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Assessment of Change in Climatic Parameter Caused by Climate Change

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Abstract : Climate change is change observed in the state of climatic parameters which further affects the general system of existence of all living beings over the earth atmosphere and also affect other cycles of life. The study is based on climatic data acquired from India Meteorological department for 37 years from 1980 to 2016 and the data is processed and calculated with the help of Mann-Kendall methods which is a Non-Parametric Test. The result of the study shows that the maximum temperature in India is showing an increasing trend at many key levels and on the other hand, minimum temperature is showing a declining trend. The annual rainfall is increasing while the pre-monsoon rainfall in last 37 years show partial increase with significance level of 0.10. In monsoon period in last 37 years, it has been observed that, rainfall is significantly increasing with significance level of 0.05 and in post monsoon period it shows decreasing pattern.
Keywords : Climate Change, Climate Parameters, Mann-Kendall, Temperature Trend, Rainfall Trend

Introduction- Climate change is a reality and there is a strong consensus in the science community (e.g., Intergovernmental Panel on Climate Change (IPCC)) that the global climate is changing rapidly (Hegerl et al., 2019). India's energy consumption is increasing at an incredible rate, and our massive use of coal, gas, and oil has made us the third-largest emitter of greenhouse gases, accounting for 5.3% of global emissions, behind the United States and China. The situation is quite contradictory even in this case. On the one hand, our greenhouse gas emissions per person are extremely low and will remain so until 2030–31. India's per capita GHG emissions in 2031 are predicted to be lower than the global per capita emissions in 2005, which is an unexpected estimate. Between 1950 and 2008, India's emissions of CO2 from fossil fuels increased dramatically, averaging 5.7% annually, making it the third-largest emitter of CO2 in the world (Lawn and Clarke, 2008). In 1950, coal accounted for 87% of emissions; in 2008, it accounted for 71%; meanwhile, the oil share rose from 11% to 20%. The oil price hikes that had such a significant influence on emissions in the United States and Western Europe in the late 1970s and early 1980s have no effect on emissions in India. India has the second-largest population in the world, with over 1.1 billion people. In 2008, its per capita carbon emissions were 0.40 metric tonnes, which is significantly lower than the global average of 1.30 and the lowest of any country where CO2 emissions from fossil fuels exceeded 50 million metric tonnes. We rely on coal for around 70% of our electricity. India's administration acknowledges that climate change is a significant issue and that continuing with business as usual is no longer the best course of action, despite the country's unwavering economic and social development imperatives (Andres et al., 2012).

1.1 Research Methodology- Research methodology comprises data sources and techniques and methods to evaluate and analyses the data to bring out valuable information about the research. The study based on both secondary as well as primary data source.

1.2.1 Data Source: The climate data as well as hydrological discharge data has been collected for study. The climate data such as rainfall, temperature, humidity, evapotranspiration, etc. has been collected from India Meteorological Department (IMD). The rainfall is one of the important components for climate which affects the hydrological system over the surface.

1.2.2 Data Analysis- The data has been used for analysis and various methods have been used for the analysis such as statistical analysis

1.2.2.1 Mann Kendall Method - The non-parametric Mann-Kendall test is used to find patterns in time series data. According to Gilbert (1987), the test examines the relative magnitudes of the sample data instead of the actual data values. The benefit of this test is that it doesn't require that the data fit to any particular distribution. Furthermore, by assigning a common value that is smaller than the smallest measured value in the data set, data reported as non-detects can be included. This exhibits important traits like trend, seasonality, discontinuities, and outliers, per Chatfield and Collins (1980). Because the scale choice, intercept size, and plotting style of the points (continuous line or individual dots) can all have a substantial impact on the plot's look, the analyst must exercise caution and judgment. How to analyse a time series that exhibits a "long term" shift in mean depends on whether one wants to (a) evaluate the trend or (b) remove the trend in order to look at local fluctuations. The Mann-Kendall non-parametric test has been identified as a great tool for determining whether trends exist in the climate data (Hirsch et al., 1984).

$$\sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(x_i - x_j)$$

Where

$$\mathrm{sgn}\ (xi - xk) = \begin{cases} +1 & \text{if}(xi - xk) > 0 \\ 0 & \text{if}\ (xi - xk)\ = 0 \\ -1 & \text{if}\ (xi - xk) < 0 \end{cases}$$

If S is very high in the positive direction, the trend is said to be positive; if S is very low in the negative direction, the trend is said to be declining. However, the probability associated with S and the sample size, n, must be calculated in order to statistically evaluate the trend's significance.
If n is more than or equal to 10, the normal approximation test is used. However, when the number of data values is approximately 10, the normal approximation could not hold up as well if the time series has several connected values (i.e., equal values). First, the following formula, which accounts for the possibility of ties, is used to calculate the variance of S:

$$\mathrm{VAR(S)} = \frac{1}{18}\left[\!\left[\mathrm{n(n-1)(2n+5)} - \sum_{\mathrm{p=1}}^{\mathrm{q}} \mathrm{t_p}_{\,(\mathrm{t_p}\,-1)(2\mathrm{t_p}+5)}\right]\!\right]$$

Where q is the number of tied groups and t_p is the number of data values in the p^{th} group.

The values of S and VAR(S) are used to compute the test statistic Z as follows:

$$Z_s = \frac{S-1}{[VAR(S)]^{1/2}} \text{ If } S > 0$$

$$Z_s = 0 \text{ If } S = 0$$

$$Z_s = \frac{S+1}{[VAR(S)]^{1/2}} \text{ If } S < 0$$

Determine the probability associated with this normalized test statistic. For a normal distribution with a mean of 0 and a standard deviation of 1, the probability density function is given by the following formula:

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$$

The trend is considered to be falling if Z is negative and the computed probability is higher than the level of significance. The trend is regarded as rising if Z is positive and the computed probability is less than the significance level. If the computed probability is less than the significance level, there is no trend. Two Mann-Kendall test parameters are necessary for trend detection. These metrics include the significance level, which indicates the strength of the trend, and the slope magnitude estimate, which indicates the direction and magnitude of the trend. The significant levels that have been evaluated in MAKESENS are 0.001, 0.01, 0.05, and 0.1. For the four tested significant levels, the symbols used in the trend statistics worksheet are:

*** if trend at α = 0.001 level of significance,

** if trend at α = 0.010 level of significance,

* if trend at α = 0.050 level of significance, and

+ if trend at α = 0.100 level of significance.

The significance level is greater than 0.1 when there is a blank cell. A trend's statistical significance is assessed using the Z value. Z indicates a downward trend when it is negative and an upward tendency when it is positive.

Result and Discussion

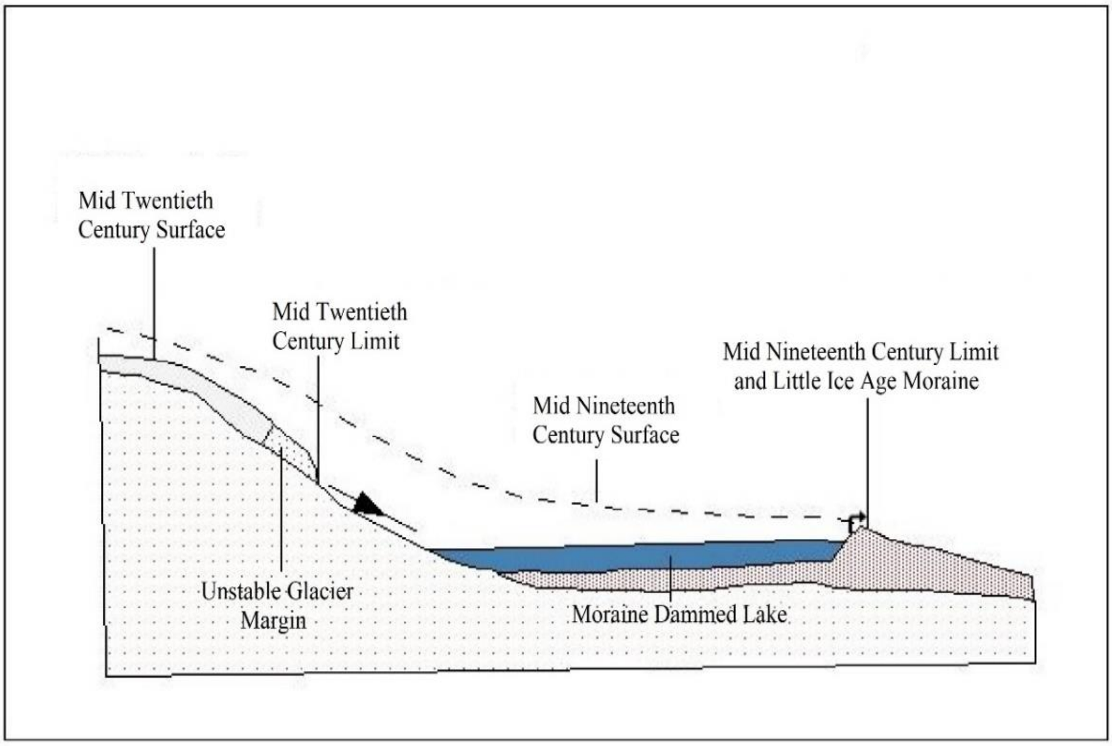
1.3 Impact of Climate Change on Himalayan Glaciers- Glaciers in particular cover almost 10% of the earth's surface with ice. The deposition of ice above the snowline in cold climates is what creates glaciers. Currently, the Arctic, Greenland, and Antarctica have permanent significant ice covering. The Alps (Europe), the Himalaya (Asia), the Rockies (North America), the Andes (South America), and Mount Kilimanjaro (Africa) are just a few of the mountain locations across the world that see snow and ice. The Himalayas are known as the "Water Tower of Asia" because they have the greatest concentration of glaciers outside of the Polar Regions and are a significant supply of freshwater in Asia. Nine river systems in Asia, including the Indus, Ganga, and Brahmaputra in India, receive meltwater from glaciers. The Himalayan glaciers provide year-round fresh water to river systems and support nearly one-third of the world's population (Chaujar, 2009).

The glacial ecosystem is being significantly impacted by climate change. The Himalayan glaciers have been melting at startling rates, according to research (Krishnan et al., 2020). Climate change has been identified as the primary cause of the roughly 60% retreat of Himalayan glaciers during the past 20 years. The glaciers in the Garhwal and Sikkim Himalaya, Chaturangi and Onglaktang-Rathong, have receded by approximately 46 meters, at a rate of 1 and 1.2 km annually, respectively. The Kashmir Himalaya's Machoi and Kolhani glaciers have receded at rates of 8.1 and 16 meters annually, respectively (Bisht et al., 2019). Last but not least, the renowned Gangotri glacier in the Garhwal Himalaya has been retreating at a rate of roughly 23 meters year on average.

Source: Taken by Researcher, 2023

Figure 4.2: Glacial Lake in Lahul and Spiti Valley

The number and size of glacial lakes are growing as a result of the melting of the Himalayan glaciers brought on by rising temperatures, but the risk of glacial lake outburst floods is also rising. The glaciers' retreat caused the Himalayan lakes to form. As time went on, these glacial lakes began to overflow, which led to a breach in the natural barriers. Eventually, these barriers were breached, and there was a glacier lake outburst (Verma, 2021). In Lahul and Spiti, a similar kind of glacial lake occurred in the Chandratal valley (Figure 4.2). The process by which Glacial Lakes arise in the Himalayan hilly or mountainous regions is depicted in the above figure 4.3. When the glaciers melt, the ocean will receive more runoff from the main river systems, although this will probably be followed by dry times. Some of the Himalaya's major rivers are predicted to become ephemeral, exhibiting monsoonal features similar to those found in peninsular India (Haque et al., 2020).



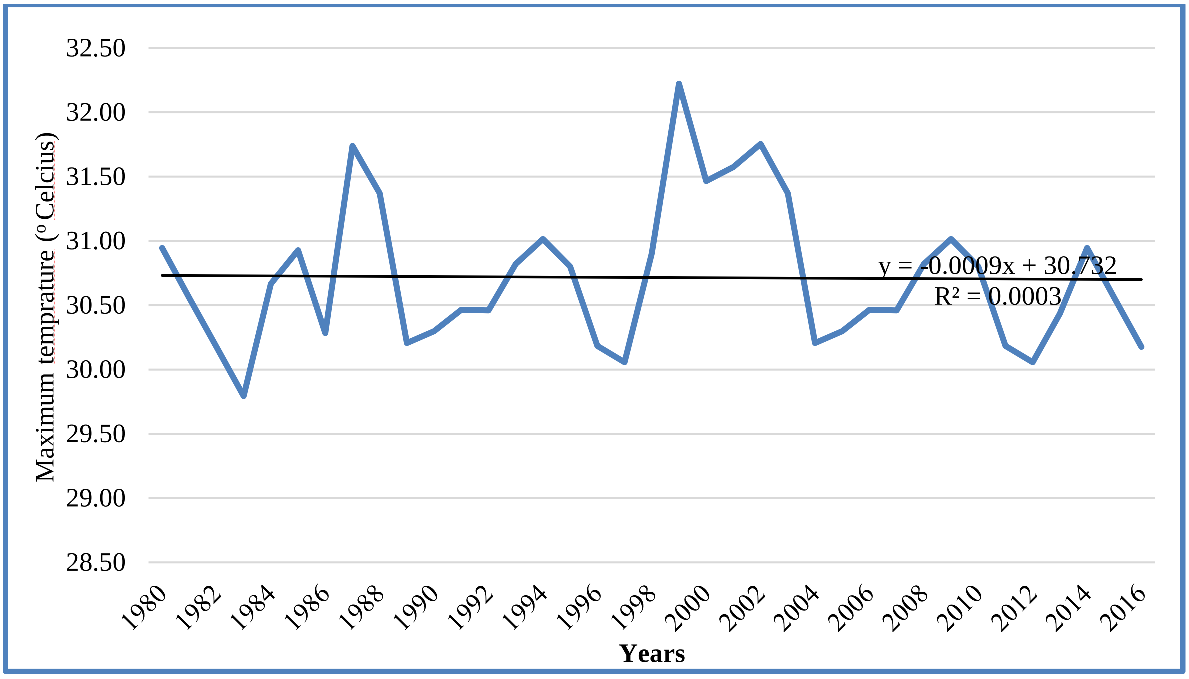
Source: Based on Evan et al., 1994

Figure 4.3: Glacial Lake Formation by Retreating of Glaciers

A significant supply of freshwater in South Asia, the ice and snow reservoirs found in the Himalayan glaciers could completely disappear if the current trends of rising temperatures continue. With their decline, the region is anticipated to see a higher danger of abrupt failure of big structures (dams) and a higher frequency of natural hazards (glacial lake outburst floods) as the amount of melt water increases. They will also have an effect on freshwater supplies for industry, agriculture, and drinking, which will limit the potential for hydropower. Because of the scarcity of water, their decline will eventually have a significant impact on fundamental human indices. Because of their sensitivity to climate change, glaciers in the Himalayan region offer a great way to measure the effects of this phenomenon (Krishnan et al., 2020).

1.2 Scenario of Climate Change impact on Climatic Parameters

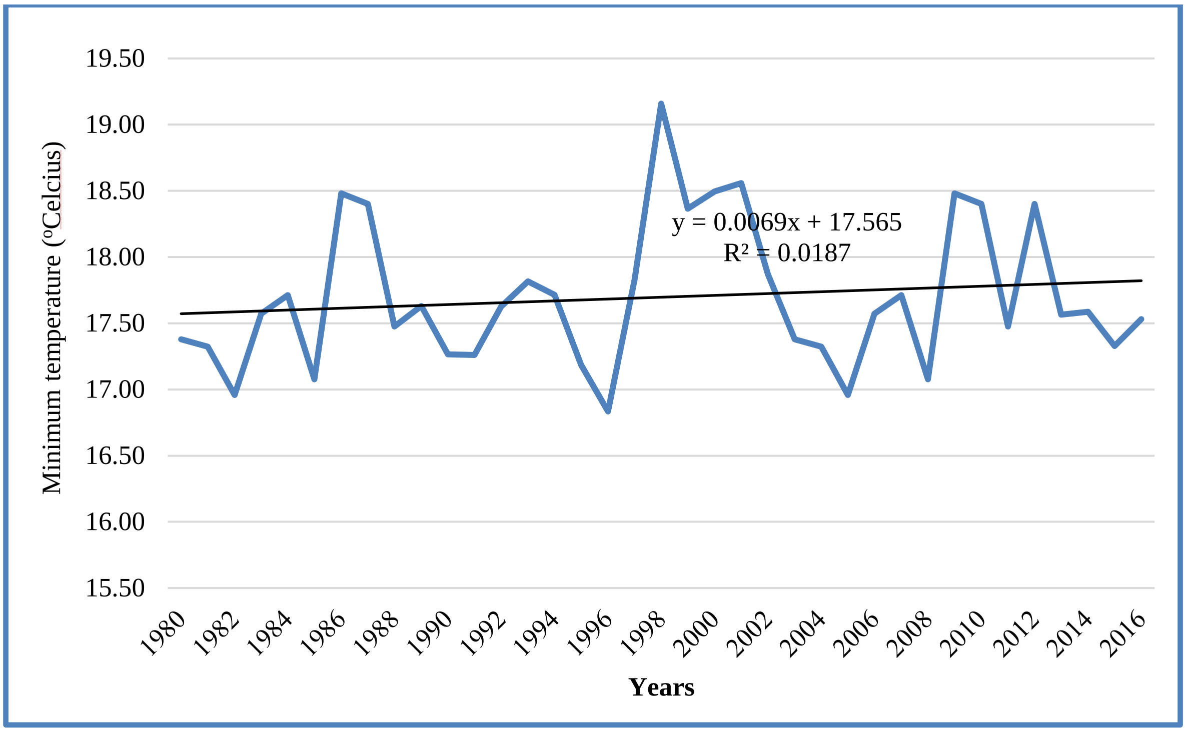
1.3.1 Trend in Maximum and Minimum Temperature- The evaluation of India's yearly average maximum temperature shows the fluctuating pattern. The highest recorded temperature has been observed to have varied from 15° Celsius in January to 32.5° Celsius in June. In the last 37 years, the year 2000 saw the highest recorded temperature. In the past 37 years, the highest temperature has only been reached seven times, at 31 degrees Celsius (Figure 4.3). 29.5 degrees Celsius has been recorded as the lowest maximum temperature. The maximum temperature indicates a scenario that is quite variable, and the trend line of the maximum temperature is partially straight, showing a downward trend over the past few years and tilting straight along 30.5.



Source: India Meteorological Department, 1980-2016

Figure 1.3: Annual Trend of Maximum Temperature in India

Figure 1.3 shows that the average maximum temperature in India is decreasing. The lowest temperature of the day is represented by the minimum temperature. An analysis has been conducted on the average minimum temperature in India each year. In the past 37 years, the lowest recorded temperature has been as low as 16.5°C, which was recorded in 1996, and as high as 19°C, which was recorded in 1998.

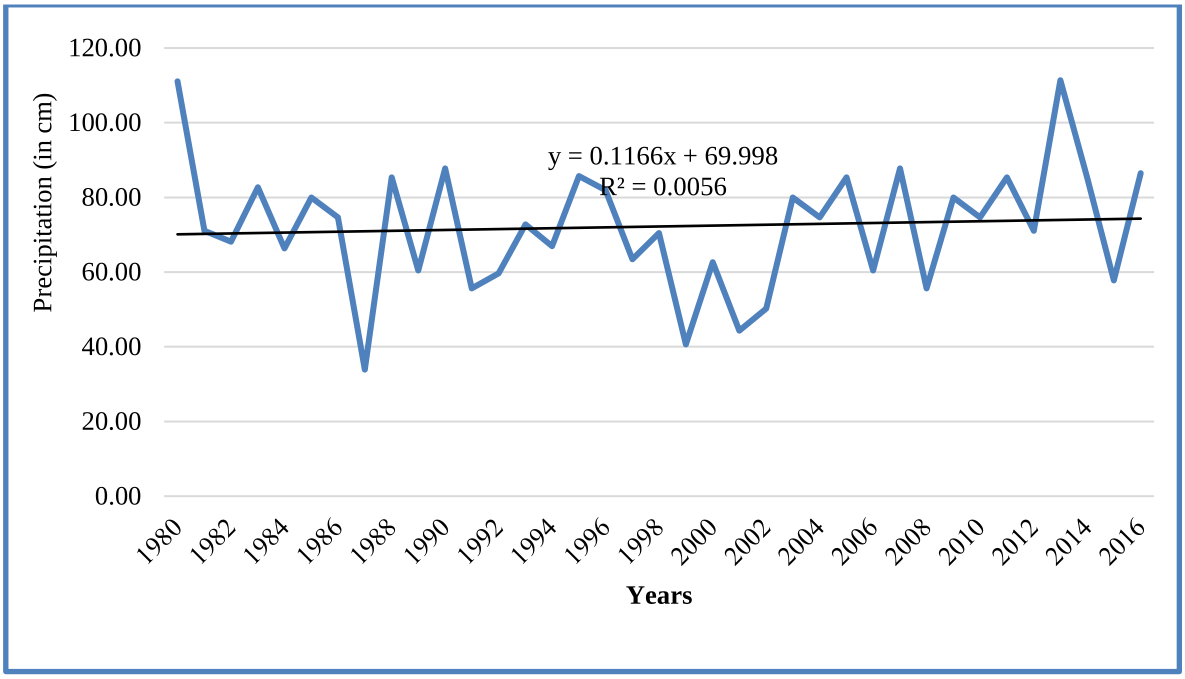


Source: India Meteorological Department, 1980-2016

Figure 1.4: Annual Trend of Minimum Temperature in Indian Scenario

Between 16.5 and 19.5 degrees Celsius is the lowest tendency for the minimum temperature. The constant low temperatures throughout the year are reflected in the minimum temperature regime. The trend line for the minimum temperature is a straight line that is rising, indicating that the minimum temperature has been rising during the past 37 years and in recent years. The temperature is seen to be rising, partially by about 0.30 degrees Celsius (Figure 1.4).

1.3.2 Trend in Rainfall- Rainfall is a key component of climate change research and a determining factor in the examination of India's climatic variability. The analysis of the annual rainfall data shows that substantial rainfall occurs during the monsoon season and in June and July (Figure 1.5).



Source: India Meteorological Department, 1980-2020

Figure 1.5: Annual Trend of Rainfall in Indian Scenario

In the studied area, the highest rainfall records were recorded in 1980 and 2013. The rainfall pattern varies greatly, with the highest rainfall of 110 cm in 1980 and the lowest of 30 cm in 1987. The trend line shows the research area's growing yearly rainfall trend.

1.4 Mann Kendal Assessment of Meteorological Data

Mann-Kendall assessment is done to measure the pattern in meteorological data set. In India, monthly, seasonal, and annual rainfall are measured to look for any patterns.

1.4.1 Rainfall - The values of the annual and monsoon rainfall are seen to show rising tendencies, as does the non-monsoon rainfall. The overall results for the monsoon, annual, and non-monsoon seasons show that only the monsoon trend is significant at the 0.50 significance level, whereas the annual and non-monsoon trends are not. At the 0.05 level of significance, India shows an increasing trend in rainfall from July to October. The annual rainfall shows an upward trend, but the rainfall in February and December shows a downward trend, both at a significance level of 0.10 and in June at a 0.50 level. Using MAKESENS software, rainfall trend analysis has been performed on monthly, seasonal, and annual data; the findings are displayed in Table 1.1.

Table 1.1 Mann-Kendall Trend Statistics for Rainfall

Time series	Indian Scenario		
	n	Test Z	Signif.
January	37	0.19	
February	37	-.96	+
March	37	0.17	
April	37	0.14	
May	37	0.49	*

June	37	-.69	*
July	37	0.19	
August	37	1.12	*
September	37	0.97	*
October	37	2.22	*
November	37	0.18	
December	37	-.89	+
Annual	37	1.73	+

+: significance level: 0.1; *: significance level: 0.05

Source: Calculated by Researcher Based on IMD Data.

Table 1.2 Mann Kendall Trend Statistics (Z) Rainfall

Places	Indian Scenario
Annual	□*
Pre-Monsoon (Mar-May)	□+
Monsoon (June-Sept)	□*
Post-Monsoon (Oct-Nov)	□
Winter (Dec-Feb)	□

Where, (□) shows increasing trend; (□) shows decreasing trend;

* 0.05 level of significance; + 0.1 level of significance

Source: Calculated by Researcher

Over the past 37 years, India has received an average of 870 millimeters of rainfall annually, which is sufficient to evaluate the city's decent hydrological state. The table 1.2 shows different scenario of rainfall pattern in last 37 years. The annual rainfall is increasing while the pre-monsoon rainfall in last 37 years show partial increase with significance level of 0.10. In monsoon period in last 37 years, it has been observed that, rainfall is significantly increasing with significance level of 0.05 and in post monsoon period it shows decreasing pattern.

1.4.2 Maximum and Minimum Temperature - The analysis of Monthly, yearly, and seasonal maximum and minimum temperature data have been done. The highest temperature in India is showing increasing tendencies at many key levels. In contrast, India's minimum temperature is showing declining tendencies. During the winter, the calculated Mann-Kendall statistics for Tmax were found to be significant at the 0.10 level, whereas they were found to be inconsequential for the yearly, NEM, and summer seasons. According to these figures, Tmax has been trending upward with 99.9% certainty throughout the winter, while the trending downward with 99% confidence during the SWM season.

Table 1.3 Mann-Kendall Trend Statistics for Maximum and Minimum Temperature

Time series		Max.	Temp.	Min.	Temp.
	n	Test Z	Signif.	Test Z	Signif.
January	37	2.73	+	-.79	+
February	37	2.22	*	-1.98	*
March	37	3.14		-1.49	*
April	37	0.39	*	-2.44	*
May	37	2.14	*	-3.07	
June	37	2.22	*	-2.20	
July	37	1.22		-2.24	*
August	37	2.26	*	-1.40	+
September	37	1.69	+	-3.41	*
October	37	2.13	*	-1.86	*
November	37	0.29	*	-2.88	
December	37	0.46	+	-2.20	*
Annual	37	1.39		-2.18	*

+: significance level: 0.10; *: significance level: 0.05;

Source: Calculated by Researcher Based on IMD Data.

The Tmin was insignificant at 0.10 and 0.05 during the summer, and significant at 0.05 during the yearly and winter seasons; however, it was insignificant during the SWM and NEM seasons (Table 1.3). According to these numbers, there was a 99.9% confidence level for a growing trend in Tmin during the summer and a 99.1% confidence level for an annual and winter rise in Tmin. While the NEM was insignificant, the Tmean for the winter, summer, and annual periods were shown to be significant at the 0.10 and 0.05 levels, respectively. According to these figures, the Tmean showed an upward tendency with 99.9 percent confidence in the winter, 99.9 percent in the summer, and 95 percent confidence each year.

1.3 Conclusion- Climate change is serious threat for human and environment. Climate change is change in the state of climatic parameters which further affects the general system of existence of all living beings over the earth atmosphere and also affect other cycles of life. The study shows that rainfall and temperature are two major component of climate which are continuously changing due to climate change. The maximum temperature indicates a scenario that is quite variable, and the trend line of the maximum temperature is partially straight, showing a downward trend over the past few years. The maximum temperature in India is showing an increasing trend at many key levels and on the other hand, minimum temperature is showing declining trend. The annual rainfall is increasing while the pre monsoon rainfall in last 37 years show partial increase with significance level of 0.10. In monsoon period in last 37 years, it has been observed that, rainfall is significantly increasing with significance level of 0.05 and in post monsoon period it shows a decreasing pattern.

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