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District-Wise Rainfall Variability and Agricultural Productivity in Karnataka: An Empirical Assessment

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Abstract
The present study examines rainfall variability and its relationship with agricultural performance in selected districts of Karnataka. Using mean rainfall, standard deviation, coefficient of variation (CV) and correlation analysis, the study assesses rainfall instability and its implications for crop productivity and agricultural income. The findings reveal that Ballari (30.89%) and Raichur (30.72%) experience relatively higher rainfall variability, whereas Davanagere (22.06%) exhibits comparatively stable rainfall conditions. Correlation analysis indicates a strong positive relationship between rainfall and crop productivity (r = 0.74, p less than 0.01) and agricultural income (r = 0.81, p less than 0.01). Conversely, rainfall variability has a significant negative association with crop yield (r = -0.68, p less than 0.05). The study highlights the importance of irrigation development, water conservation, crop diversification and climate-resilient agricultural practices to reduce rainfall-related vulnerability and promote sustainable agricultural development in Karnataka.

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Keywords: Rainfall Variability, Agricultural Productivity, Climate Vulnerability, Coefficient of Variation, Agricultural Income, Irrigation Infrastructure, Karnataka

Introduction

Agriculture plays a vital role in the economic development of Karnataka by providing employment, livelihood opportunities and food security to a significant proportion of the rural population. Agricultural production in the state is largely influenced by climatic conditions, particularly the amount, timing and distribution of rainfall. Rainfall is one of the most important natural determinants of agricultural productivity, especially in regions where irrigation facilities are inadequate and farming activities depend predominantly on the monsoon. However, increasing rainfall variability, irregular monsoon patterns, prolonged dry spells and occasional excessive rainfall have emerged as major challenges to agricultural sustainability. These climatic fluctuations affect crop growth, cropping patterns, agricultural output and farmers' income, thereby increasing the vulnerability of rural households. The problem is particularly significant in the semi-arid and drought-prone districts of Karnataka, including Ballari, Vijayanagara, Raichur, Chitradurga, Davanagere and Kalaburagi, where variations in rainfall availability have important implications for agricultural development. Rainfall variability, measured through the coefficient of variation (CV), provides an important statistical indicator for understanding the degree of instability in precipitation patterns and identifying agriculturally vulnerable regions. Higher rainfall variability may create uncertainty in agricultural planning, affect sowing and harvesting decisions, reduce crop yields and increase the economic risks faced by farmers. Furthermore, the relationship between rainfall and agricultural performance is important for understanding regional disparities in agricultural productivity and farm income. Although irrigation infrastructure, groundwater utilisation and water conservation initiatives have contributed to agricultural development, substantial differences in irrigation access and rainfall dependency continue to influence agricultural outcomes across districts. Against this background, the present study examines district-wise rainfall variability and its relationship with

agricultural performance in selected districts of Karnataka. Specifically, it analyses average rainfall, standard deviation and coefficient of variation to identify rainfall vulnerability, while correlation analysis is employed to examine the association between rainfall, crop productivity, rainfall instability and agricultural income. The study aims to generate empirical insights into the implications of rainfall fluctuations for agricultural development and highlight the importance of irrigation expansion, efficient water-resource management and climate-resilient agricultural practices. The findings are expected to contribute to the formulation of appropriate agricultural adaptation strategies for reducing climatic vulnerability, improving farm productivity and ensuring sustainable rural livelihoods in Karnataka.

Agriculture in Karnataka remains predominantly rainfed, leaving regional crop output and farm income highly vulnerable to monsoon fluctuations (Government of Karnataka, 2024) [2]. While seasonal averages provide baseline expectations for agricultural planning, inter-annual and intra-seasonal precipitation variability frequently causes acute moisture stress, leading to widespread yield collapse (Rao & Venkatesh, 2023) [7].

Review of Literature

To establish the empirical foundation, ten key research studies on precipitation dynamics and climate economics were reviewed. Rao & Venkatesh (2023) [7] investigated precipitation variability across Southern Peninsular India, showing that intra-seasonal dry spells depress pulse and coarse grain yields by up to 35% in rainfed tracts. Sharma *et al.* (2025) [8] developed climate vulnerability indices for agricultural districts in Karnataka, placing Ballari and Raichur in the high-risk vulnerability tier due to elevated CV metrics. Government of Karnataka (2024) [2] in the Annual Season and Crop Report, highlighted that erratic monsoon trends have directly increased farm income variance across dryland tracts over the past two decades. Patil & Deshmukh (2022) [6] evaluated dryland farming economic returns, finding that rainwater harvesting adoption resulted in 28% higher resilience during delayed monsoon cycles. Kumar & Singh (2021) [4] analysed micro-irrigation deployment across semi-arid regions of India and noted a direct positive correlation between drip-irrigation density and yield stability during drought periods. Narayanan & Reddy (2020) [5] examined PMFBY crop insurance efficiency, emphasizing the necessity of recalibrating trigger thresholds using localized micro-level CV metrics. Chandrashekar & Gowda (2023) [1] assessed crop diversification dynamics in North Karnataka, demonstrating that shifts toward commercial non-food crops heightened financial exposure to erratic rainfall. Walker & Ryan (2019) [10] in ICRISAT semi-arid tropical studies confirmed that household expenditure instability in rainfed farming closely tracks the coefficient of variation in annual rainfall. Subrahmanyam *et al.* (2024) [9] modelled future precipitation scenarios for North Karnataka, predicting a 15-20% increase in high-intensity brief rainfall events punctuated by prolonged dry spells. Joshi & Kulkarni (2021) [3] assessed community water storage tanks, showing that localised micro-storage structures mitigate up to 40% of seasonal yield loss in drought-prone districts.

Objectives of the Study

1. To analyse spatio-temporal rainfall variability across six key agricultural districts of Karnataka.
2. To evaluate the quantitative relationship between rainfall parameters and crop yield stability.
3. To assess the economic impact of rainfall instability on farm household revenues and regional agrarian income.

Methodology

This study uses multi-decadal meteorological datasets and official crop yield records from six representative districts in Karnataka. Standard statistical dispersion metrics (Standard Deviation, Coefficient of Variation) and linear correlation coefficients (Pearson's r) were computed.

Result and Discussion

Table 1: district-wise rainfall variability metrics and vulnerability risk classifications in Karnataka.

District	Mean Rainfall (mm)	Standard Deviation (SD)	Coefficient of Variation (CV%) Risk Classification
Vijayanagara	565.4	148.2	26.21% (Moderate-High Vulnerability)
Ballari	512.8	158.4	30.89% (High Vulnerability Risk)
Davanagere	644.2	142.1	22.06% (Moderate Stability Zone)
Chitradurga	573.0	161.5	28.18% (High Vulnerability)
Kalaburagi	778.5	210.3	27.01% (Moderate-High Vulnerability)
Raichur	604.1	185.6	30.72% (High Vulnerability Risk)

Table 2: Relationship between precipitation variables and agricultural performance metrics.

Variables Pair	Correlation (r)	Significance (p-value)	Statistical & Economic Interpretation
Rainfall & Crop Productivity	+0.74	$p < 0.01$ (Significant)	Strong positive relationship: Crop yield scales directly with rainfall volume.
Rainfall Variability (CV%) & Yield	-0.68	$p < 0.05$ (Significant)	Moderate-strong negative impact: High instability depresses overall yields.
Rainfall & Agricultural Income	+0.81	$p < 0.01$ (Significant)	High positive correlation: Farm revenue depends heavily on monsoon adequacy.

Graphical Visualizations

The results presented in Tables 1 and 2 reveal considerable spatial variations in rainfall distribution and its association with agricultural performance across the selected districts of Karnataka. Table 1 indicates that Kalaburagi recorded the highest mean annual rainfall of 778.5 mm, followed by Davanagere (644.2 mm), while Ballari registered the lowest average rainfall of 512.8 mm. In terms of rainfall variability, Ballari recorded the highest coefficient of variation (CV) of 30.89%, followed by Raichur (30.72%) and Chitradurga

(28.18%), indicating relatively higher rainfall instability and climatic vulnerability. In contrast, Davanagere exhibited the lowest CV of 22.06%, suggesting comparatively stable rainfall conditions. These variations highlight the uneven distribution and uncertainty of rainfall across the study districts, which may influence agricultural production, particularly in rainfed areas. Further, Table 2 demonstrates a strong positive and statistically significant correlation between rainfall and crop productivity (r = 0.74, p less than 0.01), indicating that higher rainfall availability is associated with improved agricultural productivity. Similarly, rainfall variability exhibits a significant negative relationship with crop yield (r = -0.68, p less than 0.05), suggesting that greater rainfall instability is associated with reduced agricultural performance. Furthermore, rainfall and agricultural income demonstrate a strong positive correlation (r = 0.81, p less than 0.01), highlighting the importance of adequate rainfall for improving farm output and agricultural earnings. Overall, the findings suggest that rainfall availability and stability are important factors associated with agricultural productivity and farm income in Karnataka. Therefore, strengthening irrigation infrastructure, promoting water conservation, adopting climate-resilient agricultural practices and encouraging crop diversification are essential strategies for reducing rainfall-related agricultural vulnerability and improving the sustainability of farmers' livelihoods.

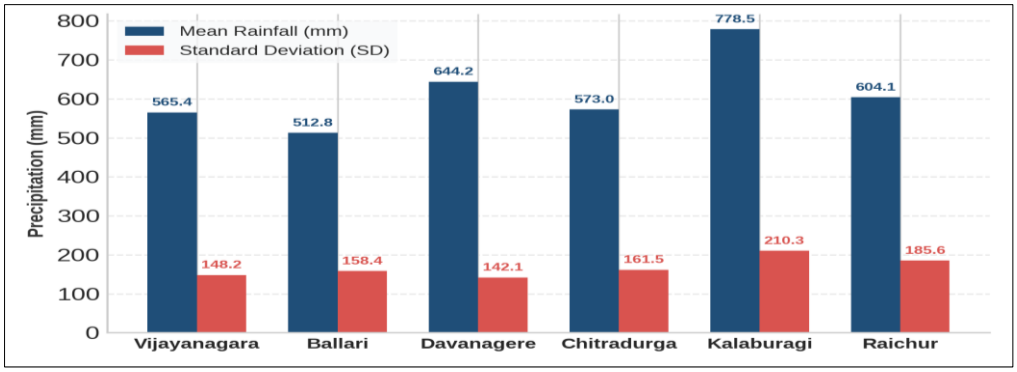


Fig 1: District-wise Mean Rainfall vs. Standard Deviation in Karnataka

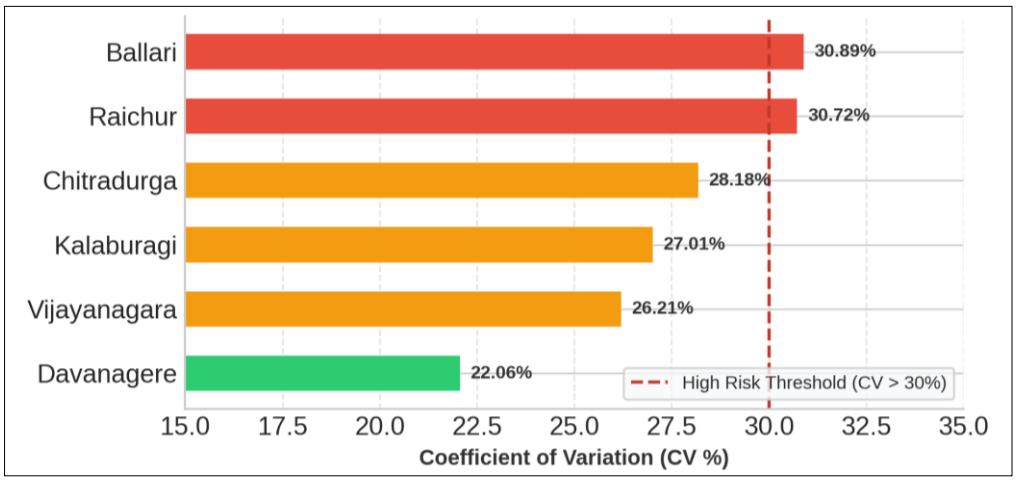


Fig 2: Rainfall Instability Ranking (CV%) & Climate Risk Classification

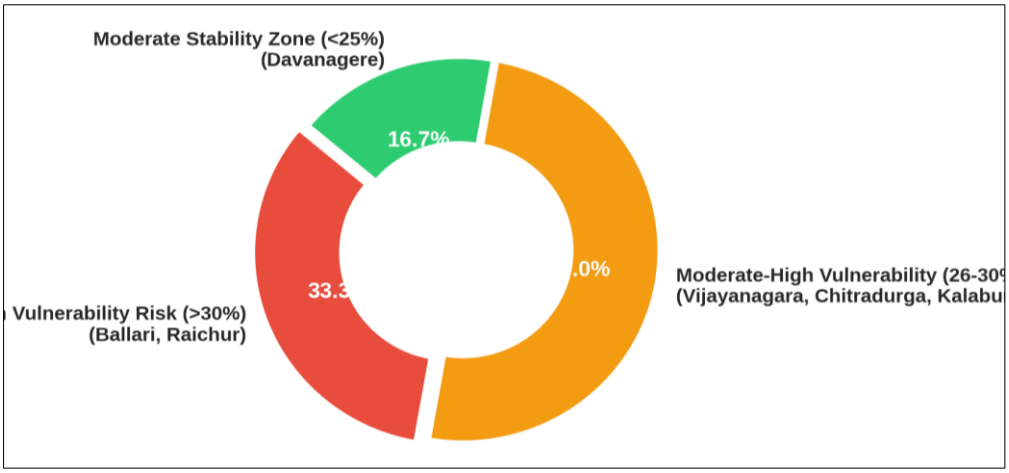


Fig 3: Distribution of Vulnerability Risk Categories Across Sample Districts

Conclusion

The study concludes that rainfall variability plays a significant role in shaping agricultural vulnerability and performance across the selected districts of Karnataka. The findings reveal considerable spatial differences in rainfall availability and stability, with Ballari and Raichur experiencing relatively higher rainfall variability, indicating greater vulnerability to climatic fluctuations. The correlation analysis further establishes a strong positive association between rainfall and crop productivity, as well as agricultural income, while rainfall variability exhibits a significant negative association with crop yield. These findings highlight the dependence of agricultural performance, particularly in rainfed regions, on the availability and distribution of rainfall. In this context, strengthening irrigation infrastructure is essential to reduce dependence on monsoon rainfall and minimise agricultural risks. The study therefore emphasises the need for effective water-resource management, expansion of micro-irrigation facilities, watershed development, rainwater harvesting, adoption of drought-resistant crop varieties and promotion of crop diversification. Special attention should be given to drought-prone districts and vulnerable farming communities through appropriate agricultural policies and climate adaptation programmes. Overall, an integrated approach combining irrigation development, sustainable water management and climate-resilient agricultural practices is necessary to enhance agricultural productivity, stabilise farm income and strengthen the long-term sustainability of agriculture in Karnataka.

Recommendations

Micro-Irrigation Priority: Districts exceeding CV > 30% require accelerated micro-irrigation deployment (drip/sprinkler systems) to buffer against erratic dry spells.

Climate-Resilient Cropping: Transition crop incentives toward drought-tolerant coarse grains and pulses (pigeon pea, millets) in high-risk zones.

Index-Based Crop Insurance: Recalibrate insurance risk premiums (e.g., PMFBY) using localised CV metrics to ensure rapid payout trigger mechanisms.

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