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Spatio-temporal variation of climatic parameters across the Northern dry zone of Karnataka

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Abstract
Climate change has been the biggest global threat of the 21st century. As Earth's climate continues to warm, extreme temperatures, floods, droughts, and heat waves are expected to become more intense. The Northern Dry Zone (NDZ) of Karnataka was purposively selected for the study because of its largest area (i.e., 4.81 m.ha.) and was found affected by changing climate, especially droughts. Data on climatic parameters like Precipitation (PCPN), Maximum Temperature (TMAX), Minimum Temperature (TMIN) and Relative Humidity (RH), were collected from NASA power from the year 1981-2021 for 35 NDZ taluks. Belagavi Dry Zone taluks received the highest PCPN (i.e., 676.96 mm) whereas Koppal Dry Zone taluks received the lowest (521.26 °C) and highest (35.80 °C) PCPN and annual mean TMAX respectively. Harappanahalli taluk received the lowest annual mean (34.65 °C) and highest RH (62.05%). Dharwad and Raichur Dry Zone taluks had the lowest 16.99 °C and highest 17.80 °C annual mean TMIN Vijayapura Dry Zone taluks had lowest annual mean RH. The highest variability was observed in PCPN (29.64%) compared to other climatic parameters. The TMIN parameter's CAGR value was found to be significant.

Keywords: NDZ, PCPN, RH, TMAX, TMIN, CAGR

Introduction
The global mean surface temperature has increased 2 °F since the pre-industrial era (1880-1900). Earth's temperature has risen by 0.14° F (0.08 °C) per decade since 1880, and the rate of warming over the past 40 years is more than twice i.e., 0.32° F (0.18 °C) per decade since 1981 (Hansen *et al*., 2013, Hansen *et al*., 2017) [10-11]. World Health Organisation (2021) estimated that globally, 55 million people were affected by droughts every year. Drought threatens people's livelihoods, livestock, and farming increase the risk of disease and death, and fuels mass migration. Water scarcity impacts 40 percent of the world's population, and by 2030, 700 million people are at risk of migration. In the Horn Africa region, severe droughts in the years 2011, 2017, and 2019 have wiped out crops and livestock. Droughts have left 15 million people in Ethiopia, Kenya, and Somalia in need of aid and 10.7 million people died of hunger. People have been left without the means to put food on their table, and have been forced from their homes (Haile, 2019) [9]. Australian bushfires of 2020 have burned more than 19 m.ha. of land and killed at least 33 people, took homes of 3,000 families, and left millions of people affected by hazardous smoke. More than a billion native animals, species, and ecosystems were destroyed (Filkov *et al.*, 2020) [8]. The accelerating pace of climate change, combined with an increase in global population and income is threatening food security globally (Matiu *et al.*, 2017, Ray *et al.*, 2015) [14, 19].
India is the third-largest emitter of greenhouse gases after China and the United States and agriculture sector adds up to 18 percent of total national emissions. About 80 percent of this could be reduced just by adopting cost and input saving measures, i.e., efficient use of fertilizers, zero-tillage, and water management (Sapkota *et al*., 2019) [20]. India experienced severe impacts of climate change. The rise in temperatures has led to droughts for longer periods and then a sudden bout of excessive rainfall, causing extreme weather events, particularly floods which took lives, destroyed homes, and agricultural yields as well as resulted in huge revenue losses. More than 75 percent of Indian districts, populated with 638 million are under hotspots of extreme climate events. Between 1970 and 2019, there were 560 extreme events were recorded including heat waves and cold waves. The year 2005 recorded the highest flood frequency, with 140 floods affecting 69 districts, exposing 97.51 million people annually. The frequency of associated flood events such as landslides, heavy rainfall, hailstorms, thunderstorms, and cloudbursts surged by over 20 times between 1970 and 2019.

In the last 15 years from 2019, 79 districts recorded extreme drought events year-on-year, exposing 140.06 million people annually. The number of associated cyclonic events increased 12-fold between 1970 and 2019. The pattern of extreme events such as flood-prone areas becoming drought-prone and vice-versa has changed in over 40 percent of Indian districts. Districts that experienced a shifting trend from floods to droughts were higher than from droughts to floods. This results from microclimatic changes across the Indian subcontinent triggered by local climate change drivers such as land-use-surface change, deforestation, encroachments upon mangroves, and wetlands (Mohanty, 2020) [15]. India is predominantly an agrarian country with 68.84 percent of its population living in rural areas according to the population census of 2011. This means an impact on the lives and livelihoods of millions of Indians. For instance, it is reported that about 107 m.ha in the country is drought-prone and around 40 m.ha is flood-prone. Times series analysis of rainfall data of India from 1871 to 2015 has revealed that monsoon rainfall has shown a declining trend (Jain *et al*., 2013) [12]. Indian Council of Agricultural Research (ICAR) in association with NICRA conducted research on vulnerability assessment of Indian Agriculture to climate change, the study says 109 districts out of 573 rural districts (19% of total districts) are 'very high-risk' districts, while 201 districts are under moderate risk districts (Rama Rao *et al.*, 2019) [18].

The occurrence of droughts in Karnataka state is a common phenomenon, due to spatial and temporal variation in rainfall which ranges from 4747 mm in the coastal region, followed by the *Malnad* (highland) region with 3500 mm to as low as 477 mm in South Interior Karnataka. There is both temporal and spatial variability within the region (Chandrashekhar and Venugopal, 1995) [7]. A warming trend in Karnataka has been observed by the study from the period June to September months both minimum (0.3 - 0.65 °C) and maximum temperature (0.18 - 0.61 °C) were found to have risen over the last 100 years. The mean increase in rainfall in central and northern districts is up to 15 percent whereas in western Ghats districts 20-25 percent. In the Kharif season, the rainfall variability is more than 20 percent in almost all the districts whereas in rabi season variability is up to 50 percent in 85 percent of districts (CSTEP, 2020) [4]. A study by Rajegowda *et al.* (2009) [17] reports that the state's mean annual rainfall has sixteen years of cyclic periodicity with decreasing trend from 1204 mm to 1140 mm in the second half of the century (1951-2000). Few districts like Bengaluru, Kolar, and Tumkur are gaining in their mean annual rainfall and while heavy rainfall receiving districts like Kodagu, Chikmagalur and South Canara are losing in their mean annual rainfall. Net annual emissions of major greenhouse gases of the Karnataka State were estimated to be 4.98 percent of India's emissions. In this, carbon dioxide accounts for 73 percent, methane for 23 percent, and nitrous oxide for 3.3 percent. The annual percentage of sectors contributing to greenhouse gases was electricity generation (35.90%), industry (22.6%), agriculture and allied sectors (20.2%), transportation (10.4%), households excluding electricity (7.3%), and waste for (3.90%) (GHG platform, 2013). Karnataka is one of the water scare states of the country only 28 percent of agricultural land is under irrigation whereas 72 percent is rainfed. In the Agriculture sector, a net decline of 2.5 percent in agricultural production has been projected over the next two to five decades with a major reduction in coastal regions (GoK, 2012) [1].

Material and Methods

Karnataka State is divided into four regions namely South Interior Karnataka, North Interior Karnataka, *Malnad*, and Coastal Karnataka. In 1960's, these were further divided into ten Agro-Climatic Zones by UAS, Bengaluru under the NARP program based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern, and other physical and social characteristics. Among these Agro-Climatic zones (Fig 1) there are five dry zones with relatively low rainfall and high erratic distribution. The five dry zones cover the major area with 107 taluks while the three transitional zones cover 35 taluks in the state. The Hill and Coastal zones cover 21 and 13 taluks respectively. Among these zones, the Northern Dry Zone was purposively selected for the study because it is mainly affected by changing climate and the drought vulnerability was 81 percent which comes under a very high vulnerable class according to the report published by Karnataka State Natural Disaster Monitoring Centre (KSNDMC, 2017). It also has the largest area of 4.78 m.ha and comprises 35 taluks. To fulfill the objective of the study, Talukwise spatial and temporal data of climatic parameters of the Northern Dry Zone was collected from the NASA power website from the year 1981-2021 i.e., 40 years via a web interface (https://power.larc.nasa.gov/data-access-viewer/) at a grid resolution with a spatial resolution of one-half arc degree longitude by one-half arc degree latitude. By entering the latitude and longitude of the area (Table 1), we can download the data. Further, The taluk-wise data was assembled in the form of district dry taluk/s both spatially and temporally. Averages, Coefficient of variation, and Compound Annual Growth Rate (CAGR) with p values was calculated for the understanding of spatial and temporal data.

a) Coefficient of Variation (CV)

The coefficient of variation shows the extent of variability in the data about the average

$$CV = \frac{\bar{X}}{\sigma}$$

where, σ =standard deviation, $\bar{x}$ = sample mean (X)

b) Compound Annual Growth Rate (CAGR): The exponential compound annual growth rates were estimated by using log-linear functions on the time series data. That is, the growth rate is estimated by using the following semi-log functional form:

logYt = a + bt (1)

This equation (1) can be elaborated in detail as:

Yt= Yo (1+r) t (2)

Taking log on both sides, we get Log Yt = Log Yo + t Log (1+r) (3)

Equation (ii) can be rewritten as

Y = a + bt (4)

Where Y= Log Yt; a = Log Yo; b= Log (1+r), In equation (iii) Yt= time series variable

a= constant
t= Time variable in year (1, 2, 3……….n)
b= Regression Coefficient that shows the rate of change or growth rates in a series

The annual compound growth rate (s) can be worked out by using:
Antilog (b) =Antilog (log (1+r)).
Antilog (b) =1+r and r = Antilog b-1

When multiplied by 100, it gives the percentage growth rate of that time series variable.

That is, Compound Annual Growth Rate (CAGR) (%) = r = (Antilog B-1) x100.

By applying Regression, we get the p-value to check the significance of the CAGR value.

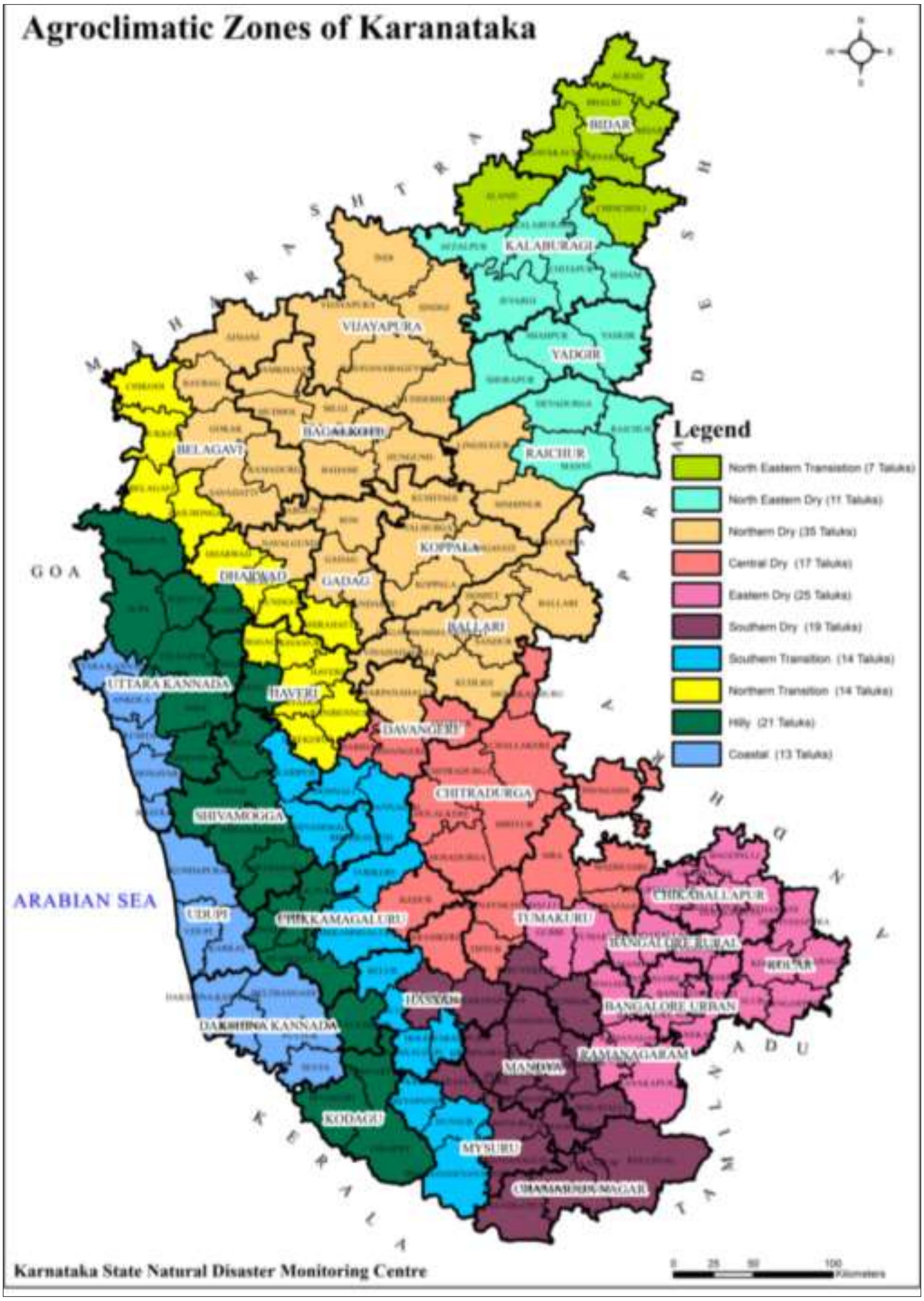

Fig 1: Agroclimatic Zones of Karnataka

Table 1: Latitude and longitudes of taluks of Northern Dry Zone

District	Dry zone taluk	Latitude	Longitude
Bagalkot	Badami	15.9186	75.6761
	Bagalkote	16.1691	75.6615
	Bilgi	16.3402	75.6295
	Hunagund	16.0576	76.0609
	Jamakhandi	16.5043	75.2918
	Mudhol	16.3333	75.2858
Belgavi	Athani	16.7261	75.0611
	Gokak	16.1592	74.8156
	Raibag	16.4941	74.7747
	Ramdurg	15.9500	75.2975
	Soundatti	15.7522	75.1253
Ballari	Bellary	15.1446	76.9173
	Hadalgi	15.0200	75.9318
	Hagaribomanahalli	15.0456	76.2074
	Harapanahalli	14.7810	75.9870
	Hospete	15.2689	76.3909
	Kudligi	14.9054	76.3898
	Sandur	15.0874	76.5477
	Siruguppa	15.6175	76.9006
Dharwad	Navalgund	15.5605	75.3556
Gadag	Gadag	15.4167	75.6167
	Mundargi	15.2055	75.8853
	Naragund	15.7214	75.3849
	Ron	15.6996	75.7330
Koppal	Kopala	15.3505	76.1567
	Kushtagi	15.7519	76.1929
	Yelaburga	15.6142	76.0131
	Gangavati	15.4319	76.5281
Raichur	Lingasugur	16.1550	76.5199
	Sindhanur	15.7702	76.756
Vijayapura	Bagewadi	16.5681	75.9754
	Bijapur	16.8302	75.7100
	Indi	17.1752	75.9555
	Muddebihal	16.3396	76.1291
	Sindhagi	16.9173	76.2334

Source: District website

4. Results and Discussions

The taluk level data was assembled in the form of district Dry Zone taluk/s both spatially and temporally. Annual mean spatial variation of climatic parameters of the NDZ from the year 1981-2021 was analysed and shown in table 2. Belagavi Dry Zone taluks received the highest PCPN (i.e., 676.96 mm) whereas Koppal Dry Zone taluks received the lowest (521.26 °C) and highest (35.80 °C) PCPN and annual mean TMAX respectively. Harappanahalli taluk received the lowest annual mean TMAX (34.65 °C) and highest RH (62.05%). Dharwad and Raichur Dry Zone taluks had the lowest 16.99 °C and highest 17.80 °C annual mean TMIN. Vijayapura Dry Zone taluks had lowest annual mean RH (55.00%).

The annual mean temporal variation of climatic parameters from the year 1981-2021 of the Northern Dry Zone was shown in table 3. Annual mean PCPN was 575.34 mm with Coefficient of Variation (CV) of 29.64 percent. The highest and lowest annual PCPN was received in the year 2020 (976.63 mm) and 2003 (321.97 mm) respectively. The annual mean TMAX was 35.59 °C with CV of 2.57 percent. The highest and lowest annual mean TMAX was recorded in 2003 (36.92 °C) and 2020 (34.38 °C) respectively. The annual mean TMIN was 17.27 °C with a CAGR of 0.10 percent with one percent level of significance and a CV of 3.43 percent. This means that there was increase in TMIN at the rate of 0.10 percent over the years from1981-2021. The highest and lowest annual mean TMIN was observed in the year 2019 (18.05 °C) and 1981 (19.81 °C) respectively. The annual mean RH in NDZ was 59.07 percent with aa CV of 6.52 percent. The annual mean highest and lowest RH was recorded in the year 2020 (66.17%) and 2018 (54.47%) respectively. However, highest mean variability was observed in PCPN compared to other climatic parameters. This variation in precipitation was observed in Karnataka as well as whole of India is due to irregularity of rainfall which was greatly influenced by deforestation, which has led to drying up of perennial rivers and lakes. Similar results were obtained by Kuttippurah *et al.* (2021) [13] due to the reduction in vegetation cover and human influence on climate, there is a decrease in annual rainfall and increase in temperature. PCPN, TMAX and RH’s CAGR was found non-significant. Here we can observe that, the year 2003 had the lowest PCPN and the highest annual mean TMAX whereas the year 2020 received the highest PCPN and RH with lowest annual mean TMAX.

Thus, there was Spatial and Temporal variation of climatic parameters in the district dry taluks of the Northern Dry Zone from the year 1981-2021. These results were in line with the results obtained by Mondal *et al.* (2015) [16] where they noticed wide variation of minimum temperature and variation of rainfall and temperature at different spatial scales of sub-divisions and regions of India. The climatic variation is not only in the Zone but the country and the world due to global warming and deforestation, which has led to irregular distribution of rainfall and increase in temperature. The signs of Global warming are everywhere and are more complex

Table 2: Annual mean spatial variation of climatic parameters of the taluk/s of Northern Dry Zone (1981-2021)

S. No.	District	Dry Zone taluk/s	Annual PCPN (mm)	TMAX (°C)	TMIN (°C)	RH (%)
1	Bagalakote	Badami, Bagalkote, Bilgi, Hunagund, Jamakhandi, Mudhol	539.70	35.79	17.07	57.84
2	Ballari	Bellary, Hadalgi Hagaribomanahalli, Hospete, Kudligi, Sandur, Siruguppa	560.66	35.31	17.67	60.77
3	Belagavi	Athani, Gokak, Raibag, Ramdurg, Soundatti	676.96	35.05	16.67	60.69
4	Davanagere	Harapanahalli	549.89	34.65	17.55	62.05
5	Dharwad	Navalgund	589.19	35.12	16.99	60.87
6	Gadag	Gadag, Mundargi, Naragund, Ron	619.27	35.03	17.04	61.54
7	Koppal	Kopala, Kushtagi, Yelaburga, Gangavati	521.26	35.80	17.49	58.57
8	Raichur	Lingasugur, Sindhanur	531.84	36.46	17.80	56.73
9	Vijayapura	Bagewadi,Bijapur, Indi, Muddebihal, Sindhagi	564.87	36.50	17.34	55.00

Source: NASA power (1981-2021)

Table 3: Annual mean temporal variation of climatic parameters of the taluk/s of Northern Dry Zone (1981-2021)

S. No.	Particulars	PCPN (mm)	TMAX (°C)	TMIN (°C)	RH (%)
1	Mean	575.34	35.59	17.27	59.07
2	SD	170.52	0.91	0.59	3.85
3	CV	29.64	2.57	3.43	6.52
4	Highest	976.63 (2020)	36.92 (2003)	18.05 (2019)	66.17 (2020)
5	Lowest	321.97 (2003)	34.38 (2020)	16.38 (19.81)	54.47 (2018)
6	CAGR	0.26	-0.01	0.10***	0.07

Source: NASA power (1981-2021), ***, ** and * means significant at the one percent level respectively.

Notes: figures in parenthesis indicate event that took place in that year than just increasing temperatures. Irregular rainfall, floods, droughts and increasing temperatures etc. The hottest years recorded globally in descending order were 2016, 2019, 2015, 2017, 2018, 2014, 2010, 2013, 2005 and 2009 (climate central, 2020).

5. Conclusions

In NDZ, it was observed that the annual PCPN ranged between 321.97 – 976.63 mm. Annual mean TMAX ranged between 34.38-36.92 °C. Annual mean TMIN ranged between 16.38 -18.05 °C whereas Annual mean RH ranged between 54.47- 66.17 percent. This shows the wide variation in the ranges of climatic parameters. Example, Belagavi and Gadag dry taluks received annual mean precipitation of 676.96 mm and 619.27 mm respectively (Table 2) which is higher than the overall mean. It was found that a significant increase in mean TMIN at a rate of 0.10 percent over the years in the zone (Table 3). Agro-Climatic Zones were classified based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern, and other physical and social characteristics by UAS, Bengaluru under the NARP program in 1960's. Thus, having a fair degree of accuracy that overall climate is changing. This change in climate may be reflected in agro-climatic zones and ultimately affect the criteria of their classification based on parameters. Therefore, reconsideration of classification of agroclimatic zones in Karnataka under the scenario of observed climate change must be given a thought.

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