. Subsequently, an increasing trend was observed during the northeast monsoon decades. Similarly, the surface temperature during the southwest monsoon season was noted to increase each decade.

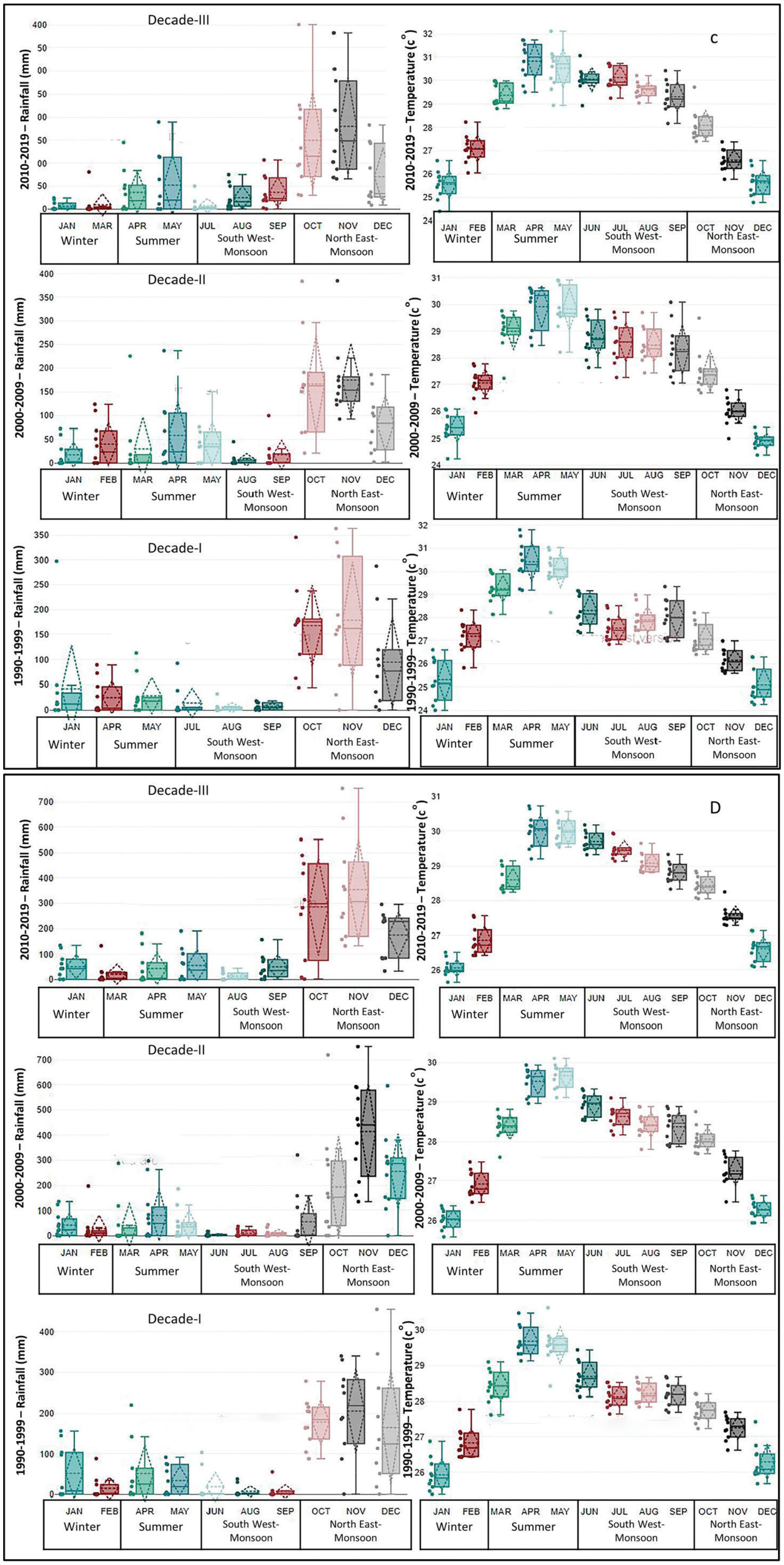
The decade-wise seasonal changes in the rainfall and temperature of the Morekulam region (Figure 5-B) reveal that the southwest monsoon of this region has noted minor changes in the amount of rain. In decade-I, the month of June and July has reflected a maximum rainfall of 102 mm. While in decade-II, it has decreased to 14 mm, and in decade-III, a further reduction in rainfall was observed. In recent decades, a rise in surface temperature has been recorded during this season.

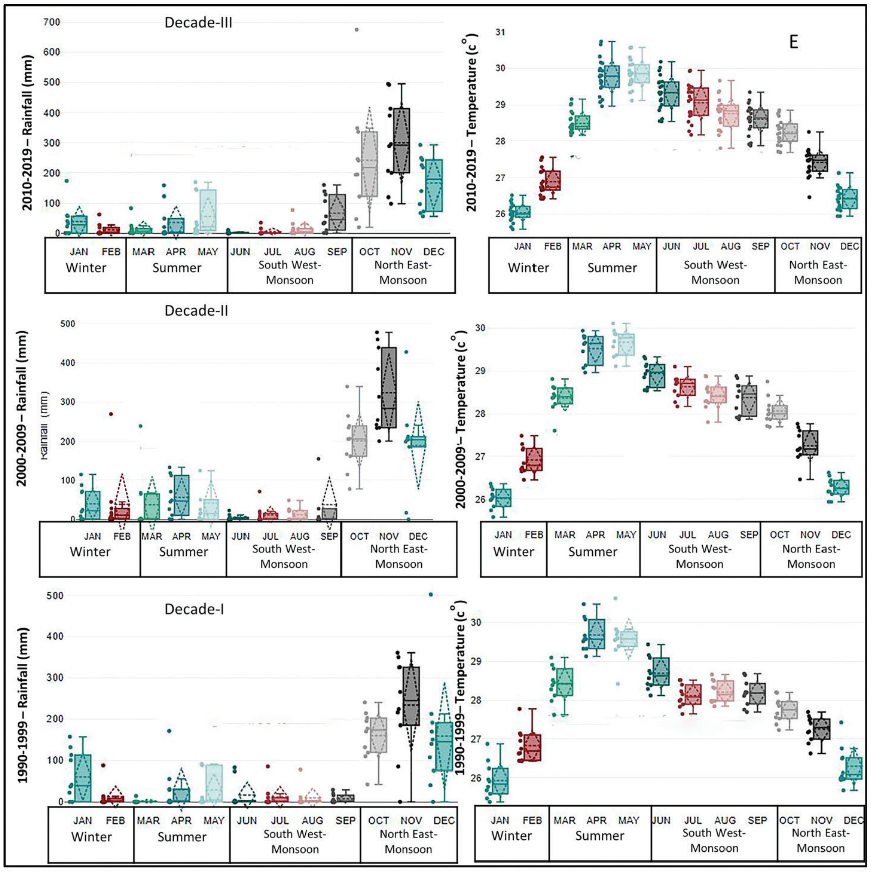
Valinockam exhibits variation during June and July of the southwest monsoon. The minimum rainfall has decreased between decade-I to decade-III (Figure 5-C). The temperature has increased through the decade during the southwest monsoon months. Mandapam recorded maximum rainfall in all decades compared to other regions with high rainfall during April, representing the summer showers (Figure 5-D). The region has also observed changes in the rain during the June and July of the southwest monsoon. The rainfall has decreased from decade-I to decade-III as well as the temperature during the particular season got a minor increase from decade-I to decade-II.

During April, the Pamban region underwent changes as the beginning of the summer season (Figure 5-E). The rate of rainfall is also comparatively high in this region. The region reflected a decreasing rain trend during the southwest monsoon's June, July, and August. A minor increase in temperature was observed from decade-I to decade III during the particular season.

The meteorological station located at Thangachimadam also shows changes in rainfall during April in the summer season (Figure 5-F). During this month, the amount of rainfall showed an increase with respect to decades. But a decrease in the rainfall was observed during June and July during the southwest monsoon.


A
Decade-III
2010-2019 – Rainfall (mm)
2010-2019 – Temperature (c°)
Decade-II
2000-2009 – Rainfall (mm)
2000-2009 – Temperature (c°)
Decade-I
1990-1999 – Rainfall (mm)
1990-1999– Temperature (c°)
JAN FEB
Winter
MAR APR MAY
Summer
JUN JUL AUG SEP
South West-Monsoon
OCT NOV DEC
North East-Monsoon
B
Decade-III
2010-2019 – Rainfall (mm)
2010-2019 – Temperature (c°)
Decade-II
2000-2009 – Rainfall (mm)
2000-2009 – Temperature (c°)
Decade-I
1990-1999 – Rainfall (mm)
1990-1999– Temperature (c°)


Decade-III
2010-2019 – Rainfall (mm)
2010-2019 – Temperature (c°)
c
Decade-II
2000-2009 – Rainfall (mm)
2000-2009 – Temperature (c°)
Decade-I
1990-1999 – Rainfall (mm)
1990-1999– Temperature (c°)
D
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Winter
Summer
South West-Monsoon
North East-Monsoon


E
Decade-III
Decade-II
Decade-I
2010-2019 – Rainfall (mm)
2000-2009 – Rainfall (mm)
1990-1999 – Rainfall (mm)
2010-2019 – Temperature (c°)
2000-2009 – Temperature (c°)
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JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
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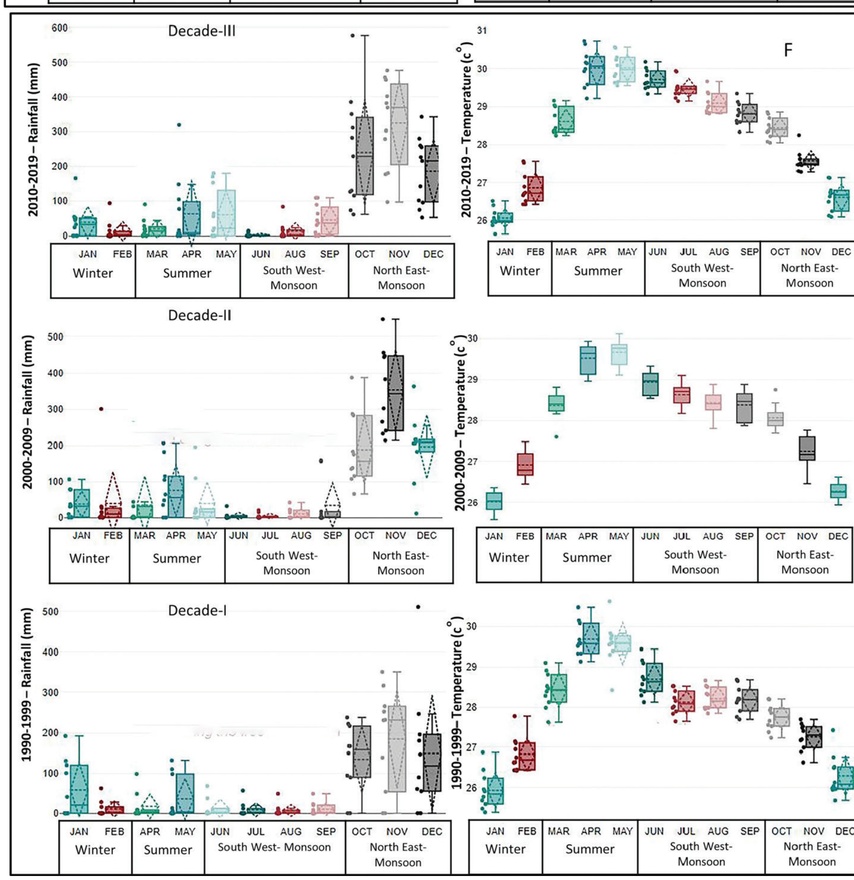
F
Decade-III
Decade-II
Decade-I
2010-2019 – Rainfall (mm)
2000-2009 – Rainfall (mm)
1990-1999 – Rainfall (mm)
2010-2019 – Temperature (c°)
2000-2009 – Temperature (c°)
1990-1999 – Temperature (c°)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Winter
Summer
South West-Monsoon
North East-Monsoon

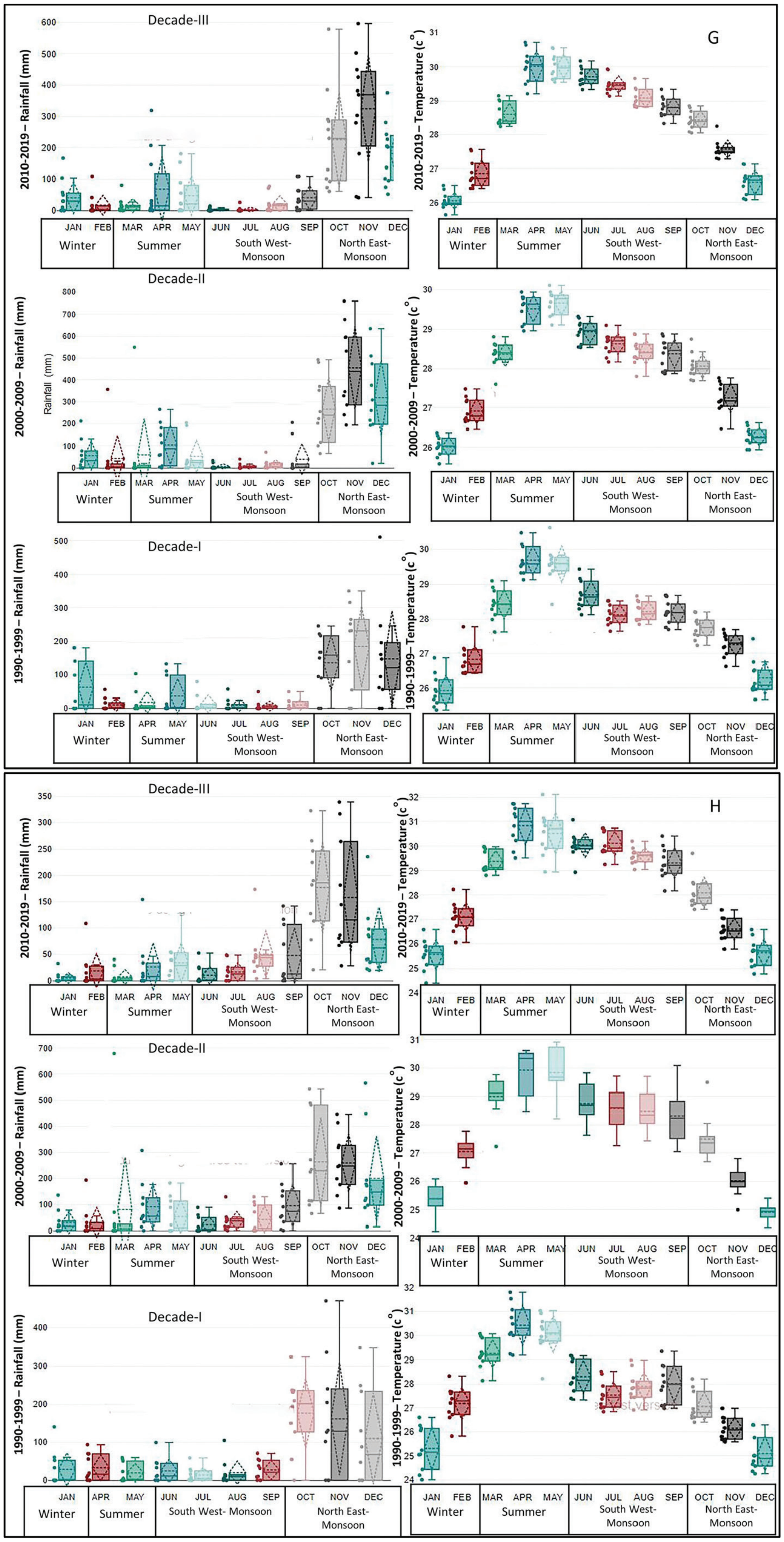

Figure 5: Rainfall and temperature (A - Ramanathapuram, B - Morekulam, C - Valinockam, D - Mandapam, E - Pamban, F - Thangachimadam, G - Rameswaram, H - Tirupalaikudi).

The temperature values during the season indicate a minor increase from decade-I to decade-III.

The decadal changes in the rainfall and temperature were observed during April at Rameswaram (Figure 5-G). There was a drastic increase in rainfall this month in the recent decade. The region has also observed a decreasing trend in the rain during the June and July of the southwest monsoon. Similarly, the temperature during the particular season showed a minor increase from decade-I to decade-III.

Figure 5-H Tirupalaikudi also shows variation in rainfall pattern during April with an increase in the amount of rainfall in decade II. Similar to other stations, this station also indicated a decreasing trend in rainfall during June. But, July and August recorded increasing rainfall during decade-II and decade-III. No major variation was observed in land surface temperature. This station is located far from the Gulf of Mannar coastal region. Hence, the area receives less rainfall in all seasons; therefore, the temperature from decade-I to decade-III got a minor increase compared to other locations.

The study has identified that Ramanathapuram, Mandabam and Thangachimadam, Rameswaram and Tiirupalaaikudi station reflects an increase in rainfall in the recent decades during April months and a decrease in rainfall was observed in Morekulam, Valinockam, Pamban, Ramanathapuram, Mandabam and Thangachimadam stations in June, July and August months. The variation in the rainfall trends in the Ramnad region (Sivakarun et al., 2016) and the Pondicherry region (Thilagavathi et al., 2017) indicated an increase in the number of rainy days and the amount of rainfall in the non-monsoonal period reflecting a shift in monsoonal periods. The current study also has identified the shift in the monsoonal period. Regionally the rainfall variation patterns were observed in Singapore (Muhammad et al., 2019), Malaysia (Wong et al., 2016), Philippines (Matsumoto et al., 2020), Indonesia (Manabu et al., 2016) and other equatorial regions (Camberlin et al., 2009; Nouaceur et al., 2020). Similarly, there has been an increase in air temperatures observed by various studies in the recent decade (Lebassi et al., 2011; Tapio et al., 2009). Hence, it is inferred that micro-scale variations in climate reflect the regional trend in climatic variables in the phase of climate change.

Conclusion

The findings infer that the amount of annual average rainfall has shown variations in the last two decades. The fluctuations in rainfall have been affected by the influence of ocean and land climatic variations. The study area located in the southern region of India adjoining the Palk Bay, influenced by different cyclonic depressions predominantly during the northwest monsoon period, reflects variation in the amount of rainfall in recent decades. Especially during April, there has been an increase in rainfall in recent decades. Further, the shift in rainy months is also observed in the data. The study also infers a significant variation in the regional rainfall pattern, and it influences the variation in the surface temperature over each location. In recent decades, these regional climatic variations have been reported in the adjoining regions reflecting the variation in the moisture sources, especially in monsoon-dependent countries. Agriculture-dependent countries like India have two cropping patterns depending on the monsoonal rainfall. Hence the shift in monsoon should be considered, and a proper management strategy should be derived to prevent agricultural loss. The study thus concludes that there are microclimatic variations observed in the recent decade.

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Data Availability Statement

All data generated or analysed during this study are included in this published article.

Ethical Approval

All the ethical standards of research publishing were taken care of during this study.

Authors' Contributions

Every author has contributed to the successful compilation of this study. Glitson Francis Pereira, B. Gurugnanam, and Chidambaram Sabarathinam: Conceptualization, Methodology, Software, Writing—original draft, Formal analysis. Santonu Goswami and

S. Bairavi: Data review and editing. All authors read and approved the final manuscript.

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