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RESEARCH PAPER

Annual and seasonal rainfall variability at taluk level for Belagavi district in Karnataka

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Abstract: Rainfall variability strongly influences agriculture and water management in semi-arid regions. This study analyzed the spatial and seasonal rainfall patterns across 15 taluks of Belagavi district in Karnataka using 30 years daily gridded data from the India Meteorological Department for the period 1995 to 2024. Results highlight pronounced disparities across taluks. Winter rainfall was highly negligible, ranging from 2.0 mm for Raibag to 4.8 mm for Savadatti, with very high variability exceeding 150% and peaking at 277.9% for Savadatti. Summer rainfall, though modest, was agriculturally significant, varying between 65.1 mm for Gokak and 136.9 mm for Kitthuru taluk with a variability ranging from 53.1% for Kitthuru to 91.5% for Yaragatti taluk, reflecting highly localized thunderstorms events. To the annual total rainfall 60 to 70% is contributed during monsoon as Kitturu taluk received the highest of 660.8 mm, while Khanapur and Belagavi taluks 613 mm, whereas Athani and Raibag taluks received <350 mm. Variability was the lowest for Athani at 28.3% and the highest for Hukkeri at 51.8%. Post-monsoon rainfall ranged from 137.0 mm for Gokak to 164.6 mm for Kitturu with more moderate variability between 42.4 and 63.8%. Annual rainfall totals varied nearly two-fold, from 526.8 mm for Gokak to 966.6 mm for Kitthuru, with variability ranging from 24.4% for Athani to 41.5% for Hukkeri. These findings emphasize the need for location-specific water management and climate-resilient agriculture practices in Belagavi district.

Key words: Monsoon dynamics, Rainfall, Seasonal distribution, Variability

Introduction

Rainfall is the most critical climatic factor influencing agricultural productivity, water availability, and livelihood security in semi-arid regions of India. The spatial and temporal variability of rainfall has direct implications for crop planning, irrigation scheduling and drought risk management (Gadgil, 2003; Kumar and Gautam, 2014). Karnataka, being largely dependent on the southwest and northeast monsoons, experiences considerable variability in rainfall across its agro-climatic zones, making the region vulnerable to both droughts and floods (Rathore *et al*., 2013; Gadgil and Rupa Kumar, 2006).

Belagavi district, situated in the northern part of Karnataka, represents a transitional zone where rainfall distribution exhibits marked heterogeneity between taluks. The district receives rainfall from both the southwest and northeast monsoons, along with contributions from pre-monsoon and post-monsoon showers. Such variability plays a crucial role in stabilizing agricultural systems, particularly in rainfed areas where crop performance depends heavily on the amount, onset and distribution of seasonal rainfall (Mall *et al*., 2006).

Recent studies across peninsular India have shown declining trends in moderate rainfall and a simultaneous rise in extreme rainfall events, leading to greater uncertainty in rainfall distribution and agricultural sustainability (Malik *et al*., 2016). At the district level, however, systematic analyses of spatial rainfall variability are limited, despite their significance in providing insights for water resource planning, climate adaptation strategies, and contingency crop planning.

Given this context, the present study focuses on the spatial analysis of rainfall variability across Belagavi district. By examining long-term seasonal and annual rainfall records at the taluk scale, the study aims to provide a comprehensive understanding of intra-district rainfall patterns and their implications for agriculture and resource management.

Material and methods

Study area

Fig. 1 depicts the location of Belagavi district, situated in the northwestern part of Karnataka state, India, between approximately 15°N and 17°N latitude and 74°E and 75°E longitude. The district covers an area of about 13,430 sq km, making it the largest district in Karnataka. Belagavi shares its borders with the states of Goa and Maharashtra and exhibits varied topography, ranging from plains in the east to hills in the western region, which are covered with dense forests. The district has a hot semi-arid to sub-humid climate, receiving annual rainfall between 500 and 1100 mm, with the majority occurring during the monsoon season (June–September). The Belagavi district comprises 15 taluks, namely Athani, Bailhongal, Belagavi, Chikkodi, Gokak, Hukkeri, Kagwad, Khanapur, Kitthuru, Mudalgi, Raibag, Ramadurg, Saundatti and Yaragatti, supporting diverse agricultural activities and forest resources.

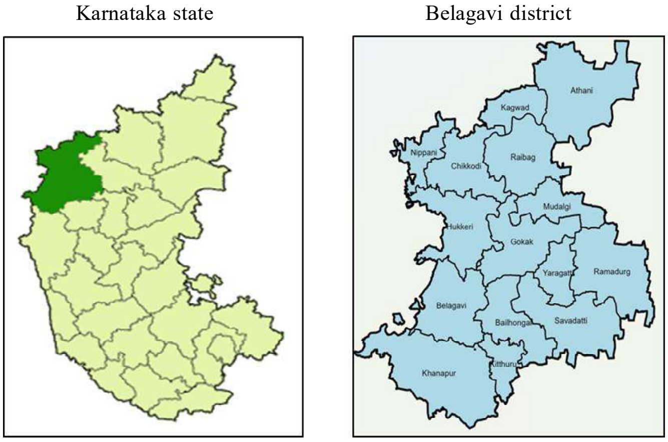

Fig1. Location map of the study area

The required rainfall data for this study with a spatial resolution of 0.25° × 0.25° were collected from the India Meteorological Department (IMD), Pune, for all the 15 taluks of Belagavi district for the period from 1995 to 2024(30 years). The mean value from all grid points within each taluk was used to calculate the daily rainfall of the district. The daily rainfall data were summed to obtain annual rainfall, which was further classified into four seasons: rainfall during January to February as winter season rainfall, March to May as pre-monsoon season rainfall, June to September as monsoon season rainfall, and October to December as post monsoon season rainfall. The annual and seasonal rainfall data were analyzed statistically, and parameters such as mean, standard deviation, and coefficient of variation were computed to examine the Spatio-temporal variability of rainfall across Belagavi district.

Results and discussion

The rainfall climatology of Belagavi district for 1995–2024 reveals significant spatial and seasonal variations shaped by its geographical position between the orographic barrier of the Western Ghats and the rain-shadow region of North Interior Karnataka. Seasonal analysis highlights that winter rainfall is very meagre across all taluks, ranging from 2.0 mm for Raibag to 4.8 mm for Savadatti. Despite its negligible contribution to annual totals, variability is extremely high, with Coefficient of Variation (CV) values exceeding 150% in every taluk and reaching 277.9% for Savadatti and 274.4% for Chikkodi. Such patterns underscore the erratic and unreliable nature of winter precipitation, rendering it insignificant for agricultural purposes. Arora *et al*. (2023) similarly reported that weak western disturbances in peninsular India result in highly negligible, but variable and unpredictable winter rainfall. Consequently, farmers in Belagavi district cannot depend on this season for water needs and must rely on other rainfall periods for crop planning.

Summer rainfall, though modest in quantum, plays a critical role in recharging soil moisture, enabling land preparation and early sowing. Taluk-level analysis shows Kitthuru (136.9 mm) receiving the highest summer rainfall, followed by Bailhongal (109.7 mm), while Gokak (65.1 mm) followed by Mudalgi (66.7 mm) record the lowest. However, variability is pronounced, ranging from 53.1% for Kitthuru to 91.5% for Yaragatti, with a district average of about 65%. These high CV values reflect the convective and localized nature of summer showers. Local thunderstorms contribute to significant year-to-year fluctuations, making the season uncertain yet agriculturally relevant. Guhathakurta *et al*. (2015) also observed high pre-monsoon variability across Karnataka linked to sporadic thunderstorm activity. Despite its unpredictability, summer rainfall remains valuable for agricultural operations, particularly in taluks like Bailhongal and Kitthuru, where its contribution is relatively higher compared to drier areas.

The monsoon period (June-September) remains the dominant season, contributing 60 to 70% of annual totals and determining agricultural outcomes. Marked spatial contrasts exist for Kitthuru (660.8 mm), Belagavi (613.0 mm) and Khanapur (613.0 mm) receive higher rainfall due to their proximity to the Western Ghats and orographic lifting, while eastern taluks such as Athani (340.3 mm), Raibag (347.5 mm) and Ramadurg (361.5 mm) record substantially lower rainfall in the rain-shadow zone.

Table 1. Taluk-wise annual and seasonal rainfall statistics of Belagavi district (1995-2024)

Taluk	Winter			Summer			Monsoon			Post monsoon			Annual		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Athani	2.9	6.8	237.1	74.8	43.4	58.1	340.3	96.3	28.3	154.9	87.1	56.3	572.8	139.9	24.4
Bailhongal	3.8	6.3	165.9	109.7	65.7	59.9	528.5	203.1	38.4	158.8	74.5	46.9	800.9	253.2	31.6
Belagavi	3.0	6.6	221.1	87.6	53.0	60.5	613.0	246.3	40.2	139.0	83.5	60.1	842.6	271.0	32.2
Chikkodi	3.3	9.1	274.4	69.4	49.5	71.3	461.7	147.6	32.0	139.9	79.1	56.5	674.4	194.5	28.9
Gokak	3.5	6.1	175.9	65.1	44.8	68.9	321.2	133.0	41.4	137.0	87.2	63.6	526.8	200.5	38.1
Hukkeri	3.0	6.5	217.5	78.4	46.2	58.9	495.4	256.5	51.8	140.0	89.2	63.8	716.7	297.3	41.5
Kagwad	3.0	6.2	209.8	69.9	45.9	65.7	385.1	136.6	35.5	149.3	80.9	54.2	607.3	174.8	28.8
Khanapur	3.0	6.6	221.1	87.6	53.0	60.5	613.0	246.3	40.2	139.0	83.5	60.1	842.6	271.0	32.2
Kitthuru	4.3	9.0	210.1	136.9	72.7	53.1	660.8	215.5	32.6	164.6	82.7	50.2	966.6	251.5	26.0
Mudalgi	3.1	6.0	189.5	66.7	42.1	63.1	350.1	104.0	29.7	139.9	82.3	58.9	559.8	158.7	28.4
Nippani	3.3	9.1	274.4	69.4	49.5	71.3	461.7	147.6	32.0	139.9	79.1	56.5	674.4	194.5	28.9
Raibag	2.0	3.8	187.5	69.3	45.2	65.3	347.5	115.5	33.2	142.0	89.4	63.0	560.7	170.3	30.4
Ramadurg	2.8	6.1	218.8	82.9	56.8	68.5	361.5	150.0	41.5	149.5	63.3	42.4	596.7	172.2	28.9
Savadatti	4.8	13.3	277.9	108.5	74.6	68.7	374.8	132.5	35.4	151.4	76.7	50.6	639.5	194.4	30.4
Yaragatti	2.5	4.9	193.7	95.4	87.3	91.5	364.6	143.0	39.2	143.8	74.2	51.6	606.4	188.0	31.0

Note: SD – Standard Deviation, CV – Coefficient of Variation

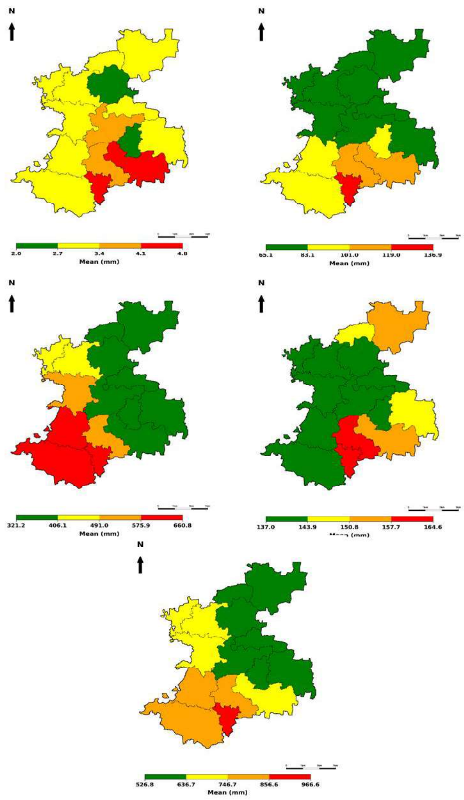

Fig 2. spatial distribution of annual and seasonal mean rainfall across Belagavi district a) winter, b) summer, c) monsoon, d) post monsoon, e) annual

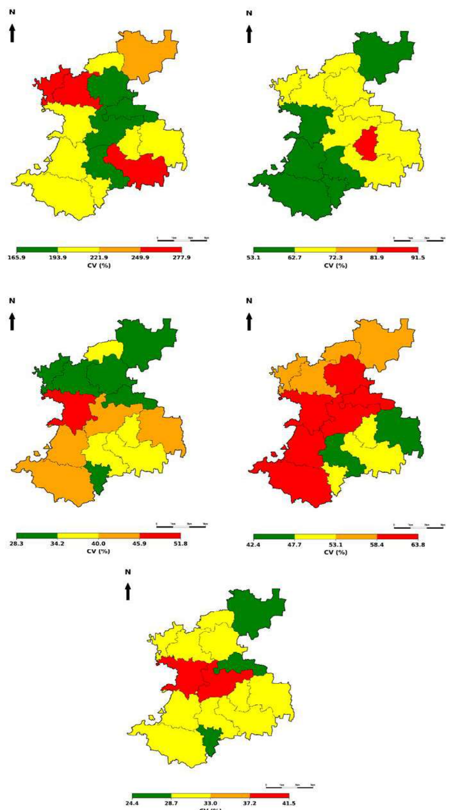

Fig3. spatial distribution of annual and seasonal rainfall variability across Belagavi district a) winter, b) summer, c) monsoon, d) post monsoon, e) annual

Variability ranges from 28.3% for Athani to 51.8% for Hukkeri, suggesting that while drier taluks consistently receive less rainfall, but wetter ones are more prone to inter-annual fluctuations, and with it brings risks of crop failure either due to excess or deficit rains. Reddy *et al*. (2024) noted a similar eastward decline in rainfall across North Interior Karnataka. The monsoon thus dictates both water availability and agricultural productivity, requiring drought-proofing measures and irrigation in drier taluks while simultaneously managing variability in wetter ones.

Post-monsoon rainfall, although smaller in volume, contributes significantly to rabi crops. Mean values ranged from 137.0 mm for Gokak to 164.6 mm for Kitthuru. CV values ranged between 42.4% for Ramadurg and 63.8% for Hukkeri, lower than those of summer rainfall, making post-monsoon showers more dependable. This seasonal rainfall is crucial for soil moisture recharge, supporting cropping systems in semi-arid areas. Pradhan *et al*. (2023) emphasized the stabilizing role of post-monsoon rainfall in Karnataka agriculture, which is clearly applicable to Belagavi district as well, especially in drier districts.

Cumulatively, annual rainfall patterns mirror the seasonal disparities, ranging from the lowest of 526.8 mm for Gokak to 966.6 mm for Kitthuru, a nearly two-fold difference within the district. The wetter taluks, including Kitthuru, Belagavi, Khanapur and Bailhongal taluks, receive over 800 mm annually and are better suited for water-intensive crops. Conversely, eastern taluks such as Raibag, Mudalgi, Athani and Gokak remain drought-prone with less than 600 mm annually. Variability in annual rainfall is moderate, with CV values from 24.4% for Athani to 41.5% for Hukkeri. This indicates that even taluks with relatively high rainfall face risks of fluctuation. Madolli *et al*. (2015) reported similar heterogeneity across Karnataka state, driven by orographic influences and changing monsoon circulation.

The high variability in both summer and monsoon rainfall across taluks of Belagavi district underscores the increasing uncertainty in rainfall distribution. This aligns with Malik *et al*. (2016), who reported that moderate rains are declining while extreme rainfall events are becoming more frequent across peninsular India. For Belagavi district, these findings emphasize the urgency of adopting climate-resilient strategies. Crop diversification, watershed development, tank rejuvenation and rainwater harvesting are critical to mitigate both excess and deficit rainfall risks. While western taluks benefit from relatively higher rainfall, the eastern belt remains agriculturally vulnerable, demanding robust contingency planning. Thus, ensuring sustainability under changing rainfall regimes requires integrated water management and climate-smart agriculture tailored to Belagavi's distinct rainfall gradients.

Conclusion

The analysis of 30 years rainfall reveals pronounced spatial and seasonal disparities across Belagavi district. Winter rainfall is extremely low and erratic, with Savadatti and Chikkodi showing the highest variability. Summer rainfall, though modest, is relatively higher for Kitthuru and Bailhongal, while Gokak and Mudalgi receive the least amount of rainfall. The monsoon season forms the principal rainfall season, with Kitthuru, Khanapur and Belagavi recording the highest amounts, contrasted by much lower rainfall in Athani, Raibag and Gokak situated in the rain-shadow zone. Post-monsoon rainfall, though moderate, supports *rabi* agriculture, with Kitthuru and Savadatti taluks receiving more compared to Gokak and Ramadurg taluks. Annual totals rainfall exhibit nearly two-fold variation, ranging from higher values for Kitthuru, Khanapur and Belagavi to much lower values for Gokak, Athani and Raibag, underscoring the contrasting hydrological regimes across the district.

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