CHAPTER 3

STUDY AREA AND DATA USED

3.1 General

Station scale analyses are suggested in the states of Uttar Pradesh and Jharkhand for an improved understanding of the trends in precipitation. Throughout the states, districts' significance and appropriate distribution led to the selection of eighteen divisional zones in Uttar Pradesh and five divisional zones in Jharkhand. Uttar Pradesh is located in northern India and accounts for about 7.34 percent of the country's total geographical area. It has a land area of approximately 240,928 km. It is India's most populous and fourth-largest state in terms of land area. Jharkhand is in East India, accounting for about 2.42 percent of the overall geographic area of the nation. It has a surface area of about 79,710 km^2. It ranks 14th in terms of population in India and 15th in terms of area. Because agriculture employs two-thirds of the Indian population, climate change and its effect on water supplies are increasingly becoming a significant issue in India. Various arrangements and initiatives have been launched over the past two to three decades to solve this issue, but the results have been disappointing. Analyzing the causes of climate change and extremes is critical for developing appropriate strategies to address the issues.

This State has a tropical climate with high temperatures and humidity, medium to high rainfall, and moderate winters that last just a few months. The agricultural activity of the states is mainly dependent on rainfall since the majority of the farmed command area is rain-fed, and there is little irrigational infrastructure. The State receives about 1200 mm of precipitation each year. Floods, droughts, and cyclones occur nearly every year in these states, varying degrees of severity. Aside from inflicting significant property damage and loss of life, repeated occurrences of natural extremes harm agricultural output. As a result,

scientists and engineers must evaluate the precipitation pattern in Uttar Pradesh and Jharkhand.

It features a varied terrain of hills, plains, valleys, plateaus, and strong rock strata. The most frequent soil types in the investigated area are sandy, loamy, clay, and their combinations, such as sandy loam, salty clay loam, and loamy sand soils. (National Bureau of Soil Survey and Land Use Planning, NBSSLUP). Cultivation is time-consuming.

The preponderance of the state economy comprises the agriculture and service industries. The services industry includes travel and tourism, the hotel business, immobilizer, insurance, and financial advisors. Consistent and reliable data or information is required for every modeling research. This kind of research is entirely dependent on field-collected measurable data and appropriate data handling (Kishore et al. 2016)

3.2 Study Area

The map of India, the State of UP and its eighteen administrative divisions, and the State of Jharkhand and their five administrative divisions were chosen for the study shown in Figure 3.1 and Figure 3.2, respectively.

3.2.1 Uttar Pradesh

This research focused on two Indian states: Uttar Pradesh and Jharkhand. Uttar Pradesh is India's fourth-biggest State, with a geographical area of 243,286 square kilometers (7.33 percent of India's total area) situated in the northern part of the country the same size as the United Kingdom. It is bounded on the west by Rajasthan, northwest by Haryana, Himachal Pradesh, and Delhi, north by Uttarakhand and Nepal, east by Bihar, on the south by Madhya Pradesh, and on the southeast by Jharkhand and Chhattisgarh. Uttar Pradesh is a state in northern India with about 200 million; India's most populous state and the world's most populated country subdivision. It was established as the United Provinces of Agra and Oudh

on April 1, 1937, under British rule and was renamed Uttar Pradesh in 1950. The state of Uttar Pradesh is split into 18 divisions and 75 districts, with Lucknow serving as the capital. The Himalayan hill region of the state was divided into a new state, Uttarakhand, on November 9, 2000. The Ganga and the Yamuna, the state's two major rivers, combine at Allahabad (Prayagraj) and travel east as the Ganga. Hindi is India's most widely spoken language, and it is also the state's official language, alongside Urdu. The state's historical, ecological, and religious tourist sites include Agra, Ayodhya, Vrindavan, Lucknow, Mathura, Varanasi, Allahabad, and Gorakhpur. The Ganga is one of Asia's most significant rivers. Its basin spans many nations and has an area of more than 10 lakh square kilometers. The basin encompasses eleven central states in India, including Uttar Pradesh. The research analyzed meteorological data from 18 divisional offices in Uttar Pradesh. These districts are among the most populous in the State. Uttar Pradesh is divided into 75 districts called Moradabad, Bareilly, Gorakhpur, Devipatan, Basti, Meerut, Lucknow, Aligarh, Kanpur, Faizabad, Azamgarh Agra, Jhansi, Chitrakoot, Allahabad, Varanasi, Mirzapur, and Saharanpur.

The study includes 18 synoptic stations in Uttar Pradesh, India, with latitudes ranging from 23°52'N to 31°28'N. It has an international boundary with Nepal on the northern coast of India. The Himalayas border the State in the north; however, most of the State's plains are far away from the high peaks. Ganges-Yamuna Doab, the plains of Ghaghra, the Ganges, and the Terai lowlands are all part of the wider north Ganges plain. The Vindhya Range and the plains are smaller towards the South. Pradesh to the northwest, Haryana and Delhi to the west and Rajasthan to the southwest, Madhya Pradesh to the southeast and Jharkhand to the south, and Bihar to the east.

The study includes four sites in India and Nepal, totaling 9,23,821 square kilometers. Between the latitudes of 23°52'N and 31°28'N and the longitudes of 77°30' and 84°39'E, it is situated. The Farakka barrage, located in West Bengal at 87.9333° E longitude and 24.8047°

N latitude, has traditionally been considered the Ganga Basin's outflow. The basin is bounded on the north by the Himalayas, west by the Aravalli, south by the Vindhyas and Chhotanagpur plateau, and the east Brahmaputra Ridge (Figure 3.1). The state's climate is mostly humid subtropical, with dry winters (CWa-type) in the majority of the state (Tropical Monsoon) and semi-arid (BS-type) in the western zone. While India's seasons are usually defined as winter, summer, and rainy, data for trend analysis has been divided into four seasons: winter, summer, monsoon, and post-monsoon. There are climatic differences across the state; however, the Indo-Gangetic plain covering a large expanse has a predominantly uniform climate with minor regional variations. A significant variation in temperature ranging between 0.0°C to 50°C and cyclical droughts & floods due to less predictable rains make UP a state of extremes in India. The summer in the State is scorching, freezing winter, but the rainy season may be very wet or dry. It may be noted that the average annual rainfall over the districts of UP ranges between 896 to 1667 mm, and most of the rain occurs during the monsoon season.

Uttar Pradesh may be classified geographically into three different regions:

1. In the north, the Shivalik foothills and Terai.

2. The Gangetic Plain in the center - Extremely fertile alluvial soils; flat terrain interspersed by ponds, lakes, and rivers; the slope of 2 meters per kilometer.

3. The Vindhya Hills and plateau in the south - Difficult rock strata; diverse topography of hills, plains, valleys, plateau; inadequate water supply.

The State contains more than 32 rivers, the largest of which are the Ganges, Yamuna, Saraswati Betwa, Sarayu, and Ghaghara, which are also religiously significant in Hinduism. The Ganges River Basin is the largest in India. Even though the Ganges is considered sacred

in Hindu mythology, people have no qualms about dumping domestic and industrial waste into it. Due to the many urban areas, medium-sized cities, and small villages located along the river, large quantities of effluents and waste enter the natural drainage system, polluting the whole basin.

Uttar Pradesh is India's fifth-largest economy, with a gross domestic product of $15.42 lakh crore (US$220 billion) and a per capita GDP of $61,000 (US$860). Uttar Pradesh is rated twenty-eighth among Indian states in terms of human development.

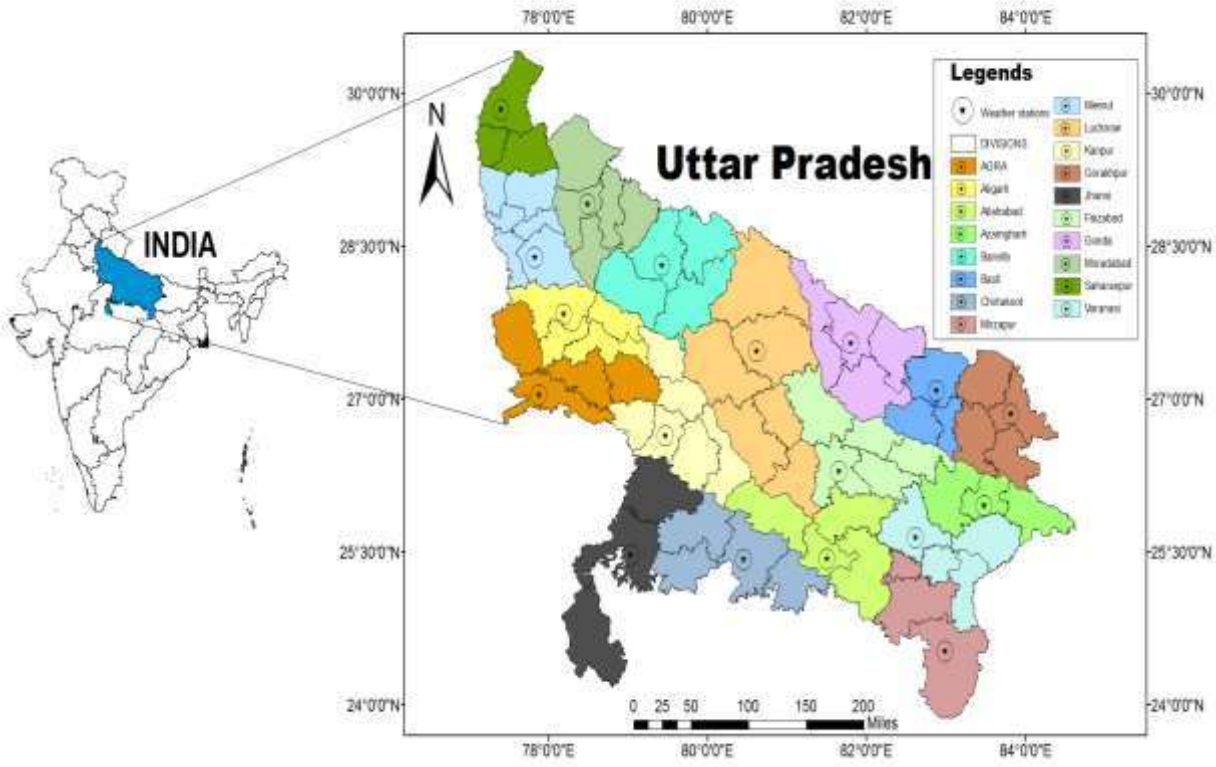

Figure 3.1 Location of study area (Uttar Pradesh state and its divisions) along with Meteorological stations.

The climate of the State is primarily humid subtropical with dry winter (CWa- type) in most regions of the U.P (Tropical Monsoon) and semi-arid (BS- type) in the western zone. Climatic variations exist in different parts of the State; however, the Indo-Gangetic plain

covering a large expanse has a predominantly uniform climate with minor regional variations. A large variation in temperature ranging between 0.0°C to 50°C and cyclical droughts & floods due to less predictable rains make UP a state of extremes in India. The summer in the State is extremely hot, winter very cold, but the rainy season may be very wet or dry.

Table 3.1 Climatic parameters of the study area from 1901 to 2018

Months	Rainfall (mm)	Relative Humidity (%)	Temperature mean (ºC)	
			Max	Min
January	59.64	76	24.84	11.12
February	89.22	89	26.39	14.23
March	64.63	76	29.18	21.30
April	64.90	75	33.45	26.35
May	59.17	69	37.89	31.30
June	131.85	89	42.60	33.10
July	258.63	95	41.47	32.46
August	301.87	93	35.59	29.45
September	126.71	91	31.42	24.20
October	61.54	89	29.34	19.20
November	12.72	81	28.54	11.80
December	18.29	86	24.34	7.20

The warmest days are often around May, while the coldest days are in December or January. Locally, temperatures are much higher owing to a lack of cloud and radiation from stony soils or outcrops. Summer brings brief squalls. This often leads to forming a cloud of dust that is so dense that it gets hazy throughout the day. The yearly average temperature exceeds 27°C. However, the mean monthly values differ significantly from the yearly averages, resulting in a wide temperature range. Summer temperatures average about 35°C and may reach as high as 45°C in May and June. Between June and September, the monsoons bring temperatures

down to approximately 23°C - 27°C, with relative humidity ranging between 68 and 80 percent. Annual precipitation averages 75 centimetres in the north and 125 centimetres in the southeast. The average rainfall in the area is approximately 100 cm and occurs mostly during the monsoon months of June to September. Around 75% of rain occurs over these three months, and the total quantity is extremely unpredictable. This insecurity is often blamed for the region's long history of famines, droughts, and deluges. Certain shallow westerly depressions provide winter rain, which benefits the rabi crop significantly.

3.2.2 Jharkhand

The study area for this research work is Jharkhand India, and the State is also called 'land of bush or forest.' Palamu, Hazaribagh, Dumka, Ranchi, and West Singhbhum are the five main chosen synoptic stations, with their administrative divisions called Palamu, North Chotanagpur, Santhal Pargana, South Chotanagpur, and Kolhan, respectively. The state is bounded on the east by West Bengal, north by Bihar, on the northwest by Uttar Pradesh, west by Chhattisgarh, and on the south by Odisha. It has a geographical area of 79,710 km^2. The study area is located in central northeast India (Figure 3.2), and geographical extension is between 22°28' to 25°30' north latitude and 83°22" to 87°40" east longitude with an altitude ranging from 3 to 1359 m above MSL.

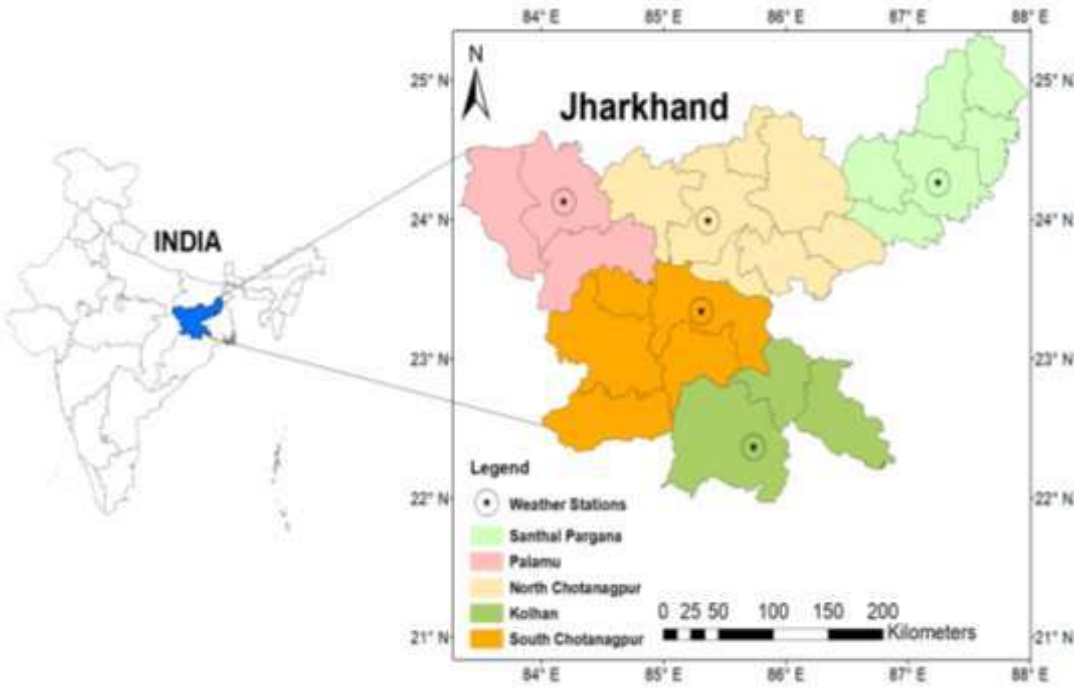

Figure 3.2 Location of the study area (Jharkhand State and its Divisions) along with Meteorological stations.

Climate change is proven to be one of the most serious problems confronting the global world today. The study of historical patterns and present unpredictable behavior in climatic occurrences demonstrates that the variations in the climate of Jharkhand are evidence of the State's inherent climate variability. Numerous studies conducted for the State indicate that Jharkhand is in a dangerous position due to its high climate sensitivity and susceptibility, coupled with a poor capability for adaptation. Already, the state is suffering as a result of its heavy reliance on natural resources. Additionally, the state's forest and water resources are in danger from industrial and urban development and unequal distribution of resources both temporally and geographically. Thus, climate change requires an appropriate, evidence-based, and cohesive policy response, followed by sufficient action that may assist the State in reducing its vulnerability and strengthening its resilience in the face of climate change effects.

The state of Jharkhand has a diverse climate, ranging from humid subtropical in the north to tropical wet and dry in the southeast. Three distinct seasons exist; the summer season runs from mid-April to mid-June. May is the warmest month, with daily maximum temperatures hovering around 38 °C (100 °F) and minimum temperatures hovering around 25 °C (77 °F). From mid-June to October, the southwest monsoon delivers almost all of the State's annual rainfall, which varies from approximately 1,000 millimetres in the west-central portion of the State to more than 1,500 millimetres southwest. July and August get almost half of the yearly precipitation. November through February is the winter season. The daily average temperature ranges from 6 °C to 46 °C, although the temperature rises to 42-46 °C in the summer. The spring season begins in mid-February and ends in mid-April. July-September is the wettest month, with an average yearly humidity of almost 60%. It has a hot and dry summer from March to October and chilly winter from November to February. The area's topography is a moderately raised central plateau, a poorly elevated lower plateau with many hills and mountain ranges, and numerous river basins such as the Damodar river, the Son river, and the Subarnarekha river. Apart from the Damodar River in the northeast, the State is drained by the Subarnarekha and Brahmani rivers in the southeast and south. A third significant river, the Son, runs along a large portion of the state's northern border. The soil of the Damodar river is sandy, while the plateau areas have red soils. It is home to a diverse range of vegetation and animals. According to the JSAC study, the state is a promising location for sustainable development and watershed management and should be prioritized.

3.3 Data Collection

While many other hydro-climatic factors such as streamflows, evaporation, humidity, and soil moisture all affect water supplies, temperature and rainfall have the greatest impact. Increased temperatures increase evaporation, which results in dangerously low water levels in

reservoirs. When coupled with less rainfall, this exacerbates the issue. As a result, rainfall and temperature were chosen as variables for investigation in this research.

In this study, the aim was to use a more accurate and consistent dataset with minimal artefacts. Therefore, any accumulations were defined as missing data in this study. The eighteen synoptic stations of UP and five Synoptic stations of Jharkhand, India, were selected as study stations shown in Figures 3.1-3.2. For determining the temporal changes in the long-term climatic variables over the study area, monthly data obtained for 118 years (1901–2018) were obtained from India Meteorological Department (IMD), Indian Institute of Tropical Meteorology, and India water portal (http://indiawaterportal.org/metdata). The data from the various stations for 1901 to 2018 were utilized to create the time series for months, seasons, and annum by a simple summation process. Thus, the length of the data series for every district is 118. The magnitude of annual precipitation for each district was calculated from monthly data, and dataset characteristics, such as mean, standard deviation, coefficient of variation, and percentage contribution to annual precipitation, were also computed. The obtained time series were converted into seasonal and annual averages for the station, and the following climatic variables were considered for trend analysis: precipitation, temperature maxima-minima, and potential evapotranspiration (PET). As per IMD, four climatological seasons with some local adjustments: season 1 refers to the pre-monsoon (summer) season (March to May); season 2 resembles the monsoon (rainy) season (June to September); season 3 resembles the post-monsoon season (October to November), and season 4 resembles the winter season (December to February) and annually (January to December) are considered for statistical analysis.

3.3.1 Seasons

While seasons in India are often defined as winter, summer, and rainy, for trend analysis purposes, data have been divided into four seasons: winter, summer, monsoon, and post-monsoon. The following sections detail the features of various seasons.

3.3.1.1 Winter

The research region experiences chilly temperatures from early November through late February. October and November have a pleasant climate. The days are sunny and pleasant, although the sun hours are not too hot. Once the sun sets, the air temperature begins to decline, and the day's heat is replaced with sharp, bracing cold. Winter temperatures in the research region typically vary between 2 and 10 °C. December and January are the coldest months of the year. Additionally, the research region has a record low temperature of -2° Celsius in its data set.

3.3.1.2 Summer

The summer season begins in March and lasts until mid-June. The study area's greatest temperatures are often reported in May, the state's warmest month. During the summer season, the study region, like the rest of northern India, suffers dust storms and dust-raising winds. Dust storms with velocities of 48-64 kilometres per hour are most common in May, with a second peak in April and June. During April and May, the UP plains' hot winds (loo) blow at an average speed of 8-16 kilometres per hour. This scorching wind has had a significant impact on human comfort throughout this season.

3.3.1.3 Monsoon

The rainy season begins shortly after mid-June and lasts until the end of September. Monsoon season officially begins when a water-laden storm from the Bay of Bengal passes over the study region. The monsoon season may begin as early as the final week of May or as late as

the second week of July. Typically, the rainy season starts around June. July and August are the wettest months. The southwest monsoon is responsible for the rain in the study region.

3.3.1.4 Post-Monsoon

The incursion of tropical cyclones originating in the Bay of Bengal at about 12° N latitude is a significant characteristic of the receding monsoon season in the study region. Typhoons originating in the South China Sea also affect the study region. Tropical cyclones occur most often in the study region between September and November, particularly around the asterism known as Hathiya. However, these cyclones seem essential for paddy maturity and for moistening the soil in preparation for Rabi crop farming.

3.4 Software's used

3.4.1 Programming tool

Matlab R2013a: MATLAB, programming, and numeric computing platform were used to analyze data, develop algorithms, and create models and graphical outputs.

3.4.2 Image processing & Geospatial analysis

ArcGIS 10.5: ArcGIS is a software package comprised of a collection of geographic information system (GIS) products developed by ESRI. It was used for a variety of purposes, including creating and utilizing maps, digitizing and compiling geographic data, analyzing mapped information, sharing and discovering geographic information, integrating maps and geographic information into a variety of applications, and managing geographic information in a database.

Further development may drain even more water from the wetlands for irrigated agriculture in upstream regions, harming both the ecosystem and the floodplain's irrigated agricultural output that relies on the shallow groundwater aquifer since recharge would be further

reduced. Inappropriate agricultural methods, such as a lack of crop rotation, the use of maximal tillage, insufficient or no fallowing, insufficient fertilizing, overgrazing, and the absence of mulching, have resulted in silting of riverbeds and the loss of watercourses.