Examining Two Decades of Climate Variability in Karnataka: Insights from Temperature and Rainfall Trends

Abstract:

Karnataka, is known for its diverse landscapes and dynamic culture, witnessed noticeable variations in temperature, relative humidity, and rainfall patterns, driven by factors such as increased population, globalization, and both anthropogenic and natural phenomena. This study looks at the impact of this climate variability on the studied districts of Karnataka over two decades. There was no significant difference in average annual rainfall, variations within districts are evident but Uttara Kannada, Hassan, and Shivamoggaexperienced increased mean rainfall than in Gadag, Raichur, and Kolar. Results suggest minimal variation in rainfall within specific districts, emphasizing geographical specificity. Raichur has the greatest average max and min temperatures, according to temperature trends, whereas Hassan has the lowest.Notably, Hassan's average minimum temperature was lowest in 2005. Kolar has the lowest average maximum relative humidity, while 2019 and 2020 have the greatest. Kolar also recorded the highest average min relative humidity, while Raichur witnessed the lowest.Recognizing the critical implications of climate variability, particularly for agriculture, this study offers invaluable insights to inform adaptive strategies and ensure the sustainability of Karnataka's diverse districts in the face of changing environmental conditions.

Keywords: Climate, Rainfall Patterns, Temperature Trends, Relative Humidity, Karnataka.

Introduction

The Indian Meteorological Department (IMD) divides India geographically into four areas: Northeast India, Northwest India, Central India, and South Peninsular India. Subdivisions within these regions are further divided, with some of these contributing to separate states. India's seasons can be roughly divided into four groups. The winter season, which runs from January to February, contributes barely 1% of the annual precipitation total. Pre-monsoon (PRM) season, which is from March to May, brings in 7% of the yearly total of precipitation. 12% of the annual rainfall occurs during the Northeast monsoon (NEM), also known as the post-monsoon season, which runs from October to December. The southwest monsoon is the main source. Karnataka, for example, is separated into three regions: North Interior Karnataka, South Interior Karnataka, and Coastal Karnataka (Kumudha and Kokila, 2023).

Karnataka has a total geographic area of 191,791 km^2 and accounts for 5.83% of the total geographical area of India. It is the sixth-largest Indian state by area. The state is situated on the western edge of the Deccan Peninsular region of India. It is located approximately between 11.5° North and 18.5° North latitudes and 74° East and 78.5° East longitudes. Karnataka comprises the Deccan Plateau, the Western Ghats Mountain Range, and the Coastal Plains. The state extends to about 760 km from north to south and about 420 km from east to west (KSAPCC, 2021). The State has seven river systems, with a catchment of 191,773 km^2. The state represents around 6% of the nation's surface water resources. The typical yearly yield of the waterways of Karnataka has been around 98,406 m^3 (3,475 TMC). Streams flowing toward the west into the Arabian Sea convey 40% of the state's surface water and those streaming toward the east 60%. The state has 31 districts and the capital of Karnataka is Bengaluru near the south eastern border (Rejini et al., 2023).

Karnataka stands out as a region where noticeable variations in temperature, relative humidity, and shifts in rainfall patterns have become increasingly apparent over the past decades. These changes are attributed to a complex interplay of factors, including alterations in consumption patterns, the influence of globalization, and a multitude of both anthropogenic and natural phenomena. The cumulative effect of these dynamics is evident in the occurrence of unseasonal weather changes, ultimately culminating in climate change.

The ramifications of these climatic shifts extend beyond mere meteorological concerns, permeating into critical domains such as agriculture productivity and beyond. The evolving climate poses a substantial threat to established patterns, necessitating a concerted effort to recognize and address the challenges posed by climate change. It is imperative that we consider climate change as a pressing contemporary issue and actively engage in comprehensive strategies to mitigate its adverse impacts.

Among the most severe concerns facing the globe today is undoubtedly climate change. With the creation of the Inter-Governmental Panel on Climate Change (IPCC), the phenomenon of human-induced climate change gained notoriety and attracted the interest of scientists and decision-makers.

A deep relationship exists between agriculture and climate, as both are dependent on one another. Understanding how climate change is affecting the agriculture industry both globally and in local contexts is vitally important. When considering how to provide food for marginalized groups within society, this understanding becomes even more important.

The consequences of shifting climate go beyond simple changes in the environment; they have a big impact on both the ecology and our way of life. As such, addressing climate change becomes imperative for the sustainable coexistence of humanity and the planet.

The nexus between vulnerability to climate change and poverty is unmistakable, as the impoverished find themselves least equipped to respond to climatic stimuli. Moreover, certain global regions bear a disproportionately severe brunt of climate change effects. This issue of vulnerability and the imperative for adaptation becomes particularly urgent in numerous developing countries.

In India, agriculture and food security emerge as primary casualties of climate change. The widespread and indisputable pace and extent of warming across the country underscore the profound impacts it imposes. India grapples with diverse and serious consequences, encompassing erratic monsoons, alterations in agricultural zones, the proliferation of tropical diseases, rising sea levels, shifts in fresh water availability, and occurrences of floods, droughts, heat waves, storms, and hurricanes.

In the state of Karnataka, a noticeable increase of 1.30°C in average annual temperature from 1950 to 1990 has been observed. The mean annual rainfall trend, spanning from 1901 to 2000, have been reported as declining. Major districts of Karnataka witnessed a definitive decline in rainfall from 1950 to 2006. In contrast, Bangalore and Kolar districts in Karnataka have experienced a notable increasing trend in annual rainfall (Rajegowda et al., 2009).

In response to the unpredictable weather, farmers are continuously adjusting their crop management practices, opting for resistant varieties, and staying prepared for ongoing changes in farming techniques. According to Mendelsohn and Dinar (1999), adaptation efforts were estimated to potentially reduce the damages caused by climate change in Indian agriculture from 25% to a range of 15-23%. Because there are many different effects of climate change, developing practical ways to lessen its negative effects requires a detailed understanding of these effects. In light of this, this study has been designed to understand variations in temperature, humidity, and rainfall over a two-decade period in particular six districts in Karnataka which includes Gadag, Raichur, Hassan, Kolar, Shivamogga, and Uttara Kannada have been chosen in order to study the changes in climate between 2002 and 2022.The knowledge acquired from this study is intended to support a better informed strategy for dealing with the problems that climate change has brought about in these areas.

Methodology

Study area

The Karnataka State experiences diverse rainfall quantities across its regions. The average annual rainfall in Karnataka is 1248 mm. The state is divided into three meteorological zones viz. North Interior Karnataka, South Interior Karnataka and Coastal Karnataka. The Coastal Karnataka receives an average annual rainfall of 3456 mm and it is one of the rainiest regions in the country. Contrasting the region of South Interior Karnataka and North Interior Karnataka receives only 1126 and 731 mm of average annual rainfall. District-wise data were collected for the period during 2002 to 2022. Analysis showed that changing trend in rainfall pattern in the study area.

Result and Discussion

Historical Trend of Annual Rainfall between Districts

From **Table 1**, Results showed that there was an increase in rainfall amount in some districts, however, for the same time period other districts showed a decrease in rainfall. More specifically, rainfall in Uttara Kannada, Hassan and Shivamogga received more mean rainfall during last decade and Gadag, Raichur and Kolar received comparatively less rainfall.

Table 1. Mean Annual Rainfall Data for Selected Districts in Karnataka

Sl.No	Years	District-wise Average Annual Rainfall (in mm)					
		Gadag	**Raichur**	**Hassan**	**Kolar**	**Shivamogga**	**Uttara Kannada**
1	2002	453.6	485.4	731.4	573.3	1384.8	2284.5
2	2003	343.4	511.2	650	606.3	1295.4	2617
3	2004	651.9	566.2	1009	913.5	1599.6	2536.3
4	2005	608.7	763	1417.6	1281.5	1819.7	2971.9

5	2006	537.7	479.9	1140.4	671.3	1846.6	3219.3
6	2007	859.2	780.5	1274.2	781.2	2465	3430.7
7	2008	688.3	588.6	1233.3	897.7	1827.5	2544.4
8	2009	944.7	1018.7	1251.7	839.1	2282	2992.4
9	2010	840.6	795.6	1360.2	908	2265.2	3044.4
10	2011	474.2	505.4	1006.8	750.4	1810.4	3207.1
11	2012	450	439.2	715.6	646.6	1234.8	2691.4
12	2013	529.2	771.4	1083	655.8	1945.8	2914.7
13	2014	778.2	623.2	1122	645.4	1845.4	2828.9
14	2015	424.6	442.5	1028.9	1004.1	1467.2	2164.1
15	2016	343.8	460.7	709.9	601	1214.8	2221.4
16	2017	505.3	702.2	1005.8	1027.9	1478.2	2476.8
17	2018	445.1	275.3	1425.1	549.7	2037.1	2943.2
18	2019	691	510.1	1436.7	705.4	2423.3	4287.6
19	2020	725	822.1	1128.6	991.9	1905.9	3590.2
20	2021	690.7	624.9	1326.4	1287.3	2229.5	3309.2
21	2022	1000	799.5	1614.2	1247.4	2242.8	3021.3

(Source: ksndmc.org, 2023)

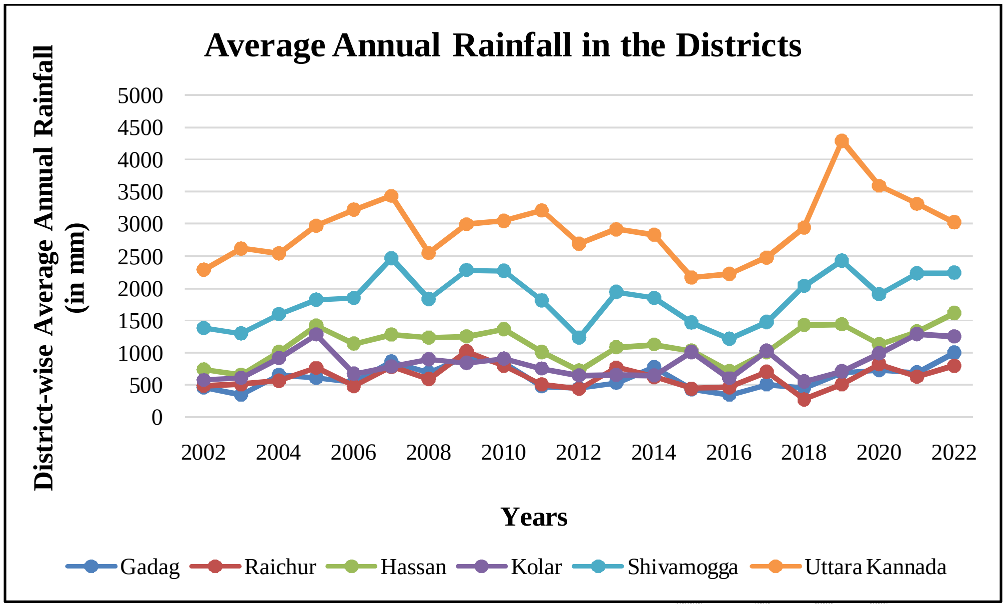

Figure 1. Mean Annual Rainfall Data for Selected Districts in Karnataka

In 2008, 2012 & 2015, there was a noticeable decrease in annual rainfall across the selected districts in Karnataka (except Kolar district) when compared to their respective annual rainfall figures in other years. Notably, Uttara Kannada district received a higher amount of rainfall compared to other districts. For instance, in 2019, Uttara Kannada district received 4287.6mm of rainfall, indicating a substantial amount. On the contrary, Raichur district received significantly less rainfall compared to other districts, with only 275.3mm of rainfall recorded in 2018 **(Table 1, Fig. 1)**. In the current study, there is not a significant difference in average annual rainfall over the two decades examined. The results indicate minimal variation in rainfall over the years within the selected district, suggesting that any discernible increase or decrease in rainfall patterns is specific to the geography of that particular region. Several prior studies examining rainfall patterns across India have asserted that there is no definitive trend indicating an increase or decrease in the average annual rainfall nationwide (Mooley & Parthasarathy, 1984, Thapliyal & Kulshrestha, 1991, Lal, 2001). Despite the absence of a discernible trend in monsoon rainfall on a national scale over an extended period, certain studies have identified localized areas experiencing noteworthy long-term changes in rainfall (Koteswaram & Alvi, 1969, Jagannathan & Parthasarathy, 1973). Raichur and Gadag regions are situated in the rain shadow region of the Western Ghats. Rain shadow areas receive less rainfall due to the obstruction of moisture-laden air by the Western Ghats, leading to drier conditions. Uttara Kannada, on the other hand, are located on the windward side of the Western Ghats similarly Shivamoga. The elevated terrain allows these regions to receive more rainfall as moist air from the Arabian Sea is forced to ascend, cool, and condense into precipitation. Therefore, the amount of rainfall is primarily influenced by geographical location, topography, and monsoon patterns. As of now, there has been no significant change in rainfall over the decade across all the districts.

Average Temperature in the Districts

In Karnataka there are more than 100 meteorological stations strategically distributed across the state to monitor weather conditions. The state experiences a wide temperature range, with summer temperatures typically spanning from 23°C to 43°C and winter temperatures ranging from 9°C to 27°C.

Table 2. Mean Annual Maximum Temperature for Selected Districts in Karnataka

Sl.No	Years	District-wise Average Max Temperature (in Degree Celsius)					
		Gadag	Raichur	Hassan	Kolar	Shivamogga	Uttara Kannada
1	2002	29.5	34.1	29.6	32.5	31.5	30.4
2	2003	32	34.4	29.4	32.4	30.9	30.2
3	2004	32.8	33.4	28.7	31.5	30.8	30.8
4	2005	32.7	33.3	29.1	31.6	31.5	31.2
5	2006	31.7	33.5	29.4	31.6	31.8	30.5
6	2007	32.2	33.5	28.6	31.4	30.1	30.4
7	2008	32.4	33.4	28	31	29.9	30.1
8	2009	33.4	33.8	28	31.8	30.7	30.7
9	2010	33.4	33.8	28.4	31.1	29.2	30.2
10	2011	31.7	34	27.3	31.2	30.1	29.9
11	2012	32.4	34.7	27.9	31.7	31.1	30.2
12	2013	32.4	33.9	27.5	31.9	30	29.9
13	2014	30.8	33.9	27.6	31.3	30.4	30.1
14	2015	31.4	32.5	30.3	31.5	31.6	32.6
15	2016	33	33.9	30.9	32.3	31.9	32.4
16	2017	32.9	33.4	30.4	31.7	31.7	32.3

17	2018	32.6	34.2	30.1	31.5	31.4	32.4
18	2019	32.4	34.3	30.4	31.9	31.8	32.3
19	2020	32	33.4	30.4	31.1	31.4	31.7
20	2021	32.2	33	29.6	30.5	30.9	31.5
21	2022	32.8	34.3	29.2	29.9	30.6	31.5

(Source: ksndmc.org, 2023)

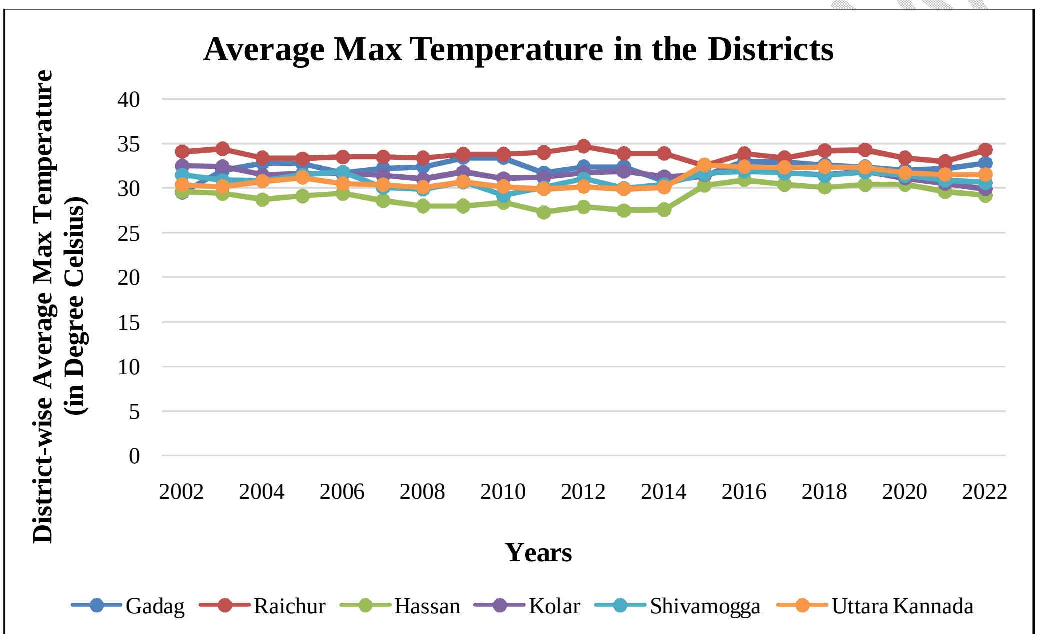

Figure 2. Mean Annual Maximum Temperature for Selected Districts in Karnataka

During 2009 and 2012, the selected districts observed varying average max temperatures in Karnataka. The highest average max temperature occurred in 2012, with a peak of 34.7 Degrees Celsius in Raichur district, while the lowest average max temperature was recorded in 2011, measuring 27.3 Degrees Celsius in Hassan district **(Table 2, Fig. 2).**

Table 3. Mean Annual Minimum Temperature for Selected Districts in Karnataka

Sl.No	Years	District-wise Average Min Temperature (in Degree Celsius)

		Gadag	**Raichur**	**Hassan**	**Kolar**	**Shivamogga**	**Uttara Kannada**
1	2002	19.5	21.8	19.1	18.2	20.3	20.8
2	2003	20.6	22.3	19.5	18.4	20	20.8
3	2004	19.6	21.3	17.7	17.3	19.6	20.6
4	2005	19.7	21.1	16	16.8	18.9	20.5
5	2006	19.7	21.4	17.4	16.1	18.9	20.5
6	2007	20	21.5	18.7	16.1	18.8	20.7
7	2008	19.8	21.5	17.8	17	18.2	20.6
8	2009	20	22	18.3	19.2	19.4	21.2
9	2010	20.6	22.1	19.4	20.3	19.9	22.1
10	2011	18.6	20.9	18.6	19.2	19.3	21.7
11	2012	18.7	21.4	18.6	17.7	19.3	21.8
12	2013	19.8	21.3	18.8	20.1	19.7	22
13	2014	19.3	21.6	18.8	19.4	20.1	22.1
14	2015	19.3	20.9	18.6	19.6	19.8	21.6
15	2016	20.6	21.5	18.5	19.8	19.6	21
16	2017	20.5	18.1	18.4	19.9	19.6	21.2
17	2018	20.8	21.7	17.9	18.8	19.2	20.9
18	2019	21.1	22.5	18.5	19	20	21.4
19	2020	21	21.8	18.9	18.8	19.9	21.3
20	2021	20.4	21.4	18.5	18.5	19.8	21.4
21	2022	20	21.5	17.8	18.6	19.4	21

(Source: ksndmc.org, 2023)

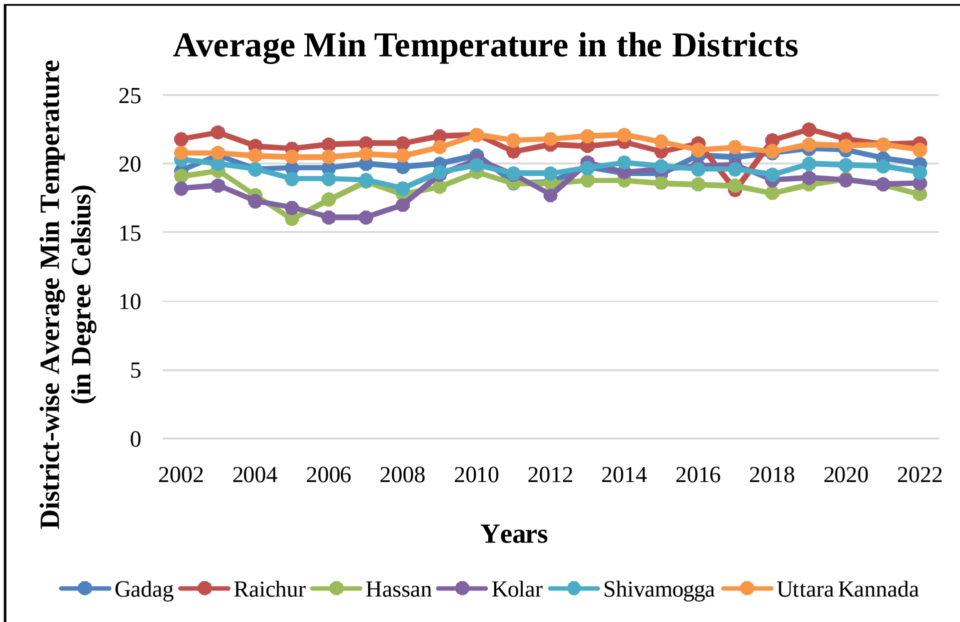

Figure 3. Mean Annual Minimum Temperature for Selected Districts in Karnataka

During 2011, the selected districts observed varying average min temperatures in Karnataka. The highest average min temperature occurred in 2019, with a peak of 22.5 Degrees Celsius in Raichur district, while the lowest average min temperature was recorded in 2005, measuring 16 Degrees Celsius in Hassan district **(Table 3, Fig. 3)**.

Raichur may be in proximity to arid or semi-arid regions, where dry air masses and limited moisture content can lead to higher temperatures. Certain seasons, such as summer, may bring intense heat to the region, influencing the overall increase in temperatures. Raichur may be in proximity to arid or semi-arid regions, where dry air masses and limited moisture content can lead to higher temperatures. Raichur district, of Karnataka falls in a plateau region and located between 15º 33'and 16º 34' N latitudes and 76º 14'and 77º 36' E longitudes. It is a drought prone region and falls within the most arid band of the country. Raichur weather remains almost dry throughout the year, a very hot summer with mean monthly maximum temperature of 46.15^{o} C in May and a minimum of 16.6^{o} C in December (Sruthi and Mohammed, 2015). Hassan district generally experiences lower temperatures compared to Raichur due to a combination of geographical and climatic factors. Located in the Malnad region of Karnataka, Hassan benefits from its higher elevation and proximity to the Western Ghats, which may contribute to a more temperate climate. The hilly terrain and abundant vegetation in the Western Ghats might influence the local weather, providing cooling effects through increased cloud cover and reduced solar radiation. Additionally, Hassan may be more influenced by the South-West monsoon, resulting in higher rainfall **(Table 1)**and lower temperatures. In contrast, Raichur, situated on the Deccan Plateau, tends to have a drier and warmer climate due to its lower elevation, flat topography, and proximity to arid regions. These geographical and climatic distinctions contribute to the temperature variations between Hassan and Raichur districts. It is predicted that regions that already witness lower rainfall and higher temperatures, such as northern Karnataka, will experience even lower rainfall and increases in average temperatures (Kamal et. al 2018).

Average Relative Humidity in the Districts

Table 4. Mean Annual Maximum Temperature for Selected Districts in Karnataka

Sl.No	Years	District-wise Average Max Relative Humidity (%)					
		Gadag	Raichur	Hassan	Kolar	Shivamogga	Uttara Kannada
1	2002	84.1	78.4	87	73.9	90.9	92.9
2	2003	82.1	80.8	88	76.6	90.2	92.8
3	2004	78.1	80.6	87.1	70.8	90.7	91.5
4	2005	78.5	79.9	88.5	76.8	90.4	91.4
5	2006	76.4	79.7	87.9	75.9	92	92.8
6	2007	78.2	82	89.4	75.7	90.3	92.6
7	2008	79	81.9	90.4	75.6	90.6	92.5
8	2009	79.3	81	88.5	73.2	91.3	92.6
9	2010	84.3	82.9	89.9	68.8	90.7	92.1
10	2011	80.9	83.2	89.8	61.8	90.3	91.1
11	2012	79.8	82.7	89.1	79.3	90.7	91.7
12	2013	82	81	89.1	87.3	91	91.5
13	2014	78.6	82.2	90.2	83.7	91	92.5
14	2015	92.7	92.1	99.5	98.3	99.4	99.3

15	2016	90	92	99.4	97.8	99.4	99.3
16	2017	92.9	92.1	99.6	98	98.9	99.4
17	2018	93.8	94.6	99.2	98.7	99.1	99.1
18	2019	95.2	94	99.6	98.8	99.7	99.5
19	2020	97	98	99.7	99.6	99.7	99.7
20	2021	95.7	96	99.7	98	99.4	99.7
21	2022	96.6	97.3	99.1	94.9	97.2	99.2

(Source: ksndmc.org, 2023)

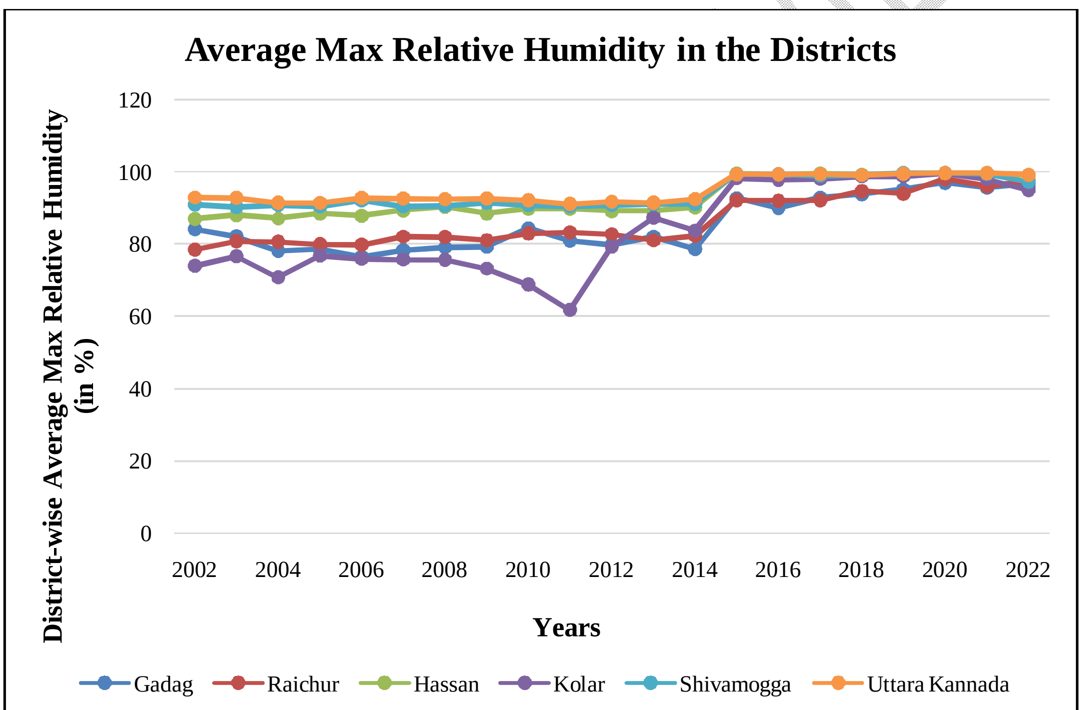

Figure 4. Mean Annual Maximum Temperature for Selected Districts in Karnataka

The Karnataka state has a dynamic and erratic weather that changes from place to place within its territory. Due to its varying geographic and physio-graphic conditions, Karnataka experiences climatic variations that range from arid to semi-arid in the plateau region, sub-humid to humid tropical in the Western Ghats and humid tropical monsoon in the coastal plains.

During 2015, the selected districts observed varying average max relative humidity in Karnataka. The highest average max relative humidityoccurred in 2019 and 2020, with a peak of 99.7% in Shivamogga and also in 2020 and 2021, with a peak of 99.7% in Hassan and Uttara Kannada district, while the lowest average max relative humiditywas recorded in 2011, measuring 61.8% in Kolar district **(Table 4, Fig. 4)**.

Average Min Relative Humidity in the Districts

Table 5. Mean Annual Minimum Temperature for Selected Districts in Karnataka

Sl.No	Years	District-wise Average MinRelative Humidity (in %)					
		Gadag	Raichur	Hassan	Kolar	Shivamogga	Uttara Kannada
1	2002	50.1	38.5	54.4	47.4	54	63.6
2	2003	47.6	39.2	49.6	46.3	55.3	64.7
3	2004	47.1	39.8	57.1	49.7	56.4	65.8
4	2005	47.1	39	53.9	55.9	55	64.6
5	2006	45.5	37.8	49.8	49.7	52	66.6
6	2007	43.6	39.6	50.2	49.3	55.4	69.1
7	2008	43.5	41.4	53.9	49.1	50.4	65.9
8	2009	41.7	40.3	55.5	53.3	54.5	66.6
9	2010	47.2	42.2	54.8	77.1	57.8	68.6
10	2011	48.7	43	49	69.6	54.5	65.9
11	2012	42.4	37.6	46.7	61.6	51.8	62.3
12	2013	45.5	40.4	46	52.6	50.3	63
13	2014	46.5	41.9	55.1	47.9	52.9	63.7
14	2015	30.5	24.8	34.4	30.3	36.2	34.3
15	2016	30.2	28.7	33	28.9	33.6	31.9

16	2017	35.3	23.7	35.6	33.9	38.5	38.9
17	2018	27.2	24.8	36.7	33.1	38	41.8
18	2019	31.1	29	40.7	35.8	42.9	41.4
19	2020	36.4	37.1	42.8	40.8	45.9	47
20	2021	43.3	37.7	46.5	47	49.1	46.8
21	2022	45.2	37.7	44.7	49.1	49.7	50.8

(Source: ksndmc.org, 2023)

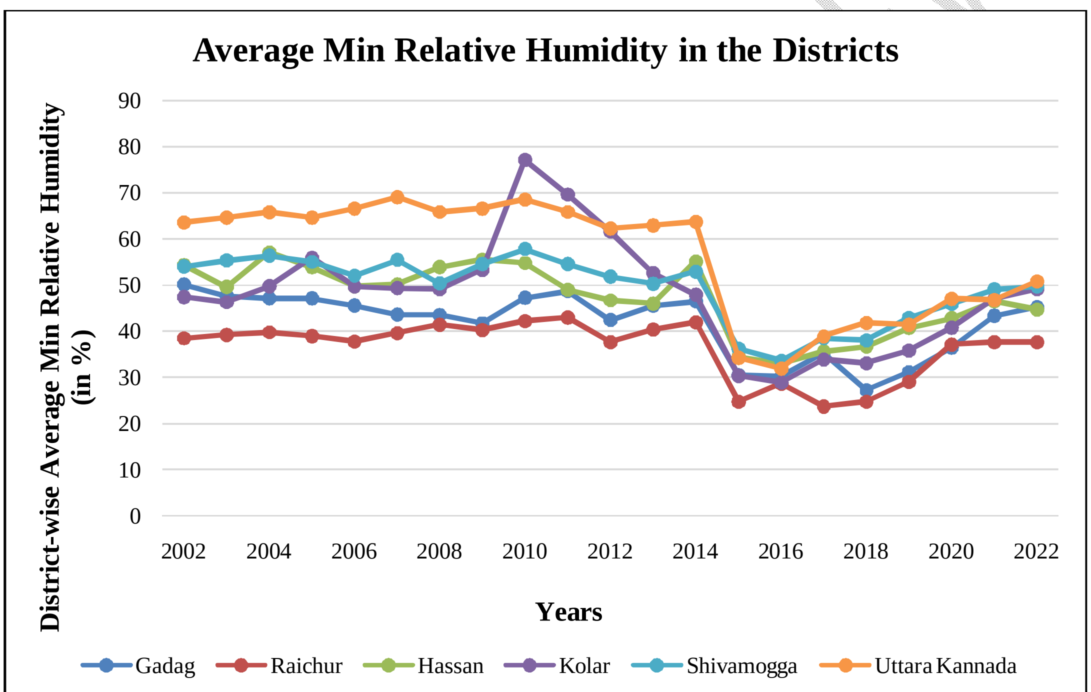

Figure 5. Mean Annual Minimum Temperature for Selected Districts in Karnataka

During 2015, the selected districts observed varying average min relative humidity in Karnataka. The highest average min relative humidity occurred in 2010, with a peak of 77.1%in Kolar district, while the lowest average min relative humiditywas recorded in 2017, measuring 23.7% in Raichur district **(Table 5, Fig. 5)**.

The variation in relative humidity among the different districts of Karnataka can be attributed to several factors. Karnataka, encompassing areas like Shivamogga, Hassan and Uttara Karnataka experiences higher relative humidity may be to its proximity to the Western Ghats. The Western Ghats intercept moist air from the Arabian Sea, leading to orographic rainfall on the windward side, cooling and condensing the air, resulting in increased humidity. In contrast, North Karnataka regions, being more inland and away from direct Western Ghats influence, tends to have a more arid or semi-arid climate. The inland movement of air from the coast causes a loss of moisture content, leading to lower relative humidity levels. Additionally, the topography, land use patterns, and the presence of water bodies may contribute to higher humidity in uttara Karnataka and Hassan regions. These regional differences underscore the complex interplay of geographical features and weather patterns shaping the humidity levels in these two regions.Relative Humidity is a function of air temperature. Higher the temperature more is the amount of water vapour that can be hold by the atmosphere, however the relative humidity decreases with increasing temperature due to increasing saturation point. The extent of evaporation and transpiration depend on the amount of moisture present in the atmosphere. The extreme temperatures observed in Raichur, as indicated in Table 2, serve as evidence of decreased relative humidity compared to other districts. Raichur, located in North Karnataka, experiences higher temperatures, and the arid or semi-arid climate of the region contributes to lower relative humidity levels. The inland nature of North Karnataka, along with its distance from the Western Ghats, diminishes the influence of moist air masses, leading to reduced humidity. The temperature extremes in Raichur may be a consequence of these climatic conditions, emphasizing the inverse relationship between temperature and relative humidity in the region. This observation aligns with the broader patterns seen in the geographical and climatic distinctions between Shivamogga and North Karnataka.

Drought Affect in the Districts

Table 6. Drought Impact in Six Karnataka Districts

Sl.No	Years	District-wise Drought Affect					
		Gadag	**Raichur**	**Hassan**	**Kolar**	**Shivamogga**	**Uttara Kannada**
1	2002	Yes	Yes	Yes	Yes	Yes	Moderate
2	2003	Yes	Yes	Yes	Yes	Yes	Moderate
3	2004	Yes	Yes	Moderate	Nil	Nil	Nil
4	2005	Nil	Nil	Nil	Nil	Nil	Nil
5	2006	Yes	Yes	Moderate	Yes	Nil	Nil
6	2007	Nil	Nil	Nil	Nil	Nil	Nil
7	2008	Yes	Yes	Moderate	Nil	Nil	Nil

8	2009	Moderate	Yes	Nil	Yes	Nil	Nil
9	2010	Nil	Nil	Nil	Nil	Nil	Nil
10	2011	Yes	Yes	Yes	Yes	Nil	Nil
11	2012	Yes	Yes	Yes	Yes	Yes	Moderate
12	2013	Yes	Yes	Yes	Yes	Nil	Moderate
13	2014	Nil	Nil	Nil	Yes	Nil	Nil
14	2015	Yes	Yes	Yes	Yes	Nil	Yes
15	2016	Yes	Yes	Yes	Yes	Yes	Yes
16	2017	Nil	Nil	Nil	Nil	Nil	Nil
17	2018	Yes	Yes	Yes	Yes	Moderate	Moderate
18	2019	Nil	Nil	Nil	Nil	Nil	Nil
19	2020	Nil	Nil	Nil	Nil	Nil	Nil
20	2021	Nil	Nil	Nil	Nil	Nil	Nil
21	2022	Nil	Nil	Nil	Nil	Nil	Nil

The table chronicles the occurrence and severity of drought in six districts of Karnataka—Gadag, Raichur, Hassan, Kolar, Shivamogga, and Uttara Kannada—from 2002 to 2022. Years marked with "Yes" indicate the presence of drought, while "Moderate" signifies a moderate level of impact. Nil entries denote the absence of drought. The data offers a clear temporal perspective on the patterns of drought, facilitating an understanding of its fluctuations across these districts over the specified timeframe. In recent years, all districts in Karnataka have consistently shown nil occurrences of drought, reflecting a positive trend in climatic conditions. This sustained absence of drought indicates a period of relative stability and favorable conditions across the entire region. The years 2002 and 2003 witnessed widespread drought across all districts, a trend that reemerged notably in 2012, 2013, 2015, and 2016, as clearly indicated in the provided **Table 6.** Approximately 80% of Karnataka's geographical area is identified as drought-prone (Reddy and Prabhu in 2016). The uneven distribution of rainfall, particularly during the initial stages of the monsoon season in June and July, has been a recurring phenomenon in the state, notably during drought events in 2009, 2012, 2014, and 2015, as documented by (Vyas and Bhattacharya 2020). Rainfall deficits of 27%, 49%, and 20–50% were observed in June for the years 2009, 2012, and 2014, respectively (Pai and Bhan 2015). This climatic variability has had significant socio-economic repercussions, forcing approximately 80% of the total population to abandon agricultural activities and seek employment as laborers, both within and outside villages, as well as at relief sites during the drought impact period from 2002 to 2003.

Reference

JAGANNATHAN , P. AND PARTHASARATHY , B. 1973 . Trends and periodicities of rainfall over India . Monthly Weather Rev , 101 : 371 – 375.

KAMAL, K. M, SANDEEP, M. JAYARAMAN, T. AND MADHURA S. 2018. Extreme temperatures and crop yields in Karnataka, India. *Review of Agrarian Studies*. 8 : 2.

Karnataka State Action Plan On Climate Change (KSAPCC), (2021). Draft report, Environmental Management And Policy Research Institute (EMPRI).

KOTESWARAM , P. AND ALVI , S. M. A. 1969 . Secular trends and periodicities in rainfall at west coast stations in India . *Current Sci.* , 38 : 229 – 231

KUMUDHA, H. R. AND KOKILA RAMESH., (2023). Forecasting of Karnataka Seasons Rainfall Data Using ANN Approach, *Journal of Survey in Fisheries Sciences*, 10**(1)**: 3431-3448

LAL , M. 2001 . Climatic change – implications for India's water resources . *J. Ind. Water Resour. Soc.* , 21 : 101 – 119.

MENDELSOHN R. AND DINAR A., (1999). Climate change, agriculture, and developing countries: does adaptation matter? The World Bank Research Observer 14: 277-293.

MOOLEY , D. A. AND PARTHASARTHY , B. 1984 . Fluctuations of all India summer monsoon rainfall during 1871–1978 . *Climatic Change* , 6 : 287 – 301.

PAI, D.S. AND BHAN, S.C. 2015. Monsoon 2014: A Report. IMD Met. Monograph: ESSO Document No.: ESSO/IMD/SYNOPTIC MET/01 (2015)/17

RAJEGOWDA M. B, JANARDHAN N. A, PRABHAKAR SHETTY T. K AND USHAKIRAN., (2009). Jagathika tapamana mattu havamana vyparita: Krushia melee biruva parinamagalu. Krushi Jnana Bhandara-32 (Kannada). UAS, Bangalore Publication.

REDDY, G AND PRABHU, C.N. 2016. Natural Disaster Monitoring System – Karnataka Model, pp. 178–187.

REJINI SIMPSON, KAVYA R, CHITRA P, HEMA NAGARAJ AND RAMESH M.K., (2023). Evolving a Monitoring Framework for the KSAPCC Implementation in Water and Agriculture Sectors, *Hanns-Seidel-Stiftung India © Centre for Environment Education (CEE).*, Working Paper.

SRUTHI, S. AND MOHAMMED ASLAM. 2015. Agricultural Drought Analysis Using the NDVI and Land Surface Temperature Data; a Case Study of Raichur District. *Aquatic Procedia* 4**:** 1258 – 1264.

THAPLIYAL , V. AND KULSHRESHTHA , S. M. 1991 . Climate changes and trends over India . *Mausam* , 42 : 333 – 338.