

CHAPTER 2

Literature Review

2.1 General

A review of the literature is an essential component of every research project. It solves the issue by using prior work done by different scientists and experts. In the context of climate change, the term "climate change" refers to a worldwide phenomenon of climate transformation defined by changes in the average climate of the planet (in terms of precipitation, temperature, and evapotranspiration), which are driven mainly by human activity. The viability of the planet's ecosystems and humanity's future, and the global economy's stability are endangered by uncontrolled weather on Earth. To understand the changing behavior of climate and its impact, it is necessary to understand the statistical analysis of climatic variables and the characterization of trend patterns. The literature related to the study of the research area is presented in the following sections.

2.2 Preview of Impact of Climate Change

Intensification of greenhouse gasses (forcing) is alleged to be a primary cause of climate change which accelerates the hydrologic cycle, resulting in changes in patterns of precipitation, nature of Intensity-Duration-Frequency (IDF) curves (Cheng and Aghakouchak 2014) runoff characteristics (Milly et al. 2008), and frequent occurrences of extremes. After a lengthy period (approx. thirty years), climate change is attributed to natural climatic variability and human activity. The evaluation of the variability and trend of meteorological variables is an important part of climate change research. Significant climate change has been reported around 1950, and the emission of greenhouse gases (GHG) caused by anthropogenic activities has been attributed as the reason for the alteration (Pachauri et al. 2014.). The

increase in the world average temperature to 4 °C is expected by 2100, as per the evaluation report 5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2014). The scale and the trends of warming India during the past several decades have been the same as global warming (Datta and Das 2019). Consistent increase in temperature also alters the patterns of long-term precipitation that influence the surface and sub-surface water bodies available. The climatic shift in South-West India is unfavorable to hydrologic parameters, including precipitation, stream-flow, and evaporation, since over 80% of total Indian rainfall occurs from June to the middle of October during the Monsoon Period (Kumari et al. 2009). Differences in precipitation, temperature, and evapotranspiration have seriously impacted the water cycle and stream-flow and the related water demand in different sectors. (Jain and Indurthy 2003; Jain S.K. and Kumar V. 2012). (Frazier and Giambelluca 2017) demonstrated that the monsoon influences the climatic condition of Kerala. Researchers reported a declining trend in precipitation during the monsoon season, whereas the post-monsoon, winter, and pre-monsoon seasons exhibited a rising trend in precipitation. They also discovered that the periodicity of the El-Nino Southern Oscillation (ENSO) corresponded to the uneven periodicity (2-8 years) of annual and seasonal rainfall. Because of monsoon-driven climatic seasonality, yearly rainfall has an irregular distribution that focuses approximately half of the year. They concluded that the declining precipitation trend during the southwest monsoon season leads to short-term meteorological droughts, which significantly affect Kerala's agricultural sector and water supplies. The rising precipitation pattern during other seasons, on the other hand, serves to mitigate the severity of the drought. (Farhangi et al. 2016) examined river discharge, temperature, and rainfall from the Qom Rood watershed in Iran from 1979 to 2016. Their findings revealed that human interference plays a vital role in the hydrological regime change of an area. In watershed development and management (Zhang et al. 2018) precipitation trends and drought conditions play a

significant role. The temperature and precipitation data observed from 40 weather plants in the Pearl River Basin in China examined the geographical features of rainfall and drought during 1959-2012. They were also examined for the effect of the El Nino-Southern Oscillation (ESO) and El Nino Modoki (ENSO-M) on seasonal drought, defined by the standardized SPEI. Their findings showed that annual and seasonal precipitation had dropped somewhat in most regions with reduced daily annual and seasonal rainfall. They found drought severe in upper reaches during recent years and seasonal drought to occur more frequently throughout the Pearl basin. ENSO and ENSO-M were discovered to have an impact on summer drought in the region. ENSO dominated autumn drought patterns throughout the Pearl River basin, while ENSO-M significantly affected autumn drought patterns in the middle-upper and northern regions of the middle-lower reach. (Villafuerte et al. 2020) examined severe rainfall occurrences in the Philippines using daily rainfall data from 35 meteorological stations over 60 years (1951–2010). On a seasonal basis, seven extreme precipitation indices (EPI) describe daily rainfall in intensity, accumulation, and duration. Their findings indicated a trend toward a drying state throughout the dry season. The trend analysis was also performed for larger time series of EPI at four meteorological sites with rainfall data from 1911 to 2010. Longer historical data showed that the patterns observed during the shorter period (1951–2010) were consistent with continuous long-term trends or reflected interdecadal variability. The ENSO was shown to have a significant impact on interannual changes in EPI. According to (Rana et al. 2014), urbanization has burdened cities with many issues related to the development and the physical environment. Some Indian cities are growing more susceptible to natural disasters such as floods and heavy rains. It is becoming more important to study the characteristics of these events and their physical explanation. This research aimed at rainfall trends in Delhi and Mumbai, India's two biggest metropolitan areas, from 1951 to 2004. Precipitation data were analyzed by months,

seasons, and years, with the whole period divided into two time periods for comprehensive examination: 1951–1980 and 1981–2004. Man-Kendall rank statistics and linear regression were used to determine long-term rainfall trends. Furthermore, this research attempts to explain precipitation patterns throughout the monsoon season using several global climatic events. The connection between southwest monsoon precipitation and global climate events was determined using climatic variables, principal component analysis, and singular value decomposition. The majority of the rainfall at both sites was discovered to be occurring during the Southwest monsoon season. The results of the study showed a high degree of variability in precipitation at both sites. Long-term southwest monsoon rainfall in Delhi falls insignificantly, whereas long-term southwest monsoon rainfall in Mumbai is dropping insignificantly. The average maximum rainfall in a day decreased for both locations, according to statistical analysis. Southwest monsoon precipitation in Delhi was directly linked to the Scandinavian Pattern and the East Atlantic/West Russia pattern and inversely associated with the Pacific Decadal Oscillation. On the other hand, Precipitation in Mumbai was inversely related to the Indian Ocean Dipole, the El Nino-Southern Oscillation, and the East Atlantic Pattern. Any variation in rainfall and temperature may cause significant issues with the water supply and agricultural productivity. Trend analysis is essential for a nation like India, whose food security and economy rely on timely water supply.

2.3 Studies on Trend Analysis

The studies on the trend analysis require long-term meteorological data for geographical locations. The time and spatial scales usually suffer from restriction because of the unavailability of accurate data. For example, a recent study by (Zaifoğlu et al. 2017) quality control test was carried out to identify the errors due to missing data in daily precipitation data series. The precipitation data from gauge stations in Northern Cyprus was comprehensively analyzed for annual and seasonal changes in extreme precipitation indices

using Mann-Kendall and Sen's slope methodologies. Four homogeneity tests were carried out, and overall classification was performed. They observed non-significant but increasing trends for extreme precipitation indices for annual and seasonal data series. A positive trend was found during winter month for 77% of gauge stations, with 11% significantly increasing. Their results did not reflect any spatial coherence besides the existence of a mixed pattern in trend. (Thattai and Rangarajan 2018) Using 115-year precipitation data attempted to quantify the precipitation trend for the city of Chennai. They found non-significant increasing trends in annual rainfall and decreasing trends for the winter season. They further found that the precipitation concentration index (PCI) predicted irregular rainfall distribution in 38% of the data. The seasonality index (SI) that refers to the most rainfall months in a season was also analyzed by them. They also observed that the rainfall anomaly index (RAI) predicted that four extremely wet while five arid years contributed to the city out of 115 years. (Farhangi et al. 2016) conducted rainfall trend analysis for ten sub-basins in western Iran. They found that six sub-basins out of 10 have decreasing trend for average annual rainfall.

Several researchers (Ghosh et al. 2009; Pai et al. 2014; Ramesh and Goswami 2007) have focused on the trends of meteorological variables (temperature and rainfall, its seasonality, temporal and spatial distribution) as the possible changes in the future (Gajbhiye et al. 2016; Yuksel et al. 2008) may be anticipated by it. The phenomenon of precipitation extremes (Pandey and Khare 2017) (Carrera-Hernández and Gaskin 2007) has also been investigated.

Summer rainfall in eastern Australia increased abruptly about 1950, according to (Nicholls and Lavery 1992), and the pattern remained constant for decades after the first observation. (Rodrigo et al. 1997) rebuilt 500-year series from historical sources and investigated precipitation variability on precipitation patterns to centennial periods in Andalusia (southern Spain). (Moreno et al. 2008) used the Mann-Kendall test to evaluate changes in seasonal rainfall reported in Mexico from 1920 to 2004, and they found increasing rainfall in both the

arid/semi-arid and tropical humid areas. (Kothyari and Jain 1997) discovered a declining trend in precipitation across India beginning about 1965, while (Riebsame et al. 1994) discovered a 5% rise in rainfall from 1931 to 1960. (Kothyari and Jain 1997) Also, the amount of monsoon precipitation and the number of wet days during the monsoon season decreased as the annual maximum temperature in the Ganges basin rose. Several studies on trend analysis of precipitation and temperature have been conducted throughout the world, with different results, and a comprehensive overview of the existing literature with respective contributions is provided in the following sections.

Various research on rainfall and temperature trends in different parts of India have been performed. On an all-India basis, research by (Mooley D. A. and Parthasarathy B. 1984; Sarker and Thapliyal 1988; Thattai and Rangarajan 2018) showed no substantial change in annual rainfall. However, a major trend was found in India (Dash et al. 2009; Jagannathan and Parthasarathy- 1973; Jain S.K. and Kumar V. 2012; Koteswaram and Alvi 1969; Kumari et al. 2009) that utilized linear trend analysis for 306 rainfall stations and revealed rising and declining trends in various regions of India. They discovered that southwest monsoon rainfall is decreasing in the northeast region and the northeast and northwest peninsulas. However, there has been a rise in the west coast, central peninsula, and northwest India. The decreasing trend is about 6–8% of the average per 100 years, whereas the increasing trend is approximately 10–12%. Based on a study of rainfall time series data from 1871 to 2002 in India, (Dash et al. 2009) discovered a decreasing trend in monsoon rainfall and a rising trend in pre- and post-monsoon periods. Between 1901 and 2003, (Rajeevan et al. 2008) conducted a linear trend analysis for monthly rainfall observations from 1476 rain gauge stations located in 36 meteorological sub-divisions (representing various parts of India) and discovered a significant decrease in monsoon rainfall for Jharkhand (our study area is in this state),

Chhattisgarh, and Kerala sub-divisions. However, only three sub-divisions have statistically significant increases in yearly rainfall Haryana, Punjab, and Coastal Karnataka.

An investigation of long-term changes in precipitation and evapotranspiration over the Narmada River in India (Pandey and Khare 2017) shows a substantial declining trend in precipitation and an increasing trend in evapotranspiration due to temperature changes. Several studies have been conducted in this context to assess the effect of climatic variability on trends in annual and seasonal rainfall and intensity (Kothawale et al. 2010; Ramesh and Goswami 2007), the number of rainy days in different areas of India, and temperature trend (Diop et al. 2016; Pal and Al-Tabbaa 2011). These changes in climatic factors have also had a major impact on the nation's inclusive economy and the management of water resources and the agricultural sector (Gosain et al. 2006; Sonali and Nagesh Kumar 2013). As a result, significant research on long-term trend analysis for hydrologic variables is being conducted utilizing climatic data to investigate the possible effects of climate variability in the hydrological cycle. Here are some examples of such work: (Arora et al. 2005; Kishore et al. 2016; Sharma et al. 2019; Suryavanshi et al. 2014) discovered a significant rise in the highest temperature over Jharkhand, resulting in wheat crop sterility. Their research found that years with below-average rainfall, irregular distribution, and extended dry spells are the worst affected by temperature increases. The Jharkhand Action Plan (Government of Jharkhand 2014) highlighted the negative consequences of raising the maximum temperature in Jharkhand. According to the study, Jharkhand had the greatest number of heat waves from 2000 to 2010, which mostly impacted the poor owing to their lack of coping skills (Kumari et al. 2009), there were 29 occurrences of heat waves during the summer season (March–June) in 2004, 41 in 2005, and 100 in 2010(Disaster Management Department 2011)

The significance of trend monotonicity and important statistical parameters are included in the long-term trend analysis. (Gupta et al. 2020; da Silva et al. 2015) presented a novel trend

detection technique and trend simulation and application utilizing graphical and statistical analysis, and this improved new trend application methodology has been applied for the rise in global temperature (Mohorji et al. 2017) Techniques using parametric procedures or non-parametric tests may be used to examine a trend (Shahid and Osman Salleh 2009). Non-parametric techniques make fewer assumptions than parametric tests, and failure to meet those assumptions leads to irrelevant findings. Because most hydro-meteorological data are not normally distributed (Huth and Pokorná 2005; Van et al. 1984), non-parametric distribution-free inferential statistical methods such as Sen's slope (Sen 1968) method were used to determine the magnitude/slope of trend, and their statistical significance was analyzed using MK test (Kendall 1975; Mann 1945) and SQMK methods, in which the inferential statistical significance was analyzed (Pingale et al. 2016). (Bandyopadhyay et al. 2011) and (Subash et al. 2011) describe combined methods and formulae and techniques for the MK test statistic and Sen's estimator. Data pre-whitening and variance correction methods are used (Kumar et al. 2017) to minimize trend persistence. The findings of trend analysis studies across Jharkhand state revealed a substantial decrease in monsoon rainfall and increased winter rainfall (Chandniha et al. 2017; Guhathakurta and Rajeevan 2008; Sharma et al. 2019). An increase in maximum temperature was also recorded in the eastern portion of India (Mondal et al. 2015; Subash et al. 2011). The variation in trends may be attributed to the varied topography and thermodynamic and orographic forces at various data points. Diverse land-use changes caused by increased agricultural activities, forest degradation, deforestation, and rapid urbanization lead to significant variability in temperature (Rawat and Kumar 2015; Riebsame et al. 1994), which may explain the varying magnitudes of increase or decrease in different parts of Jharkhand.

(Sayemuzzaman and Jha 2014) conducted a trend analysis of yearly and seasonal data from 249 uniformly dispersed sites in North Carolina, USA, from 1950 to 2009. They used the

Mann–Kendall test, the Theil–Sen approach (TSA), and the sequential Mann–Kendall (SQMK) test to assess the significance of trend, size of trend, and trend change, in that order. Their findings revealed a significant state-wide rising tendency for winter precipitation and a declining trend for autumn precipitation. Spring and summer precipitation data showed a mixed (increasing/decreasing) pattern throughout the state. The SQMK test revealed a substantial change in most areas of the state between 1960 and 1970. (Bari et al. 2016) examined seasonal and yearly rainfall patterns and fluctuations in northern Bangladesh over 50 years (1964–2013). The sequential Mann–Kendall test was also used to find any precipitation patterns variations and discover potential sites of the change in the rainfall data set. They discovered rising patterns in pre-and post-monsoon rainfall for the majority of the rainfall stations but decreasing trends in monsoon rainfall across the bulk of the region. However, the SQMK test showed a declining trend in pre-monsoon rainfall after the early 1990s.

Furthermore, the yearly precipitation trended in the same direction as the monsoon season rainfall. (Gajbhiye et al. 2016) examined precipitation and temperature data for eastern India from 1970 to 2004 using the Mann–Kendall test, Sen's slope estimator, least-square linear regression, Spearman rank correlation, and SQMK test. The various techniques of analysis yielded comparable findings for eastern India. Eastern India's north-eastern, south-eastern, and western portions exhibited a rising tendency, while the north-western, central, and southern parts showed a declining trend. Seasonal rainfall data were subjected to a similar methodology. A declining tendency was seen in the central region during the winter season, whereas comparable findings were found in the pre-and post-monsoon seasons in the western region.

The pattern during the monsoon season was found to be comparable to the yearly rainfall trend. Furthermore, there were no dramatic changes in precipitation patterns in eastern India.

The study of maximum temperatures revealed a rising tendency in the western portion for all seasons (excluding monsoon) and a decreasing trend in the eastern section. In the lowest temperature, a rising tendency was found in the eastern half of the research region and a decreasing trend in the western half of the study area for all seasons. Significant differences were found between the monsoon season and the other seasons. Mean temperature decreased in the central, southern, and north-western portions, while it increased in the north-eastern, western, and south-eastern parts. The majority of people in the eastern India area did not notice a sudden shift in the temperature trend. They discovered a negative relationship between rainfall and maximum temperature throughout eastern India. Similar findings were found for minimum temperature (monsoon) and mean temperature (pre-monsoon and monsoon).

(Gavrilov and Markovic 2015) examined changes in seven meteorological variables collected from 12 weather stations in Serbia between 1980 and 2010. With their significance level, the non-parametric Mann-Kendall and Sen's techniques were employed to assess whether there was a positive or negative trend in meteorological data. Cumulative sum charts and bootstrapping techniques were also used to identify the incidence of sudden shifts. They discovered rising patterns in the annual and seasonal minimum and maximum temperature data sets. They found no significant changes in the summer and winter precipitation data. Because most of the African continent is semi-arid, rainfall varies greatly from year to year (Nicholson et al. 2018). The severe droughts that have afflicted the Sahel and eastern Africa are well-known.(Onyutha 2018) examined patterns in rainfall data sets from 39 sites in Africa's Nile River basin. Trend findings from long-term and short-term data series were compared. The trend bias resulting from a succession of short-term data was measured. A homogeneity test was performed to evaluate the geographical coherence of trend orientations. They discovered that trends at stations with short rainfall records might be deduced from

those at adjacent sites with longer-term records but in the same area. At the 5% significance level, the trend in annual rainfall in the equatorial area was shown to be mainly rising at 4 out of 7 sites. Using Sudan, Ethiopia, and Egypt as a whole, yearly rainfall trends were mainly negative at 69 percent of 32 sites at a 5% significance level. Fitting the Lognormal, Normal, and Generalized Extreme Value distributions to the three aforementioned data sets with a time covariate for both the position and scale parameters resulted in a Bayesian trend analysis. Their findings showed that the inter-annual variability of annual precipitation reduced with time at all sites and that the average annual precipitation dropped significantly at many stations.

(Basistha et al. 2008) used 80-year data from 30 rain gauge stations maintained by the India Meteorological Department to study changes in rainfall patterns in the Indian Himalayas over the twentieth century (IMD). The modified Mann–Kendall (MMK) test was used to identify trends, and the Pettitt–Mann–Whitney (PMW) test was used to detect potential shifts. The alteration's implications are addressed in terms of percentage change over mean. According to the findings, the most likely year of change in annual and monsoon rainfall is 1964. Up to 1964, there was a rising tendency (along with the rest of India and the surrounding plains), followed by a declining trend from 1965 to 1980. (Exclusive to this region). Changes are particularly noticeable in the Shivaliks and the southern portion of the Lesser Himalayas throughout the whole area. (Kumar et al. 2010) precipitation patterns; in this work, monthly, seasonal, and yearly rainfall trends were examined using monthly data series spanning 135 years (1871–2005) for 30 Indian sub-divisions (sub-regions).

(Guhathakurta and Rajeevan 2008; Kumar et al. 2010) discovered that monsoon rainfall in Chhattisgarh state is decreasing (UKC is located in Chhattisgarh). (Sonali and Nagesh Kumar 2013) examined the applicability of trend detection techniques and recommended that many tests be conducted to get a conclusion. As a result, we used the techniques described above

(i.e., MK, LR, SRC, SS, TFPW, and BBS-MK) to evaluate precipitation and stream-flow trends in the Xiangxi River watershed at the same time. Furthermore, the sequential Mann-Kendall (SQMK) test analyzes changes over time and pinpoints any trend's start (Modarres and Sarhadi 2009). The sequential results, $u(t)$ and $u'(t)$, acquired from the Mann-Kendall test's progressive and retrograde analyses, are computed. Detailed instructions may be found in (Karpouzou et al. 2010) For abrupt change point identification in data series, a combination of cumulative sum charts (CUSUM) and bootstrapping is also employed, and a time where the CUSUM chart follows a reasonably straight course suggests a period when the average does not change. The cumulative sums and confidence level are computed iteratively, as stated in (Mahmoud M. Smadi and Ahmed Zghoul 2006) and (Zhang et al. 2016), and the analysis is based on 2,000 bootstrap samples.

While studying the rainfall history of the Indian Himalayas, (Basistha et al. 2008) discovered a rising tendency from 1902 to 1964, followed by a declining trend from 1965 to 1980. (Pal and Al-Tabbaa 2011) examined winter, spring, and autumn severe rainfall patterns across Kerala, India, from 1954 to 2003 on a sub-regional scale. They discovered that severe rainfall in the winter and autumn increased, whereas extreme rainfall in the spring decreased in amount, intensity, and frequency. (Kumar et al. 2010) looked at long-term rainfall trends in India from 1871 to 2005 and found "no significant trend for annual, seasonal, or monthly rainfall for the whole country."

Furthermore, they discovered an increasing trend in seasonal rainfall in 23, 10, 27, and 20 subdivisions during the pre-monsoon, monsoon, post-monsoon, and winter seasons, respectively. (Tabari et al. 2012) studied long-term annual and seasonal precipitation patterns at 41 Iranian rainfall stations from 1966 to 2005, finding a declining trend in annual precipitation at around 60% of the stations and a negative trend in winter and spring precipitation time series. (Zou et al. 2013) used the Mann-Kendall test to find significant

decreasing trends in annual precipitation, annual streamflow, and annual sediment discharge in the Yellow River basin from 1950 to 2008. In Jiangxi Province, southeast China, (Montanari et al. 2013) found strong increasing precipitation patterns in January, August, winter, and summer, while major decreasing trends are most evident between October and autumn. From 1964 to 2013, (Bari et al. 2016) investigated seasonal and annual rainfall trends and variance at eight rainfall locations in northern Bangladesh. In the majority of the rainfall locations, they discovered increasing pre-monsoon and post-monsoon rainfall patterns, whereas monsoon and annual rainfall trends were decreasing. They found a negative trend in seasonal rainfall in the majority of the locations in the early 1990s using the sequential Mann-Kendall test. Several studies on India's rainfall patterns discovered either a decreasing or increasing trend in annual and seasonal rainfall in various country areas. (Jain and Indurthy 2003) estimate that India's northeast region (NER) covers 0.26 million km². This region boasts one of the world's highest rainfall rates.

Consequently, it has a tremendous amount of water and hydropower potential, and water and energy management would be interested in studying rainfall and temperature trends. The study of (Mondal et al. 2015) is mainly concerned with the changing pattern of rainfall in an Orissa river basin near the seashore. It is frequently every year susceptible to water damage. This is an effort to evaluate the rainfall trend in the area by looking at one of the most important meteorological variables, precipitation. (Duhan and Pandey 2013) examined the Spatio-temporal variability of precipitation at 45 locations in Madhya Pradesh from 1901 to 2002 using the Mann-Kendall test and Sen's slope estimator. They discovered a substantial declining tendency at three sites in the yearly precipitation series and two stations in the monsoon season, whereas eight stations showed a significant rising trend in the summer season. (Narayanan et al. 2014) discovered that four stations in the "north-western and western portion of the nation see an increase in pre-monsoon rainfall by 10% or more" while

analyzing long-term (1949–2009) pre-monsoon rainfall trend for six stations in western India. In addition, ARIMA modeling for pre-monsoon rainfall prediction shows that two sites, Abu and Ahmadabad, have a negative change in rainfall until 2030. (Subash et al. 2011) examined the trends in rainfall and temperature and the likelihood of any logical connection between the changes in India's homogenous areas. The pattern trend was observed increasing in annual maximum temperature and all homogenous temperature areas, and matching annual rainfall follows the same pattern in all regions, save the North East. We may conclude that the relationship between rainfall and temperature changes is spatially and temporally dependent on a broad scale.

(Dash et al. 2009) used Mann-Kendall and Sen's approach to evaluate the geographical patterns of trend in rainfall and rainy days between 1971 and 2005 during the Indian Summer Monsoon. They found a rising tendency in rainfall and rainy days throughout India's east coast and Deccan Plateau area, but a substantial decrease along the west coast, eastern portion, and western desert region. Furthermore, they discovered a declining tendency in rainfall in the north-eastern area of India, as well as a decreasing trend in rainy days in the north and central regions of India. (Sankaran and Janga Reddy 2014) I discovered that trend analysis and change point identification in hydro-climatic variables are getting much interest due to climate change and its socioeconomic implications. Long-term rainfall patterns in four southern Indian subdivisions, namely Kerala, Tamil Nadu, North Interior (NI) Karnataka, and Telangana, were examined in this research using linear regression, nonparametric Mann-Kendall (MK) test, and Sen's slope estimator techniques. Annual rainfall time series trend analysis reveals a rising tendency in three subdivisions – Tamil Nadu, NI Karnataka, and Telangana – and a declining trend in Kerala. The sequential change in annual and seasonal rainfalls in the four subdivisions is also investigated using the sequential MK (SQMK) technique. The SQMK analysis reveals an early separation of progressive and retrograde

modes of Kerala post-monsoon rainfall and Telangana winter rainfall subdivisions. Furthermore, among the many seasonal rainfalls, the post-monsoon rainfall of the Kerala subdivision has shown a statistically significant rise in the recent past. The trend analysis is then conducted on the post-monsoon rainfall time series of the Kerala subdivision using discrete wavelet transform (DWT) combined with the SQMK technique. The findings indicate that there is a dominance of short-term periodicity of less than a decade in the subdivision. (Nair et al. 2014) examined the precipitation pattern over the past 100 years in Kerala, India's coastal state that receives about three times the national average rainfall. They discovered that rainfall variance in Kerala's northern and southern areas is significant, with the deviation occurring on distinct timeframes. During the seasons, there was a change in the mean and variability of rainfall.

(Gajbhiye et al. 2016) discovered a significant increase in March and a decrease in April when analyzing monthly, yearly, and seasonal rainfall patterns in the Sindh basin, India, using the Mann-Kendall and modified Mann-Kendall tests from 1901 to 2002. They found an increasing trend in post-monsoon and summer rainfall in all research sites and a declining trend in monsoon rainfall. Furthermore, except for one site, they found a declining trend in yearly rainfall. (Kumar et al. 2017) investigated the knowledge of rainfall as a significant problem for Uttarakhand, India, which has diverse terrain and, as a result, severe rainfall produces rapid runoff, threatening the structural and functional safety of big constructions and other natural resources. In this research, an effort was made to identify the best-fit distribution of yearly rainfall data for 13 districts in Uttarakhand from 1991 to 2002. The best square (2p), exponential, exponential (2P), gamma, gamma (3p), gen. extreme (GEV), log Pearson 3, Weibull, etc., were employed (3P). The best distributions have been compared using fitness tests including Kolmogorov–Smirnov, Anderson–Darling, and Chi-squared. The

distribution of Weibull was the best, representing 46 percent of the whole area, while Chi-squared (2P) and log-Pearson were the second-best distributions.

(Varshney and Satpathy 2017) investigated precipitation patterns in five distinct districts of Bihar, namely Araria, Kishanganj, Madhubani, Purnia, and West Champaran, for a year (1950-2000). (Pandey et al. 2017) performed a linear trend analysis on observed rainfall data from 7 meteorological areas in India from 1851 to 2006. The SQMK test was also used to investigate nonlinear patterns in precipitation data sets. The partial sum of the cumulative deviation test was also shown to be effective in identifying nonlinear trends. Annual precipitation analysis showed that the West Peninsular India area had the greatest shift in mean rainfall, at 11.53 percent, while the North Mountainous Indian region experienced the greatest decrease in mean rainfall, at 7.8 percent.

(Sabarish et al. 2017) studied the use of 100 years of rainfall data to conduct extreme rainfall value research in the Tiruchirapalli City in Tamil Nadu. Statistical methods have been used in the study. The best-fit probability distribution was evaluated for 1, 2, 3, 4, and 5 days of continuous maximum rainfall. The Chi-square test has been used to evaluate fitness quality. The fitness tests indicate that log-Pearson type III is a best-fit probability distribution for maximum rainfall of one day and subsequent maximum rainfall of 2-, 3-, 4-, 5- and 6-day. The highest precipitation forecast for the selected return periods compares to the displayed position results to verify dependability.

Temperature

(Barnett et al. 2005) investigated how long-term rainfall patterns may change as temperatures rise, affecting water supply, which has been a significant global environmental issue in recent years. (Hingane et al. 1985) studied long-term time series temperature data from 1901 to 1982 from 73 sites spread throughout India. They discovered an upward trend in the mean

annual surface air temperature. Over an eight-decade period, a 0.4 °C increase was seen. Long-term hydrologic and climatic data trends and surface air temperature have been widely utilized to evaluate the possible effects of climate change and variability. (Pant and Kumar 1997)) examined a trend in annual and seasonal air temperatures from 1881 to 1997 and discovered a statistically significant rising trend for the mean annual temperature at a rate of 0.57 °C per 100 years. (Sontakke et al. 2008) researched India's Indo-Gangetic Plains and discovered a substantially (1 percent level) rising trend for the mean annual temperature at a pace of 0.53 °C/100 years 1875 and 1958. However, during the period 1958–1997, there was a substantial (5 percent level) declining tendency at a pace of 0.93 °C per 100 years. (Kothawale and Kumar 2005) conducted a trend detection test for surface temperature across India from 1901 to 2003 and discovered a substantially rising trend for the mean annual temperature at a rate of 0.05 °C per decade. However, they found a faster rise in mean annual temperature of 0.22 °C each decade from 1971 to 2003. This increase in temperature is also seen when comparing daytime and nighttime temperatures, indicating extraordinary warming over the past several decades. Based on a trend detection analysis of temperature data from 125 stations across India, the Central Water Commission (CWC) and National Institute of Hydrology (NIH) discovered an increase of 0.42, 0.92, and 0.09 °C in mean annual temperature, mean maximum temperature, and mean minimum temperature over the last 100 years. (Cui et al. 2018) elaborate the variable features of air temperature and precipitation in the Yangtze River Basin , China, were studied using linear regression (LR) analysis, a Mann-Kendall (MK) test using Sen's slope estimator, and Sen's novel trend analysis from 1960 to 2015. The findings revealed that the annual maximum, minimum, and mean temperatures rose at rates of 0.15C/10yr, 0.23C/10yr, and 0.19C/10yr, respectively, over the whole research region from 1960 to 2015. Warming magnitudes for the variables mentioned above were significantly greater during 1980–2015 than during 1960–2015: 0.38C/10yr,

0.35C/10yr, and 0.36C/10yr, respectively. During 1960–2015, the seasonal maximum, minimum, and mean temperatures all rose substantially throughout the spring, autumn, and winter seasons. Although summer temperatures rose to some amount, only the lowest temperature exhibited a substantial rise. The rising trend of maximum and lowest temperature accelerated the water vapor demand, and most lakes, rivers, ponds, and other bodies of water with no restriction of water availability at this period meet the water vapor need while also showing an increasing trend of rainfall activity.

2.4 Remote Sensing & GIS Applications

The use of remote sensing and geographic information system (GIS) methods in erosion assessment has made soil loss estimate and spatial distribution analysis possible over vast regions regarding cost and reliability (Millward and Mersey 1999). Furthermore, (Cui et al. 2018) utilized geostatistical techniques to estimate soil erosion loss using a sampling ground dataset, thematic mapper pictures, and DEM data and obtained better results than conventional methods. Various research has been performed across the globe to estimate soil erosion and runoff using a GIS integrated erosion model. (Yuksel et al. 2008) utilized GeoWEPP (the geospatial interface of the WEPP model) to estimate sediment production and runoff using digital georeferenced data combined with standard GIS tools. (Tesfahunegn and Gebru 2021) carried out the research to derive and assess the spatial distribution of hydro-physical parameters developed using GIS techniques and apply them in the Morgan and Morgan Finney (MMF) model for estimating the spatial variability of soil loss in the Mai-Negus catchment, northern Ethiopia. (Pham et al. 2018) conducted research to combine Geographic Information System (GIS) with Soil and Water Assessment Tools (SWAT) for modeling soil erosion within a small mountainous watershed in Central Vietnam, upstream of the Bo River watershed. The findings revealed that GIS and SWAT worked well despite the restricted availability of input meteorological data. (Tirkey et al. 2013) used the RUSLE

model and GIS to estimate average yearly soil loss in the Daltonganj Watershed of Jharkhand (India). The agricultural areas with slopes less than 5 contributed the most to soil erosion, with soil loss of up to 10 tonnes ha⁻¹yr⁻¹. In recent years, the study of the precipitation variabilities at different spatiotemporal scales has been addressed significantly. Variability in the Indian rainfalls in various temporal and geographical scales was found in numerous studies (Iyengar and Basak 1994; Pattanaik 2005; Pham et al. 2018; Tesfahunegn and Gebru 2021; Yuksel et al. 2008) that the interdecadal variability in storm activity across the Indian subcontinent is primarily due to fluctuation of large climate patterns. In the summer monsoon rainfall in India, spatial and sub-seasonal patterns were studied (Kumar et al. 2010). In the latter half of the season, excess or scarcity of monsoon precipitation was most often observed. Monsoon precipitation on the West Coast of India and Central India was more concentrated in August. In monsoon seasons, the frequency or intensity of severe prevailing precipitation events in India increased considerably between 1951 and 2000 (Goswami et al. 2006). However, moderate occurrences showed a considerable decline, which did not alter the mean seasonal precipitation. Seventh annual and interdecadal variations and a statistically significant long-term trend changed considerably throughout time, with catastrophic rainfall occurrences. (Rajeevan et al. 2008) Different efforts have been made to understand the temporal and spatial distributional characteristics of pan-evaporation in the Chao Phraya river basin in the Kingdom of Thailand (Shah and Mishra 2016) and to investigate this trend. (Sontakke et al. 2008; Sreelash K et al. 2018; Tebakari et al. 2005) In the future projected rainfall, they showed diverse patterns. They discovered that an increasing temperature of heavy rainfall was the consequence of an abnormality in urban precipitation. 1964 is indicated as the most probable year of annual and monsoon rainfall change in the Himalayan region of India (Basistha et al. 2008; Pal and Al-Tabbaa 2009). Precipitation in this region grew until 1964 and then dropped between 1965 and 1980. A significant contribution from

extremes has been found in Kerala to increase the autumn rainfall (Pal and Al-Tabbaa 2011). They discovered that water shortages in the pre-monsoon season are more likely to occur and that the monsoon season is delayed. Seasonal and annual rainfall and rainy day pattern at five sites in the Kashmir Valley of India was studied (Kumar et al. 2010). They saw reduced rainfall at four locations and increased rainfall at one location, but none observed statistically significant annual precipitation patterns. The following study shows the statistically significant variation in precipitation in the Indian Subcontinent. However, in some regions, there has been a considerable degree of spatial variability, which requires regional study. Spatio-temporal variability of rainfall in Bangladesh was studied for 35 years (1969–2003) (Shahid and Osman Salleh 2009). Their study showed that yearly, monsoon, and pre-monsoon rainfall had increased significantly while winter rainfall has decreased. In addition, they noticed an increasing tendency in the coastal region and the northern half of the nation concerning the geographical distribution of rainfall patterns, while the central area of the country has been shown a decline in trend. Spatial precipitation patterns in Hawaii are among the most diverse in the globe. As the global climate warms, observable precipitation variations need to be understood to bring about future improvements. The spatially temporary and concentrated time-series in West Bengal, India, from 1901 to 2002 examined a similar pattern, increasing rainfall, in-state mountain and coastal regions (Dash et al. 2009; Srivastava et al. 2018). According to (Dash et al. 2009) this study aims at using statistics to understand better spatial and temporal variability and rainfall and hydrological patterns in the southern Portuguese Cobres basin.

(Pingale et al. 2016) conducted a trend study of the mean (monsoon season, non-monsoon season, and yearly) and extreme annual daily rainfall and temperature for 33 metropolitan centers in Rajasthan, India. They used the Mann–Kendall test and Sen's slope estimator to look at trends from 1971 to 2005 at a 10% significance level. Rising and declining trends

were found in the mean and extremes of rainfall and temperature in urban areas. The lowest, average, and maximum temperatures in most of Rajasthan's metropolitan areas exhibited substantially rising warming trends on yearly and seasonal scales. Using the inverse-distance-weighted (IDW) interpolation method, the geographic variations in mean (monsoon season, non-monsoon season, and annual) and extreme annual daily rainfall and temperature were also calculated. The IDW method created trends and variability in mean and extreme rainfall and temperature in space and time for study sites with unavailable or low-quality data. The resulting temperature and spatial precipitation maps assist local stakeholders and water managers in understanding the risks and vulnerabilities associated with climate change in terms of mean and severe occurrences in the area.

Extensive study has been conducted throughout the globe to assess the geographical and temporal variance of precipitation. The time ranges used for trend analysis have typically ranged from month through the seasonal, annual, decade, and even centennial (Rodrigo et al., 2000). The short time scale seems to be relevant when research investigates information regarding sudden changes that harm urban infrastructure, while lengthy time scales provide insight into climatic variability that impacts a vast terrain on a comparatively more permanent basis. The geographical size also has an impact on trend analysis findings. Studies on climate change tend to focus on long-term changes; however, water resource engineers and planners must understand short-term variability in order to ensure all-time water availability or to design a drainage network for sweeping out excess runoff on a real-time basis

2.4 Climate change impacts on Hydrology

Climate change effects are already being experienced. These consequences go well beyond a temperature rise, impacting ecosystems and people in India and globally. Things we rely on and cherish, such as water, electricity, transportation, wildlife, agriculture, ecosystems, and human health, are impacted by climate change. Many of our planet's soils are projected to

become increasingly vulnerable to wind and water erosion due to climate change and human activity (Montanari et al. 2013; Zhang et al. 2018). Increased rainfall due to climate change may result in substantial increases in runoff, with amplification higher in dry regions (up to five times more runoff than the percentage increase in rainfall) than in wet and temperate areas (twice as much runoff as the percentage change in rainfall) (Chiew A et al. 1995). Increased runoff is anticipated to result in more erosion. Furthermore, changes in precipitation volume and intensity induced by climate change may increase the energy available in rainfall for sediment detachment and transport.

Under the UN Framework Convention on Climate Change, 'climate change is a result of human activities directly or indirectly, altering the characteristics of the atmosphere, in addition to the variability of earth's climate over similar periods.' The primary objective of this study is to examine the variability and importance of meteorological data (rainfall, minimum temperature, and PET) using various statistical methods. Most Indian scientists have focused on one or two climate variables – rainfall and temperature. However, more than two climatic variables have been included in this research, and three statistical tests have been used to analyze the climatic trend. The Novel tool, VSCA, was created to analyze the trend pattern's intermediate behavior and identify transition points. In addition to being sensitive to other climatic factors, PET plays an important part in calculating real water balance. The current study seeks to examine the autocorrelation and trend of various climatological variables. Several non-parametric statistical tests for examining climatic variables and their long-term variability across eighteen stations in Uttar Pradesh and five stations in Jharkhand state, India, which span the entire research region, show the trend and periodic fluctuation time-series data.

2.5 Summary

The range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time. The assessment of rainfall and temperature changes in climate change has major consequences for a region's socioeconomic circumstances. Agriculture is the backbone of the Indian economy, and it is heavily reliant on precipitation delivered by the southwest monsoon, which accounts for 70% of total annual rainfall in this nation. In India, monsoon rainfall is critical for agriculture during the monsoon season and recharges groundwater for irrigation during the dry season. The "Indian summer monsoon" is a component of the "Asian monsoon system," having a "broad range of variability on daily, sub-seasonal, interannual, decadal, and centennial periods" (Rajeevan et al. 2008). They linked the declining trend in precipitation to worldwide anomalies caused by human greenhouse gas (GHG) emissions from increasing fossil fuel usage, land-use change owing to urbanization and deforestation, and the spread of transportation-related air pollutants.