

## Probability Distribution Analysis of Weather Parameters in Coastal and Hilly Zones of Karnataka

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### ABSTRACT

The Coastal and Hilly Zones of Karnataka, characterized by unique topography and proximity to the Arabian Sea, exhibit significant climatic variability. The present study examined the probability distributions of rainfall and temperature over four decades (1979-2023) to understand their patterns and identified emerging climatic trends crucial for regional adaptation strategies. The study employed probability distributions to model rainfall and temperature patterns in the Coastal and Hilly zones of Karnataka. The results reveal that annual rainfall in the Coastal Zone is effectively modeled by a normal distribution, with most values centered around 1863 mm, whereas the Hilly Zone's rainfall followed a Weibull minimum distribution, with a left skew indicating higher rainfall concentration in upper ranges. Temperature patterns further highlight regional variability. Maximum temperatures in the Hilly Zone are best described by a Weibull minimum distribution, showing a narrow range with consistent warming trends. Similarly, minimum temperatures in both the zones align with a lognormal distribution, reflecting stable, but gradually increasing values. Notable trends include a declining precipitation rate and rising temperatures, as reported in previous studies, indicating the potential impacts of climate change in these regions. The findings highlighted the interplay of climatic factors in shaping agro-climatic conditions. Reduced rainfall and rising temperatures may exacerbate water stress, disrupt crop cycles and affect ecosystem dynamics. These results emphasize the need for targeted adaptation strategies, such as optimized irrigation, climate-resilient agriculture and sustainable resource management, to mitigate the adverse impacts of changing climatic patterns in these critical zones.

**Keywords :** Probability distribution, Climate variability, Maximum & Minimum temperature, Weibull distribution, Lognormal distribution

CLIMATE change and its variability have emerged as critical challenges for Indian agriculture, significantly influencing weather patterns and agricultural productivity. Projections highlight an increase in extreme events such as heat waves, cold waves and flooding, along with higher atmospheric carbon dioxide and ground-level ozone concentrations (Sindhu *et al.*, 2024). These changes have notably altered weather parameters, particularly rainfall patterns and temperature anomalies (Reddy *et al.*, 2022).

Karnataka, a state with a 320-kilometer-long coastline on the west encompassing Dakshina Kannada, Udupi, and Uttara Kannada districts, is particularly vulnerable to climate change (Sridhar *et al.*, 2019). This region's agriculture, biodiversity and livelihoods are at significant risk, especially given its sensitivity to rainfall and temperature variability. The Western Ghats' orographic effects, combined with dense forest cover in this region, resulted in heavy monsoon rainfall, with daily precipitation often exceeding 150 mm during the southwest monsoon (Francis *et al.*, 2006).

Projections for the Coastal and Hilly zones for the 2030s indicate a 6-8 per cent increase in annual precipitation compared to the 1970s, with significant increases during the monsoon months but reduced rainfall during the winter and pre-monsoon periods (Anonymous, 2010). This variability impacts agricultural practices, such as rain-fed paddy cultivation, which faces a projected 9-10 per cent yield reduction, while irrigated paddy might slightly benefit from increased carbon dioxide levels (Gangwar, 2013). Beyond agriculture, climate change affects marine resources, ecosystems and human health, making an understanding of climatic trends vital.

This paper analyzes the probability distribution of key weather parameters, focusing on Karnataka's Coastal and Hilly zones. By exploring rainfall and temperature variability, this work aims to provide actionable insights for the farming community to adapt to these evolving climatic conditions.

#### MATERIAL AND METHODS

The present study is confined to the Uttara Kannada (14.6°N, 74.7°E), Udupi (13.3389°N, 74.7451°E) and Dakshina Kannada (12.87°N, 74.88°E) districts, which collectively form the Coastal and Hilly zones of Karnataka. This region is known for its very high yeterratic rainfall patterns and warm temperatures (Table 2). These climatic characteristics contribute to low to average productivity in both agriculture and fisheries. The zones were purposefully chosen to represent the coastal belt of Karnataka due to their diverse agro-climatic conditions.

The data on climate variables like rainfall collected from Karnataka State Natural Disaster Monitoring Cell unit, Bengaluru and maximum and minimum temperature collected from the NASA power data from the year 1979 to 2023.

The study analysed rainfall and temperature patterns in the Coastal and Hillyzones of Karnataka using probability distribution analysis. This approach identified the best-fitting distributions to capture variability and trends in weather data. Key parameters such as shape, scale and location were estimated to describe the characteristics of rainfall and

temperature patterns. Properties and parameters of probability distributions used are described in Table 1.

#### RESULTS AND DISCUSSION

Table 2 presents descriptive statistics of rainfall, minimum and maximum temperatures for the Hilly and Coastal zones of Karnataka, highlighting their distinct climatic characteristics.

The Hilly Zone recorded a mean rainfall of 2043.8 mm with a standard deviation of 319.6 mm, reflecting its proximity to the Western Ghats. The Coastal zone receives slightly less rainfall, with a mean of 1863.7 mm and a standard deviation of 304.8 mm. Minimum temperatures in the Hillyzone average with 18.9°C, ranging from 18.1 to 19.9 °C, while the Coastal zone records a higher mean minimum temperature of 22.2 °C, ranging from 21.4 to 23.3 °C, influenced by the moderating effect of the Arabian Sea.

Maximum temperatures are higher in the Hillyzone, with a mean of 33.1 °C and values ranging from 31.8 to 33.6 °C. In contrast, the Coastal zone showed a slightly lower mean maximum temperature of 32.4 °C, but with a broader range from 30.6 to 34.7 °C, reflecting a greater variability due to land-sea interactions.

The Fig. 1, illustrates the probability distribution of annual rainfall in Karnataka's Hilly zone (1979-2023), modeled using the Weibull minimum distribution. Rainfall data is grouped into intervals (e.g., 1400-1600 mm), with a histogram showing probability densities, and the red Weibull curve providing a close fit. Parameters such as the shape (4.56), scale (824.76), and location (1336.4) indicate that rainfall is concentrated between 1800-2400 mm, peaking at 2000-2200 mm. This distribution reflects the region's topography and frequent high rainfall events, while low (<1600 mm) and extremely high (>2600 mm) rainfall remains rare.

These findings align with findings by Madaddi *et al.* (2023), which highlighted variability in southwest

**TABLE 1**  
**Properties and Parameters of Probability Distributions**

Distribution	Properties	Parameters
Normal Distribution	<ol style="list-style-type: none"> <li>1. Symmetry: Perfectly symmetric around the mean.</li> <li>2. Bell-Shaped Curve: PDF follows a bell-shaped curve.</li> <li>3. Mean, Median, Mode: All are equal and at the center.</li> <li>4. Asymptotic: Tails approach but never touch the x-axis.</li> <li>5. Defined by mean (<math>\mu</math>) and standard deviation (<math>\sigma</math>).</li> </ol>	<ul style="list-style-type: none"> <li>• Mean (<math>\mu</math>): Central location.</li> <li>• Standard Deviation (<math>\sigma</math>): Determines spread</li> </ul>
Gamma Distribution	<ol style="list-style-type: none"> <li>1. Skewness: Positively skewed.</li> <li>2. Defined by shape (<math>\alpha</math>) and scale (<math>\beta</math>).</li> <li>3. Special Case: <math>\alpha = 1</math> reduces to exponential distribution.</li> </ol>	<ul style="list-style-type: none"> <li>• Shape (<math>\alpha</math>): Controls shape.</li> <li>• Scale (<math>\beta</math>): Controls spread.</li> </ul>
Weibull Distribution	<ol style="list-style-type: none"> <li>1. Flexibility: Models increasing, decreasing, or constant hazard rates.</li> <li>2. Defined by scale (<math>\lambda</math>) and shape (<math>\kappa</math>).</li> <li>3. Special Cases: (i) <math>\kappa = 1 \rightarrow</math> exponential distribution; (ii) <math>\kappa = 3.4 \rightarrow</math> approximates normal distribution.</li> </ol>	<ul style="list-style-type: none"> <li>• Shape (<math>\kappa</math>): Determines shape.</li> <li>• Scale (<math>\lambda</math>): Determines scale.</li> </ul>
Lognormal Distribution	<ol style="list-style-type: none"> <li>1. Right-Skewed: Positively skewed.</li> <li>2. Multiplicative Property: The logarithm of the variable is normally distributed.</li> <li>3. Defined by mean (<math>\mu</math>) and standard deviation (<math>\sigma</math>) of log-normal.</li> <li>4. Non-Negative: Values are positive.</li> </ol>	<ul style="list-style-type: none"> <li>• <math>\mu</math>: Mean of <math>\log(X)</math>, location parameter.</li> <li>• <math>\sigma</math>: Standard deviation of <math>\log(X)</math>, scale parameter.</li> </ul>

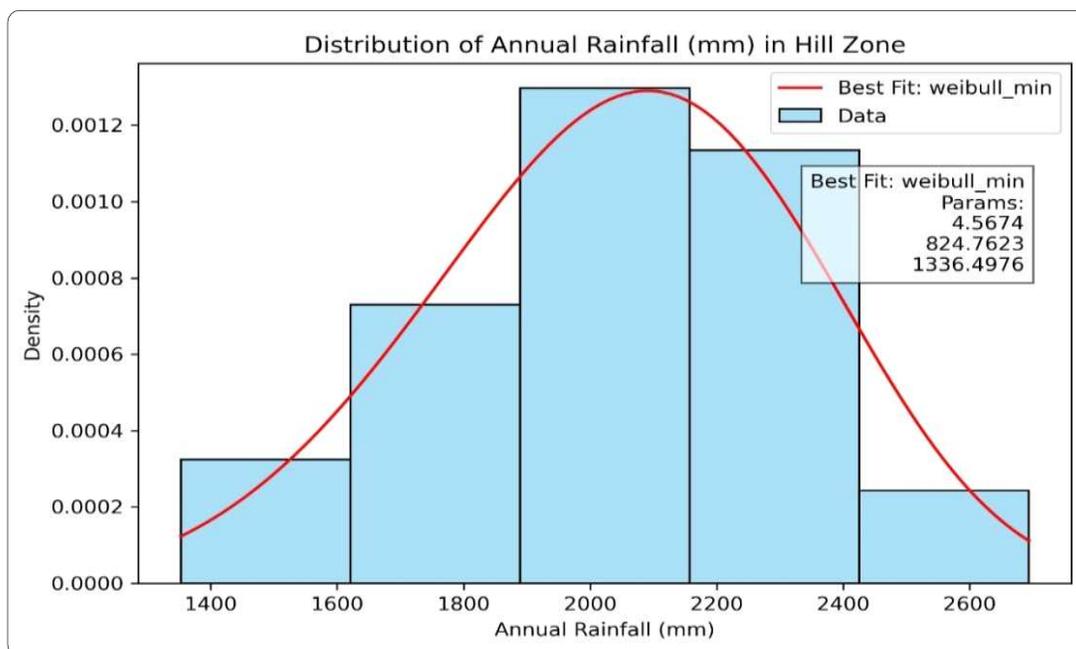


Fig. 1 : Probability distribution of rainfall in the Hillyzone (1979-2023)

**TABLE 2**  
**Descriptive statistics of rainfall and temperature for Hilly and Coastal zones of Karnataka**

Particulars	Hilly Zone	Coastal Zone
<i>Rainfall</i>		
Mean	2043.8	1863.7
SD	319.6	304.8
<i>Minimum temperature</i>		
Mean	18.9	22.2
SD	0.4	0.5
Max of min temperature	19.9	23.3
Min of min temperature	18.1	21.4
<i>Maximum temperature</i>		
Mean	33.1	32.4
SD	0.4	0.9
Max of max temperature	33.6	34.7
Min of max temperature	31.8	30.6

monsoon rainfall and moderate fluctuations during the rainy season, supporting the observed concentration of rainfall in the Hilly zone. Similarly, Rani *et al.* (2021) reported an increasing trend in

drought events, emphasizing the rarity of low rainfall (<1600 mm) in the region. Coastal Karnataka, including areas adjacent to the Hilly zone, had also experienced declining precipitation in North Canara.

The Fig. 2 illustrates the probability distribution of annual rainfall in Karnataka’s Coastal Zone (1979-2023), modeled using the normal distribution. Parameters include a mean of 1863.7 mm, representing the average annual rainfall and a standard deviation of 297.91 mm, reflecting rainfall variability. Rainfall is primarily concentrated between 1600-2200 mm, peaking around the mean value of 1863 mm. The symmetric normal distribution indicated a balanced deviation from the mean. This study aligns with Singh *et al.* (2014), who reported a declining trend in rainfall across Coastal Karnataka, including reductions of 17.69 mm/day/100 years in Mangalore and 22.38 mm/day/100 years in Udupi, reflecting long-term climatic shifts. Similarly, Madaddi *et al.* (2023) noted consistent rainfall with low variability, which supports the observed concentration around the mean and stability in overall patterns. However, findings by Rani *et al.* (2021) highlighted a significant recent decline in rainfall attributable to climate variability, emphasizing the critical need for adaptive strategies.

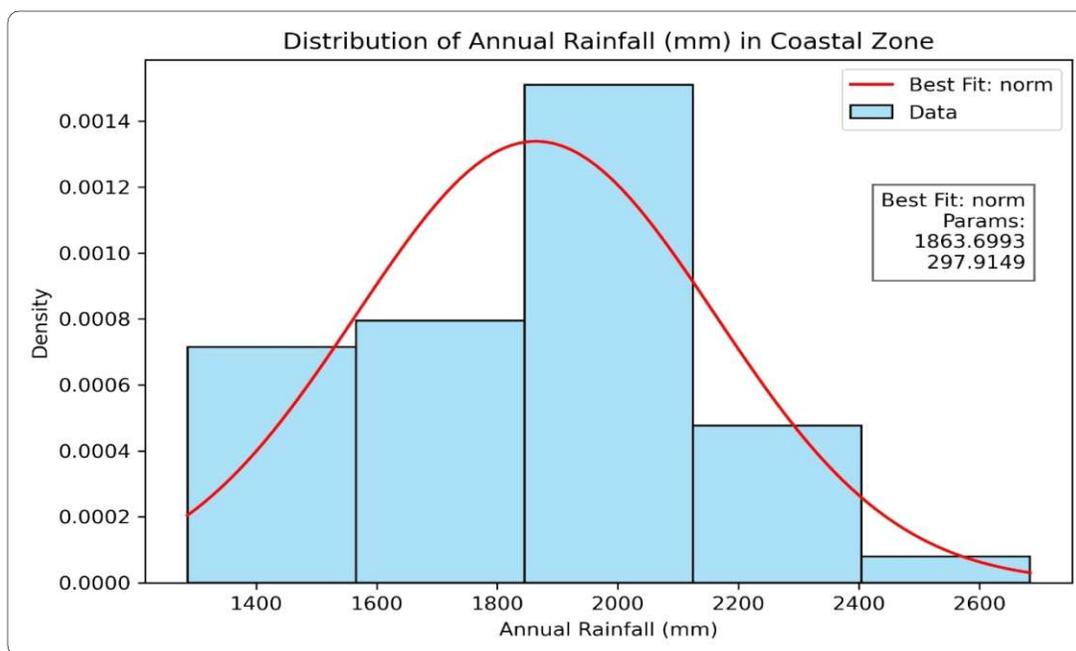


Fig. 2 : Probability distribution of rainfall in the Coastal Zone (1979-2023)

The analysis underscores the normal distribution's effectiveness in modeling rainfall patterns in the Coastal Zone. These patterns are heavily influenced by the region's proximity to the Western Ghats and the Arabian Sea, which shape both the average rainfall levels and the variability around them.

The Fig. 3, shows the probability distribution of maximum temperature in Karnataka's Hilly Zone (1981-2022), modeled with a Weibull minimum distribution. Key parameters include a shape parameter (3.22), indicating moderate skewness; a scale parameter (31.55), highlighting the typical temperature range and a location parameter (1.25), representing the minimum temperature. Maximum temperatures are mainly concentrated between 32.25°C and 32.75°C, with rare extremes below 32.00°C or above 33.25°C. This study aligns with findings of Singh *et al.* (2014), who observed an increase of 0.146°C/100 years in maximum temperatures in North Kanara, reflecting a consistent warming trend in the Hilly Zone. Furthermore, Madolli (2014) noted persistent warming patterns across the region, corroborating the gradual upward shift in temperature distributions observed in this analysis.

The Fig. 4, presents the probability distribution of maximum temperatures in Karnataka's Coastal Zone (1981-2022), modeled using a gamma distribution. Key parameters include the shape (16.66), scale (28.66) and location (0.22), representing the distribution's pattern, spread and minimum value. Maximum temperatures are predominantly between 31.5°C and 33.5°C, peaking around 32.0°C. Temperature trends indicate a rise in minimum temperatures by 0.141°C and 0.111°C/100 years in Mangalore and Udupi, respectively (Singh *et al.*, 2014). This aligns with findings by Dhorde *et al.* (2017), which highlight fewer extreme temperature events in coastal regions, emphasizing the relative stability of temperature patterns in the Coastal Zone despite long-term warming trends.

The Fig. 5, illustrates the probability distribution of minimum temperatures in Karnataka's Hilly Zone (1981-2022), modeled using a lognormal distribution. Key parameters include shape (0.15), indicating slight asymmetry; scale (16.23), reflecting central tendency; and location (2.66), denoting the minimum offset. Minimum temperatures are primarily concentrated between 18.75°C and 19.25°C, peaking around 19.00°C, with rare occurrences below 18.50°C or

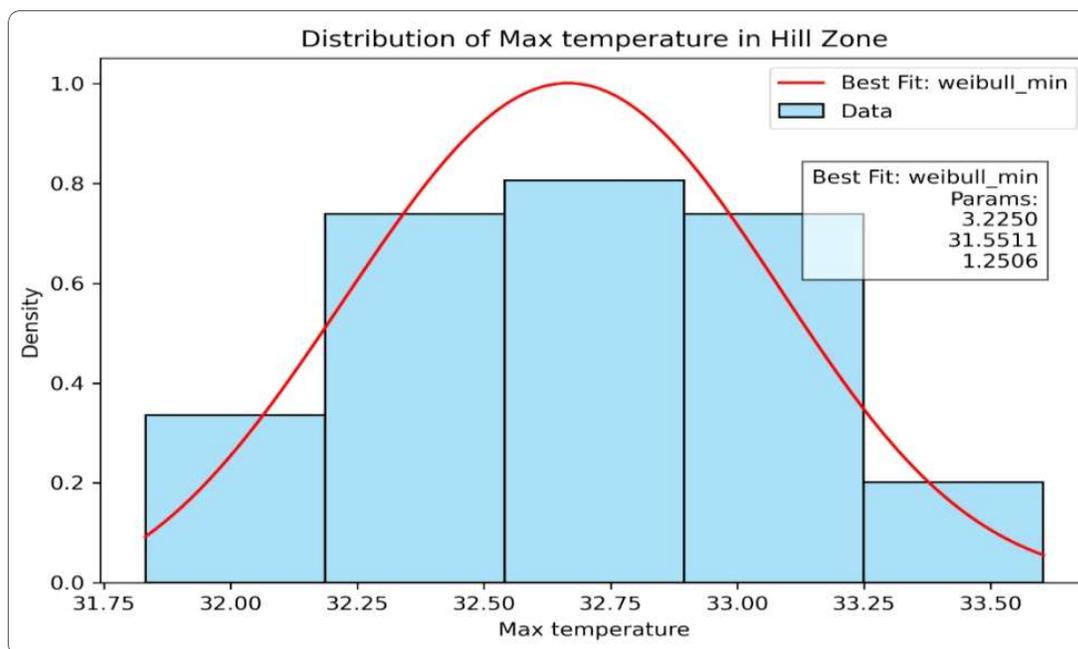


Fig. 3 : Probability Distribution of maximum temperature in the Hilly Zone (1981-2022)

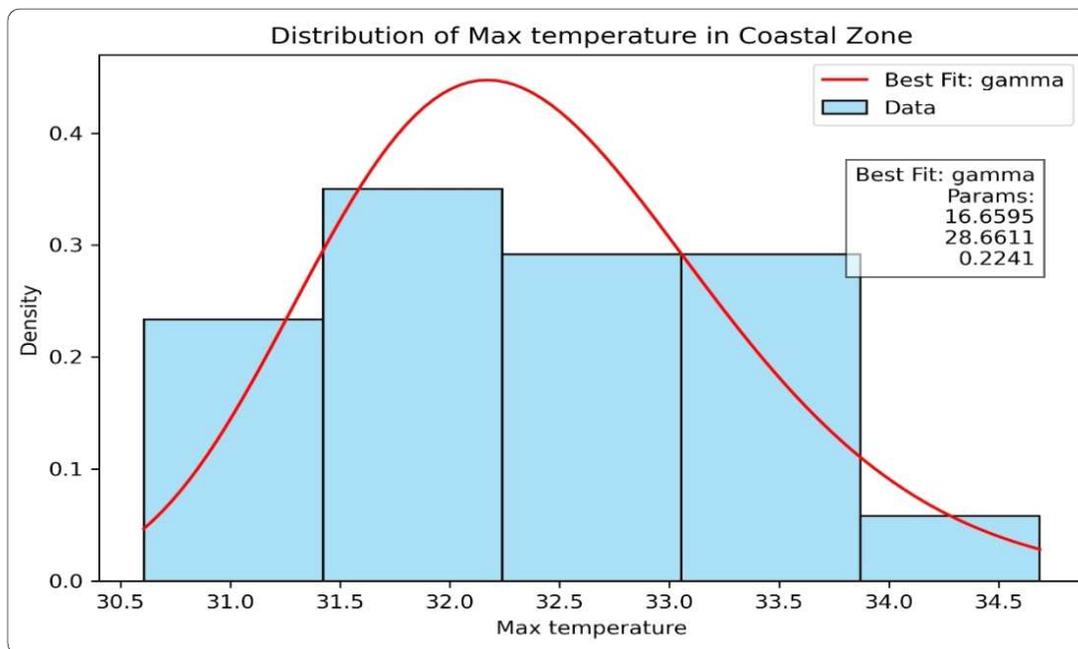


Fig. 4 : Probability distribution of maximum temperature in the Coastal Zone (1981-2022)

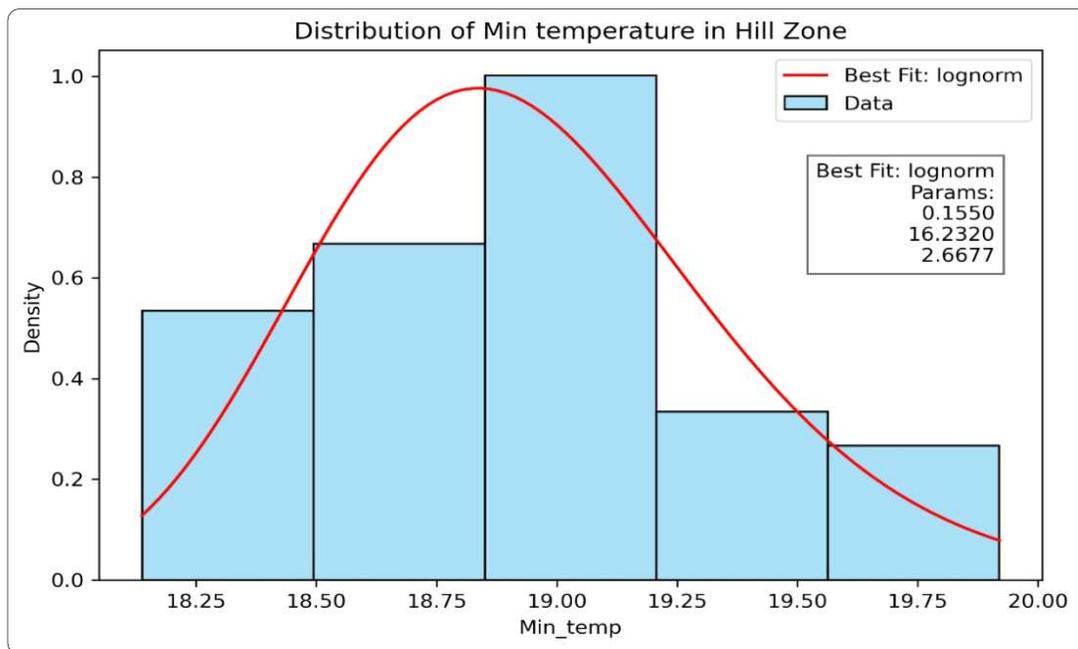


Fig. 5 : Probability Distribution of minimum temperature in the Hilly Zone (1981-2022)

above 19.50°C. This consistent temperature range aligns with Singh *et al.* (2014), who reported a rise of 0.146°C/100 years in North Canara, underscoring the gradual but consistent warming trend in the region.

The Fig. 6, illustrates the probability distribution of minimum temperatures in Karnataka’s Coastal Zone (1981-2022), modeled using a lognormal distribution. Key parameters include shape (0.25), indicating

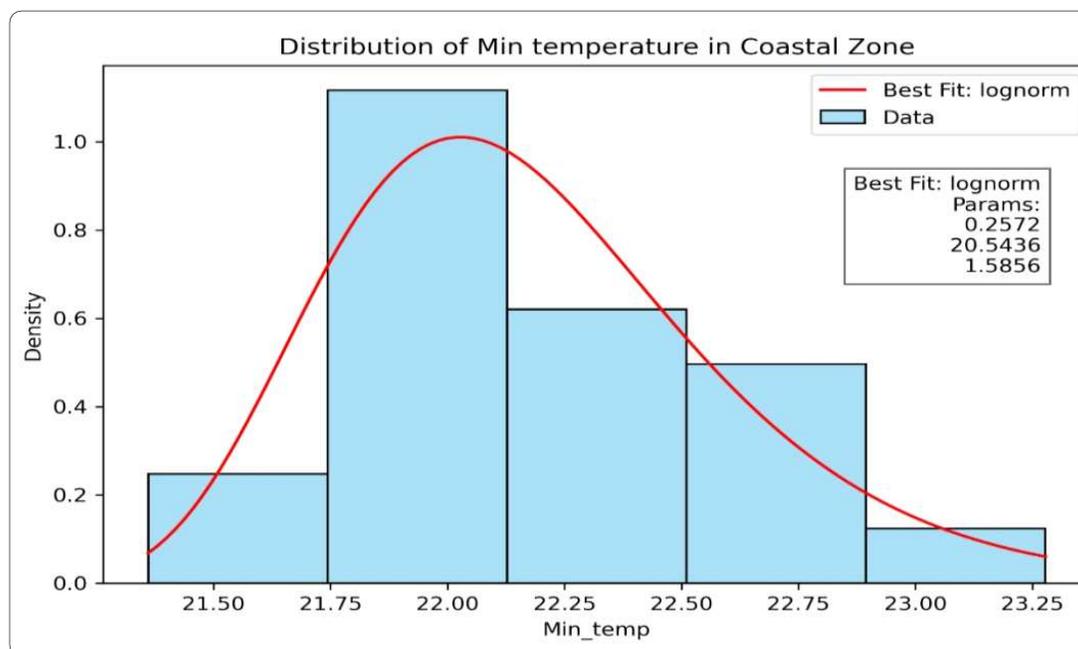


Fig. 6 : Probability distribution of minimum temperature in the Coastal Zone (1981-2022)

slight asymmetry; scale (20.54), reflecting central tendency and location (1.58), representing the minimum offset. Minimum temperatures are mainly concentrated between 21.75°C and 22.50°C, peaking around 22.00°C, with rare occurrences below 21.50°C or above 23.00°C.

This stable temperature range aligns with observations by Singh *et al.* (2014), who noted gradual increases of 0.141°C/100 years in Mangalore and 0.111°C/100 years in Udupi, reflecting the region's long-term warming trends. Additionally, Dhorde *et al.* (2017) emphasized the Arabian Sea's moderating influence, which helps maintain this relatively stable temperature range while mitigating extremes.

The analysis of rainfall and temperature patterns in Karnataka's Coastal and Hilly Zones highlights notable climatic characteristics and trends. Rainfall in both zones is concentrated within specific ranges, but a declining trend has been observed over the years, signaling the need for improved water resource management and climate adaptation strategies.

Maximum and minimum temperatures in both regions exhibit stable patterns within narrow ranges but show

a gradual warming trend over time. These changes underline the impact of climate variability on agricultural productivity and ecosystem stability, necessitating proactive measures like adopting climate-resilient crops and enhancing conservation efforts. Overall, the findings emphasize the importance of understanding climatic trends for sustainable resource management and effective planning in response to evolving climate challenges.

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