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GEOSPATIAL ANALYSIS OF CYCLONE FENGAL'S TRACK AND RAINFALL DISTRIBUTION OVER KARNATAKA, INDIA

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Abstract

Tropical cyclones are among the most destructive natural hazards, affecting both coastal and inland regions and posing major challenges to disaster management and climate resilience. Although India's eastern coast frequently experiences severe cyclones, interior states such as Karnataka also face heavy rainfall and related disruptions during these events. This study examines Cyclone Fengal (25 November–2 December 2024), which developed over the Bay of Bengal and indirectly influenced weather conditions across southern India. Using daily press releases from the India Meteorological Department (IMD), the cyclone's track was mapped to visualize its movement and intensity. Concurrently, rainfall distribution across Karnataka from 25 November to 5 December 2024 was analyzed using geospatial techniques in ArcGIS, generating daily rainfall maps to capture spatial and temporal variations. Results highlight significant differences in rainfall intensity, with coastal and southern districts recording the highest precipitation. The integration of cyclone tracking and rainfall mapping provides valuable insight into localized cyclone impacts and contributes to the broader understanding of tropical cyclone dynamics. These findings support the mitigation of cyclone-related impacts through improved early warning systems, water resource planning, and disaster risk reduction strategies.

Keywords: *Tropical cyclones, Cyclone tracking, Rainfall distribution, Geospatial analysis, Disaster risk mitigation.*

Introduction

Tropical cyclones are among the most destructive natural hazards, producing intense winds, heavy rainfall, and storm surges that cause extensive damage to life, infrastructure, agriculture, and ecosystems (Harr & Elsberry, 1991). These weather systems significantly influence regional climate and hydrological conditions, and understanding their behavior is crucial for effective disaster preparedness and climate adaptation strategies. India's eastern coastline is especially vulnerable to cyclonic storms that originate in the Bay of Bengal; however, interior regions such as Karnataka also experience indirect effects, including heavy rainfall and localized flooding resulting from weakened but moisture-laden cyclonic systems (Wu & Wang, 2004; Matyas, 2010).

Cyclone Fengal, which developed over the Bay of Bengal in late November 2024, exemplifies such an event. Although it made landfall near Cuddalore and Puducherry on 1 December 2024, its remnants influenced extensive rainfall across southern India, including Karnataka. The present study focuses on analyzing the track of Cyclone Fengal and examining its associated rainfall distribution over Karnataka using geospatial techniques. By integrating meteorological data from the India Meteorological Department (IMD) with spatial analysis in ArcGIS, the study traces the cyclone's movement, identifies rainfall-affected regions, and evaluates the spatial variation in precipitation intensity. Through this approach, the research aims to enhance the understanding of cyclone dynamics and their inland hydrological impacts, thereby supporting better regional planning, early warning, and disaster mitigation strategies (Knight & Davis, 2013).

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Study Area

Karnataka, located in the southern part of India, is the eighth largest state in terms of geographical area, covering approximately 191,791 km², which accounts for about 5.83% of India's total land area (Government of India, 2011). Geographically, it lies between 11.5°N and 18.5°N latitudes and 74°E and 78.3°E longitudes, forming a significant portion of the Deccan Plateau. The state is bounded by Maharashtra and Goa to the north and northwest, the Arabian Sea to the west, Kerala and Tamil Nadu to the south, and Andhra Pradesh and Telangana to the east.

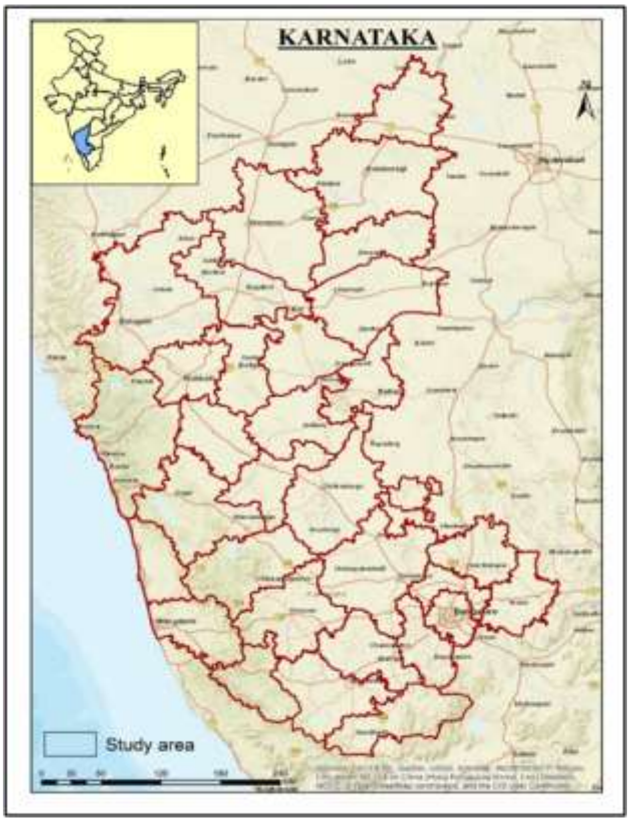

Figure 01: *Study Area*

Karnataka stretches roughly 750 km from north to south and 400 km from east to west, exhibiting notable physiographic and climatic diversity. According to the 2011 Census, the state has a population of approximately 6.11 crore (61.1 million) and a population density of 319 persons per km² (Government of India, 2011). Rainfall distribution across Karnataka is highly variable, ranging from 50 cm in the northeastern districts to more than 350 cm along the Western Ghats (IMD, 2021). The southern parts of Vijayapura, Raichur, Ballari, and Kalaburagi districts receive relatively low rainfall, averaging 50–60 cm annually, while the coastal belt experiences a humid tropical climate. Temperature extremes have also been recorded, with the highest temperature of 45.6°C in Raichur and the lowest of 2.8°C in Bidar (India Meteorological Department, 2021).

Methodology

This study focuses on identifying the cyclone track of Cyclone Fengal and analyzing the spatial distribution of rainfall across Karnataka during its period of influence. The research is based entirely on secondary data sources, which were processed using geospatial techniques to understand the cyclone's formation, trajectory, and associated precipitation patterns (Vanitha et al., 2021).

To analyze and generate the cyclone track over the Bay of Bengal, daily press release reports were collected from the official portal of the India Meteorological Department (IMD) for the period between 25 November and 5 December 2024. These reports contained coordinate information related to the cyclone's position, intensity, and movement. The coordinates were first tabulated in Microsoft Excel, formatted for geospatial analysis, and then imported into ArcGIS 10.8.2. Using the Add XY Data function, the latitude and longitude values were plotted as point features, which were subsequently connected sequentially to create a polyline representing the cyclone's track (Bisht et al., 2020).

In addition to the cyclone track, the study analyzed the rainfall distribution over Karnataka during the same period. Daily rainfall data were obtained from the Climate Hazards Center (CHRS) portal, which provides gridded precipitation datasets with high spatial resolution (Funk et al., 2015). The data underwent preprocessing, including geometric correction and reprojection to the WGS 84 coordinate system (EPSG:4326). The gridded rainfall data were then converted into point features, and kriging interpolation was applied to generate continuous rainfall surfaces across the state (Mahmoud,

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2014). The resulting rainfall distribution was classified into five categories and represented symbolically in thematic maps.

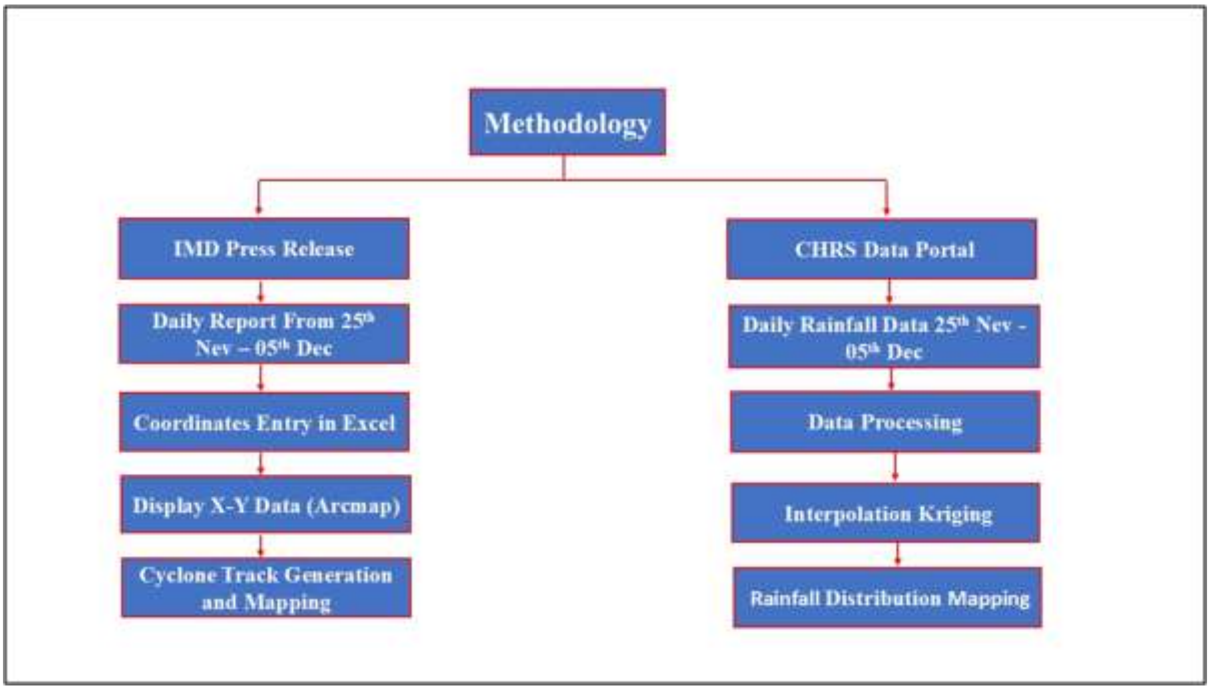

Figure 02: *Methodology flow chart*

This methodological framework integrates meteorological observations with spatial modeling, enabling a detailed assessment of cyclone dynamics and rainfall variability across Karnataka. Such an approach enhances the understanding of storm-induced precipitation patterns and provides a reproducible workflow for similar geospatial analyses in future studies.

Results and Discussion

Cyclone Fengal originated over the southwestern Bay of Bengal on 25 November 2024 as a low-pressure system that gradually intensified into a cyclonic storm. Between 25 and 30 November, wind speeds increased steadily from 55 km/h to 95 km/h as the system moved northwestward (IMD, 2024). On 1 December 2024, around 11:30 IST, the cyclone made landfall near Cuddalore and Puducherry, with sustained winds of approximately 65 km/h. It was located about 30 km north of Cuddalore, 40 km north of Villupuram, and 120 km southwest of Chennai at the time of landfall. Subsequently, the storm weakened while moving westward and downgraded to a well-marked low-pressure area over Tamil Nadu by the early hours of 2 December 2024. The residual system continued westward, emerging over the southeast Arabian Sea near the coasts of north Kerala and

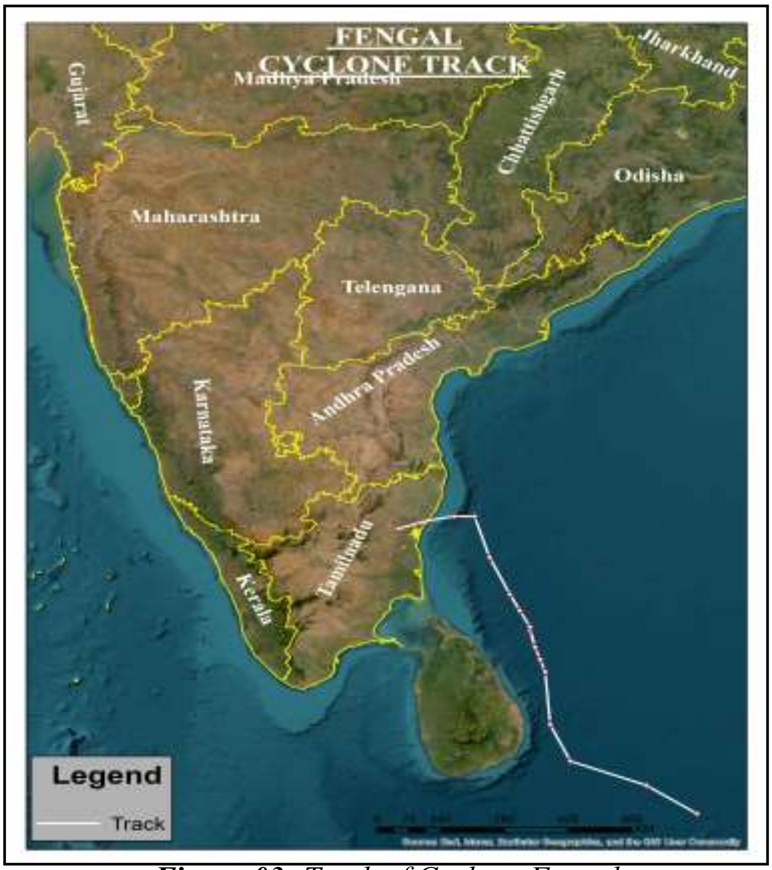

Figure 03: *Track of Cyclone Fengal*

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Karnataka by 3 December 2024. Fengal caused severe weather conditions across Tamil Nadu and Puducherry, resulting in substantial damage and reported fatalities in India and Sri Lanka (Vanitha et al., 2021).

Rainfall analysis reveals distinct spatial and temporal variations across Karnataka during the cyclone period. The daily CHRS gridded rainfall data (0.05° resolution) were analyzed for 25 November–5 December 2024 to understand precipitation dynamics.

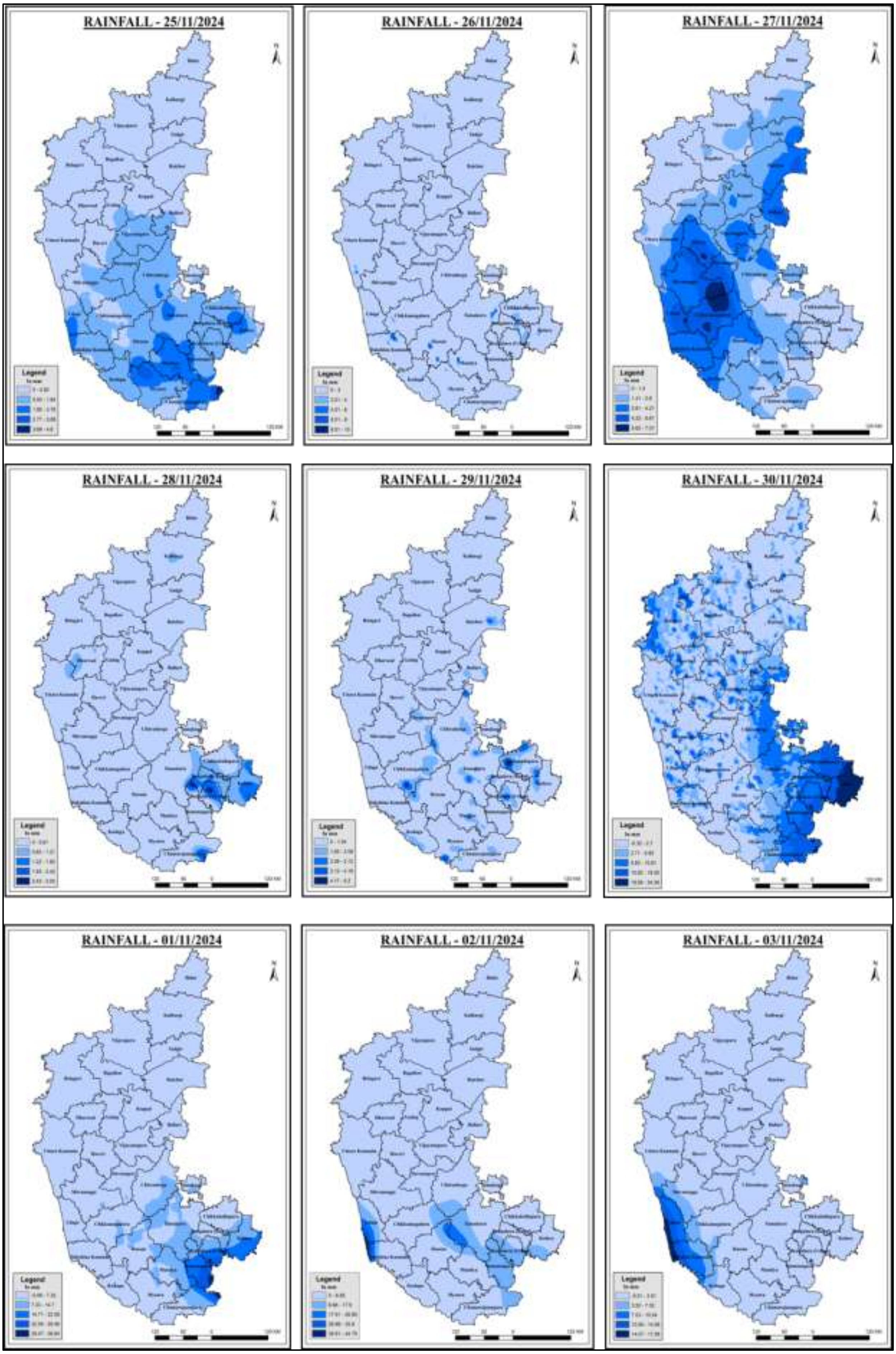
At the onset of the event (25–26 November), light to moderate rainfall occurred in southern and southeastern districts such as Chamarajanagar, Mandya, Mysuru, Kolar, and Tumakuru, with intensities ranging between 2 and 10 mm/day. By 27 November, rainfall intensified in Chikkamagaluru, Shivamogga, and Davanagere, recording up to 7 mm/day, indicating the early inland influence of the cyclone.

As Fengal approached landfall (30 November–1 December), Karnataka experienced a marked increase in rainfall intensity. The southern interior districts, particularly Kolar, Ramanagara, and Chamarajanagar, recorded daily rainfall between 20 and 35 mm, while Bengaluru and Tumakuru experienced moderate rainfall ranging from 5 to 20 mm. The peak precipitation occurred on 2 December 2024, when Dakshina Kannada and Udupi districts along the coastal belt registered rainfall exceeding 40 mm/day. This reflects the westward migration of the system's moisture field and its interaction with the Western Ghats, which enhanced orographic rainfall (Mahmoud, 2014; Knight & Davis, 2013).

In the post-landfall phase (3–5 December), rainfall gradually weakened but persisted in coastal and adjoining districts. On 3 December, the coastal zones of Dakshina Kannada and Udupi received moderate rainfall between 7 and 18 mm, while the northern districts such as Kalaburagi, Bidar, and Vijayapura experienced minimal rainfall (<5 mm). By 5 December, residual precipitation was limited mainly to coastal Karnataka, confirming the dissipation of the system's influence.

Spatially, the rainfall gradient observed from southeast to northwest aligns with the cyclone's westward trajectory and the topographical control exerted by the Western Ghats. Similar inland rainfall extension patterns were documented by Wu and Wang (2004) and Bisht et al. (2020) in studies of other Bay of Bengal cyclones. The use of geospatial interpolation (kriging) effectively visualized these rainfall variations, providing valuable insight into how weakened cyclonic circulations influence inland precipitation regimes.

Overall, the results indicate that although Karnataka was not directly impacted by Fengal's landfall, the remnant system significantly altered local rainfall dynamics, especially over southern and coastal districts. Such findings reinforce the importance of integrating meteorological datasets with geospatial modeling to improve cyclone impact assessment and regional preparedness strategies.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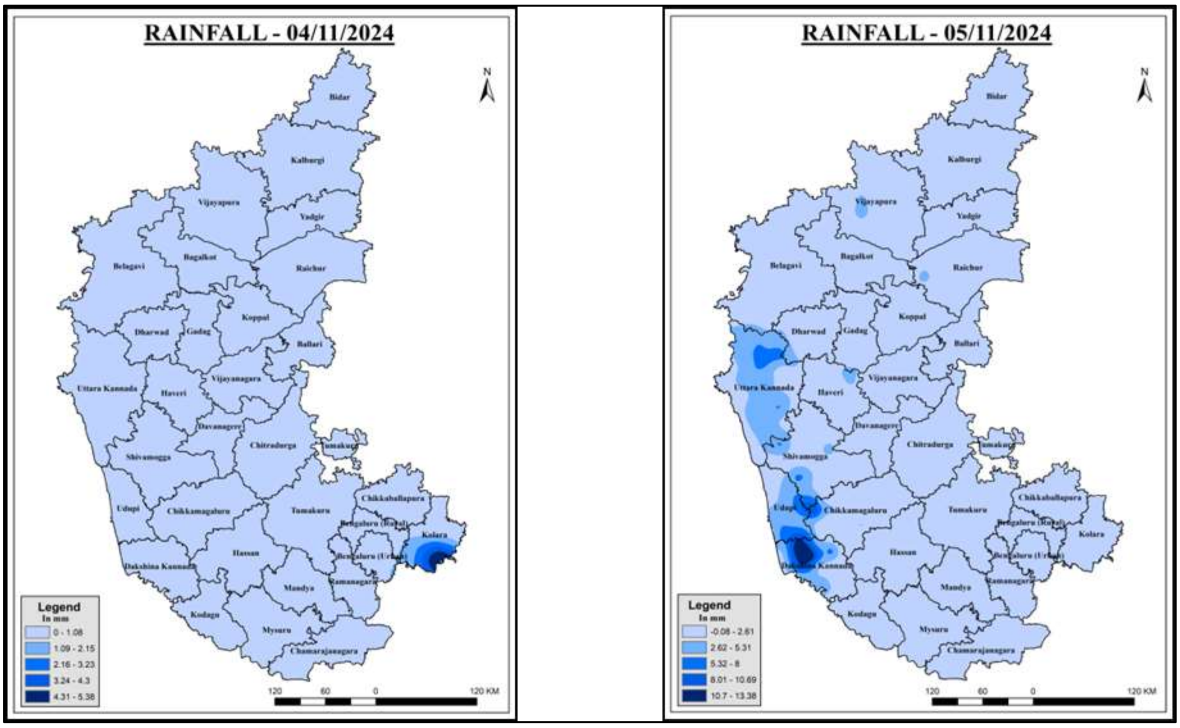

Figure 04: *Rainfall distribution in Karnataka*

Conclusion

This study on Cyclone Fengal and the associated rainfall distribution over Karnataka provides valuable insights into the storm's dynamics and its hydrometeorological impact on the region. By analyzing the cyclone's track using IMD datasets and mapping rainfall patterns through geospatial interpolation, the research revealed clear spatial variations in precipitation intensity across the state. The southern and coastal districts experienced the highest rainfall, while the northern and interior regions remained comparatively less affected.

These findings emphasize the importance of integrating meteorological observations with geospatial analysis for real-time disaster monitoring and response. Accurate cyclone tracking and rainfall mapping not only improve the understanding of tropical storm behavior but also contribute to the formulation of data-driven early warning systems and disaster preparedness strategies. The study further highlights that even non-coastal states like Karnataka can experience significant secondary impacts from Bay of Bengal cyclones, underscoring the need for region-specific risk assessment and climate resilience planning.

Overall, this research demonstrates that the application of GIS-based analysis serves as a vital tool for enhancing cyclone monitoring, optimizing water resource management, and strengthening disaster risk reduction frameworks across India.

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