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Spatial Analysis of Rainfall Distribution in Serang City Using the Isohyet Method (Period 2020-2024)

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Abstract

High and uneven rainfall distribution in Serang City frequently leads to hydrological problems, particularly flooding. The objective of this study is to analyze the spatial rainfall distribution in Serang City from 2020 to 2024 using the Isohyet method. The secondary rainfall dataset was obtained from three rainfall observation stations: Class 1 Serang Meteorological Station, BPTPH Sawah Luhur Station, and BRMP Ciruas Station. Data normality was evaluated using the Rainfall data from 2020 to 2024 at the Class 1 Serang Meteorological Station are normally distributed ($p > 0.150$ KS = 0.077). Meanwhile, the Sawah Luhur BPTPH and BRMP Ciruas stations exhibit KS statistics of 0.166 and 0.146, respectively, with p-values reported as > 0.010, indicating that the assumption of normality for these datasets requires further verification at the 0.05 significance level. The analysis shows that the average monthly rainfall in Serang City is relatively high (>100 mm/month). The highest average rainfall was recorded at the Class 1 Meteorological Serang (152.7 mm). The spatial mapping results based on the Isohyet approach show that rainfall distribution within the study area is relatively homogeneous. However, higher rainfall intensity is observed in the western region (Taktakan), influenced by orographic factors, while the northern region (Kasemen) records relatively lower rainfall intensity. These findings provide important information for understanding rainfall patterns and supporting hydrological management in Serang City. This study provides important baseline data for flood mitigation and urban drainage planning in Serang City.

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INTRODUCTION

Rainfall is one of the crucial of climate, defined as the volume of water that falls onto a flat ground surface within a specific period of time, such as daily, monthly, or annual intervals (Gita Ayu Windari dan Sudarti, 2024). Rainfall is generally measured as the depth of water (mm) accumulated on a horizontal surface. Monitoring rainfall elements data is essential in hydrological studies because high rainfall intensity often serves as a primary factor triggering flood disasters, which have widespread impacts on the environment and human activities (Ruswanti, 2020).

In Serang City itself, the annual rainfall is relatively high, ranging from 1500-2000 mm with an uneven distributon throughout the year (Dinas Lingkungan Hidup Kota Serang, 2023). Based on data from Badan Penanggulangan Bencana Kota Serang, 2025 annual rainfall is recorded to be relatively high, with a distribution pattern that is uneven throughout the year. The urgency of this research is based on records of significant flooding events that occurred in Serang City in early 2025, which disrupted community activities and caused damage to urban infrastructure. This condition indicates the need for a more comprehensive mapping of rainfall distribution to better understand the hydrological characteristics of the area as an effective step toward disaster mitigation.

Advances in Geographic Information System (GIS) technology have enabled the mapping of rainfall distribution areas to be conducted more effectively using software such as ArcGIS. One technique recognized for its high precision is the Isohyet method, which generates contour lines connecting points of equal rainfall intensity through spatial interpolation (Nurhijriah et al., 2022). While previous studies often rely on broad regional averages, there is a significant research gap in localized mapping that accounts for specific topographic influences. This study addresses this gap by utilizing RBI (Rupa Bumi Indonesia) Maps as a geomorphological baseline and Minitab for statistical validation, variables that are crucial yet often overlooked in standard spatial modeling.

The urgency of this research stems from the increasing unpredictability of localized weather patterns, where accurate rainfall measuring instruments at meteorological stations become the only reliable source for valid primary data (Abdillah et al., 2020). By synthesizing these technical variables into a high-resolution Isohyet model, this research provides a necessary tool for more precise hydrological risk assessment and water resource management that large-scale models cannot provide

While several studies have addressed regional rainfall patterns in Banten, specific high-resolution spatial mapping for Serang City remains limited. Most existing research relies on broad-scale Thiessen Polygon methods which may overlook local topographical influences. This study addresses this gap by utilizing the Isohyet method combined with IDW interpolation to provide a more nuanced visualization of rainfall gradients (Susanto et al., 2024). By identifying specific high-intensity zones, this research offers a more precise tool for urban drainage planning in Serang City

Based on this background, this study aims to Spatial Analysis of Rainfall Distribution in Serang City using the Isohyet Method (Periode 2020–2024). Through this study, it is expected to obtain comprehensive information and spatial visualization that provide a clear representation of rainfall distribution in Serang City, which can serve as a basis for flood risk management and regional spatial planning by relevant authorities.

RESEARCH METHODS

This study was conducted in the administrative area of Serang City. From a geographical perspective, Banten Province is positioned between 6°7'–6°21' South Latitude and 106°7'–106°25' East Longitude. The research area includes six districts: Cipocok Jaya, Curug, Kasemen, Serang, Taktakan, and Walantaka.

Figure 1. Administrative Map of Serang City

The study is based on secondary data, with the analysis conducted for the five-year period from 2020 through 2024. Besides annual rainfall data, the dataset also includes the geographic coordinates of each location where rainfall stations or observation posts are situated. Furthermore, data derived from the Rupa Bumi Indonesia (RBI) Topographic Map are incorporated. **Table 1** below presents the types of data and their respective sources.

Table 1. Classification and Sources of Research Data

No	Type of Data	Source
1	Rainfall Data	Station Meteorologi Class 1 Serang, BPTPH Sawah Luhur Rainfall Station, BRMP Ciruas Station
2	Rain Post Coordinate Data	Station Meteorologi Class 1 Serang, BPTPH Sawah Luhur Rainfall Station, BRMP Ciruas Station
3	RBI Map	Geospatial Information Agency (BIG)

This study uses daily rainfall data for a five-year period (2020-2024) obtained from three observation points: Station Meteorologi Class 1 Serang, the Banten Provincial Food Crops and Horticulture Protection Center at BPTPH Sawah Luhur Rainfall Station, and the BRMP Ciruas Station. Although the number of stations is limited, the selection of these three points is based on the availability of continuous historical data and geographic representation covering the northern, central, and western regions of Serang City to minimize spatial bias in the Isohyet method.

The gathered data underwent a comprehensive analysis phase, including monthly rainfall calculations, statistical detection using Minitab software, and spatial mapping via ArcGIS. The spatial interpolation was conducted using the Inverse Distance Weighting (IDW) method, which is expressed as:

$$P_p = \frac{\sum_{i=1}^{n} \frac{P_i}{d_i^k}}{\sum_{i=1}^{n} \frac{1}{d_i^k}} \quad (1)$$

Where P_i is the rainfall at station i, d_i is the distance, and k is the power parameter. Despite the limitation of having only three primary stations, the data was cross-validated with historical regional trends to ensure reliability.

Due to the limited density of the observation network (n = 3), a formal quantitative validation such as Root Mean Square Error (RMSE) was not conducted, as the sample size is below the statistically significant threshold for rigorous cross-validation. However, the IDW method was deliberately chosen as it is more robust for sparse datasets compared to other interpolation techniques like Kriging, which requires a larger sample size for variogram modeling. To ensure reliability, the resulting Isohyet patterns were verified qualitatively by comparing the patterns with regional topographic features from RBI (Rupa Bumi Indonesia) Maps. This constraint is recognized as an inherent research limitation, and thus, the results provide a localized spatial baseline for rainfall distribution in Serang City rather than a high-resolution regional climate model. The flow diagram of the research process can be seen in Figure 2.

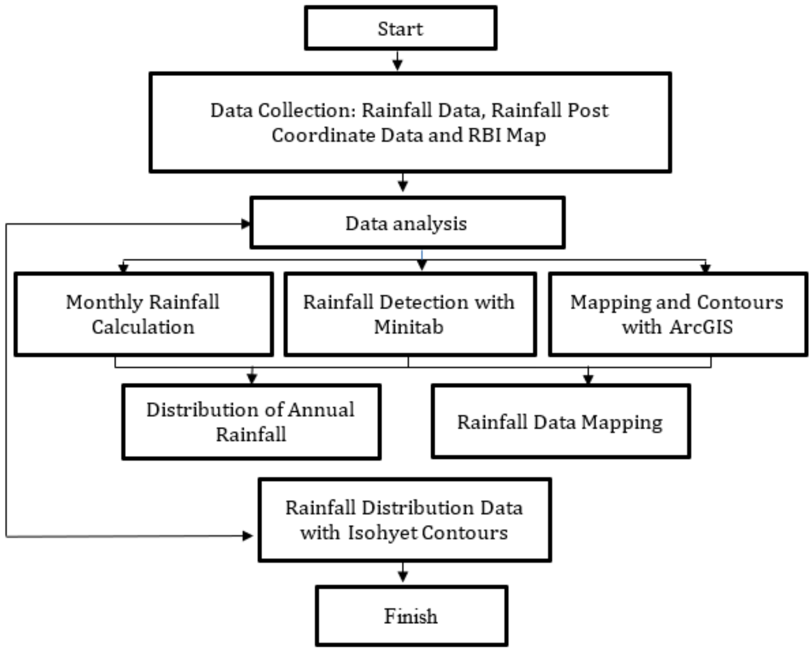

Figure 2. Research Flow Diagram

The research methodology is systematically executed as illustrated in the flow diagram in Figure 2. The process begins with the data collection phase, gathering primary inputs such as historical rainfall data, rainfall post coordinates, and the Indonesian Topographic Map (RBI). These datasets are then subjected to a rigorous analysis phase involving three main components: monthly rainfall calculation, statistical rainfall detection using Minitab, and spatial mapping with contouring via ArcGIS.

The results of these analyses are further processed to determine the annual rainfall distribution and to generate spatial rainfall mapping. The final output of this methodology is the production of comprehensive rainfall distribution data visualized through Isohyet contours. Notably, the framework incorporates a feedback loop between the final mapping and the data analysis stage to ensure the precision and consistency of the resulting contours before the study is concluded.

RESULTS AND DISCUSSION

Average Rainfall

The rainfall data in this study were collected over a five-year period, from 2020 to 2024. The rainfall data for the Serang City area are presented below.

Table 2. Average Rainfall Data for 2020-2024 in mm

Rain Station	Year					Ave
	2020	2021	2022	2023	2024	
Station Meteorologi Class 1 Serang	167	152.8	143.4	116	184.4	152.7
BPTPH Sawah Luhur	128.7	159.4	99.7	85.9	119,5	118.6
BRMP Ciruas	153.5	152.4	114.1	114.8	156.1	138.2

Rainfall metrics delineated in Table 2 reveal mean precipitation across Serang City derived from three monitoring stations, with Station Meteorologi Class 1 Serang registering the preeminent five-year average of 152.7 mm. Aggregated observations from Serang Class 1 Meteorological Station, BPTPH Sawah Luhur Rainfall Station, and BRMP Ciruas collectively yield citywide averages exceeding 100 mm, signifying comparatively elevated precipitation regimes characteristic of West Java's coastal tropics (Rifqi Maulana et al., 2026).

This classification aligns with regional climatological benchmarks, where annual totals exceeding 1,800 mm implicit in sustained monthly precipitation above 100 mm characterize high-rainfall domains prone to pluvial hazards, as evidenced by Banten Province hydrological assessments (Yuningsih & Wibowo, 2024)

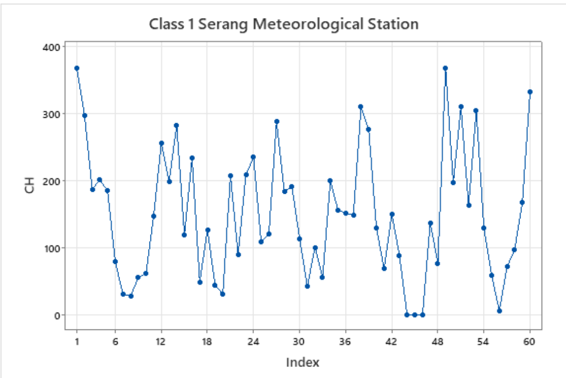

Figure 3. Rainfall Trend Graph For 2020-2024 mm, Class 1 Serang Meteorological Station

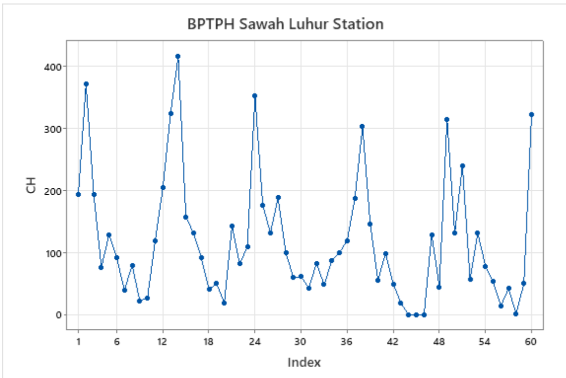

Figure 4. Rainfall Trend Graph For 2020-2024 mm, BPTPH Sawah Luhur Station

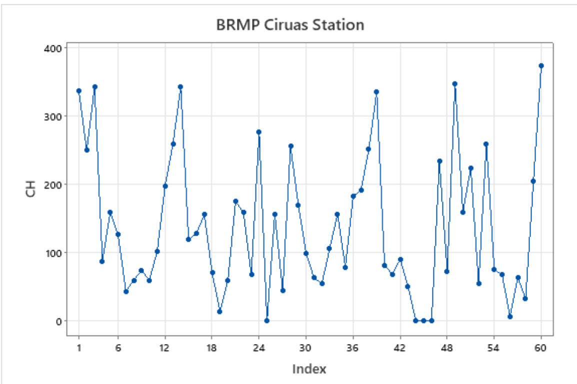

Figure 5. Rainfall Trend Graph For 2020-2024 mm, BRMP Ciruas Station

The time series graph of rainfall for the 2020–2024 period at Figure 3, Figure 4, Figure 5 shows monthly rainfall fluctuations during the 2020–2024 period at three stations, namely the Serang Class I Meteorological Station, BPTPH Sawah Luhur, and BRMP Ciruas. All three show a similar pattern, high rainfall occurs in certain months, then decreases sharply in others, thus forming a strong seasonal pattern. This pattern is consistent with the characteristics of Indonesia's monsoon climate, where rainfall tends to increase during the rainy season and decrease during the dry season (Mulsandi et al., 2021).

The Rainfall Trend Graph at the Class I Serang Meteorological Station shows significant variations in rainfall between months, with several peak rainfall levels approaching 300–380 mm and several periods with very low rainfall. This indicates that the Serang region experiences strong rainfall dynamics over time, resulting in uneven rainfall distribution throughout the year. In the Banten region, such variations are important because they demonstrate that a single rainfall station may not necessarily represent conditions across the entire region uniformly, especially when there are differences in local influences such as distance from the coast, land use, and topography (Febrianty D & Yuningsih, 2022).

The rainfall trend graph at the Sawah Luhur BPTPH (BPTPH Sawah Luhur) also shows a sharply fluctuating pattern, but with several peaks appearing more prominent during certain periods. This indicates intense rainfall events likely related to the peak of the rainy season or local convective events. Compared to the first graph, the pattern at Sawah Luhur appears quite consistent in showing wet and dry phases, confirming that rainfall in this area is strongly influenced by seasonal cycles and intermonthly variability (Tukidi, 2010)

The rainfall trend graph for the Ciruas BRMP shows a similar pattern, but with a wider range of values, including several months with low rainfall and several high spikes above 300 mm. This indicates significant monthly rainfall instability, making average analysis alone insufficient to explain rainfall distribution. For flat areas like Ciruas, rainfall patterns are also influenced by the spatial distribution of rain gauges and the local characteristics of the catchment area (Irawan et al., 2024).

The three graphs above show no extreme differences in the underlying pattern between stations, but there are differences in the magnitude of fluctuations and the location of peak rainfall. This indicates that rainfall at the Aerang Class 1 Meteorological Station, the Sawah Luhur BPTPH Station, and the Ciruas BRMP Station tends to be driven by the same regional factors, yet still exhibits local influences at each station. These results support the importance of using more than one station to describe regional rainfall distribution, as rainfall is highly spatial and temporal (Alfiandy & Permana, 2020).

Rainfall Distribution

Station Meteorologi Class 1 Serang

The results of rainfall distribution based on Figure 6 with observation data from the Station Meteorologi Class 1 Serang for the 2020-2024 period are shown as follows.

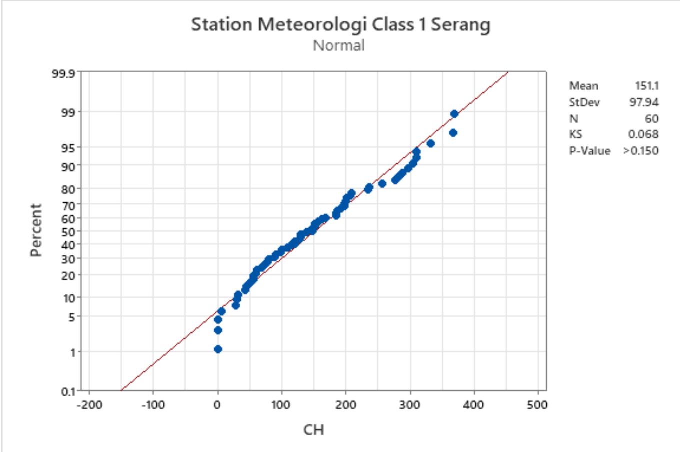

Figure 6. Results of the Smirnov Kolmogorov Rainfall Test for the 2020-2024 Period at the Station Meteorologi Class 1 Serang

Based on Figure 6, The rainfall data from 2020 to 2024 the Class 1 Serang Meteorological Station are normally distributed, as indicated by a p-value greater than 0.150 and a Kolmogorov Smirnov statistic of 0.077.

Station BPTPH Sawah Luhur

The results of rainfall distribution based on Figure 7 with observation data from the Sawah Luhur BPTPH Station for the 2020-2024 period are shown as follows.

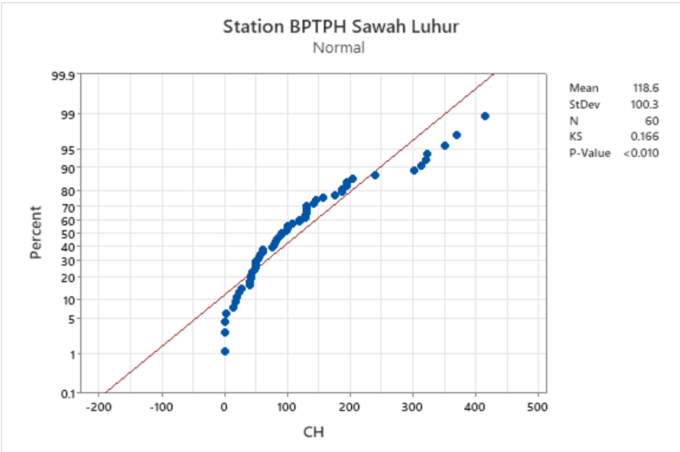

Figure 7. Results of the Smirnov Kolmogorov Rainfall Test for the 2020-2024 Period at the BPTPH Sawah Luhur Rainfall Station

Based on Figure 7, The rainfall data at the Sawah Luhur BPTPH Station from 2020 2024 period follows a normal distribution, as evidenced by a p-value exceeding 0.010 and a Kolmogorov Smirnov value of 0.166.

Station BRMP Ciruas

The results of rainfall distribution based on Figure 8 with observation data from the Ciruas BRMP Station for the 2020-2024 period are shown as follows.

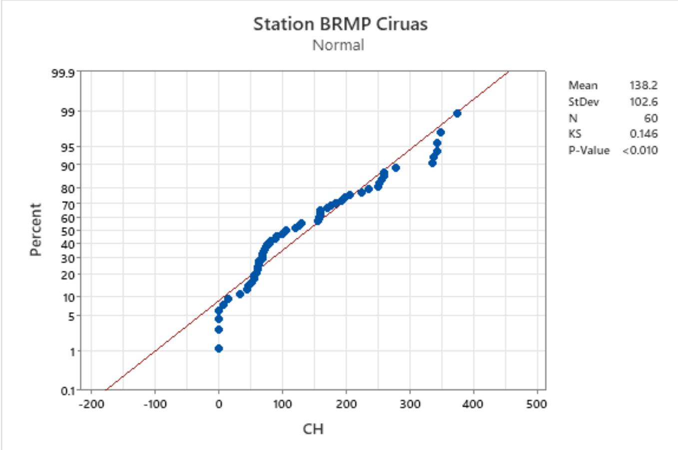

Figure 8. Results of the Smirnov Kolmogorov Rainfall Test for the 2020-2024 Period at the BRMP Ciruas Rainfall Station

Based on Figure 8, the rainfall data recorded at the BRMP Ciruas Station during the 2020–2024 period followed a normal distribution, as evidenced by a p-value exceeding 0.010 and a Kolmogorov–Smirnov value of 0.146.

Rainfall Distribution Pattern in Serang City

The rainfall distribution pattern was generated by applying the Isohyetal method. This method necessitates a sufficiently dense station network and contour mapping to illustrate the isohyet map. The rainfall isohyet analysis was conducted using the IDW function (Suharmanto & Supriyanto, 2025).Table 4 displays spatial data for several sub-districts in the Serang City area.

Table 4. Spatial Data of Serang City Area

Shape	District
Polygon ZM	Serang
Polygon ZM	Kasemen
Polygon ZM	Walantaka
Polygon ZM	Curug
Polygon ZM	Cipocok Jaya
Polygon ZM	Taktakan

The spatial data listed in Table 4 will undergo digitization. This process includes the generation of vector data to serve as the foundation for the research analysis.. Following the digitization of the Serang City area, rainfall data from three monitoring stations were analyzed using the IDW based Isohyet method to depict the overall rainfall distribution across the entire city. Figure 9 illustrates the results of rainfall integration in the Serang City area.

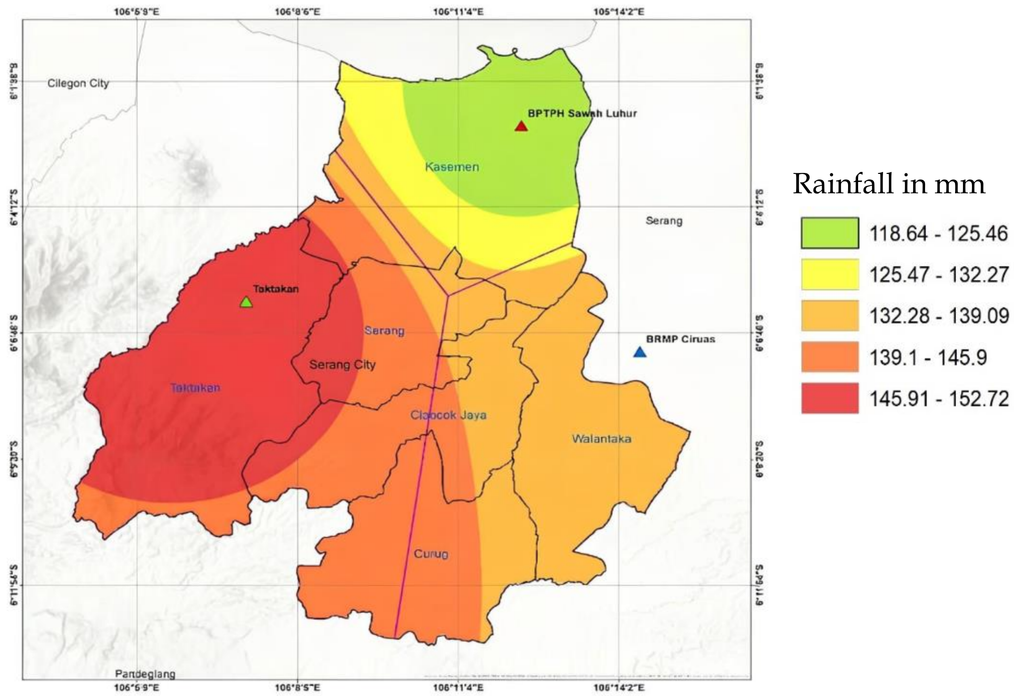

Figure 9. Isohyet Map of Serang City 2020-2024 in mm

The results of the rainfall distribution mapping in Serang City, as illustrated in Figure 9, depict a spatial distribution pattern where each measuring station characterizes its respective influence zone without significant overlap. The rainfall intensity is categorized into five distinct levels, visualized through a specific color gradient on the Isohyet map to provide a clear visual hierarchy. Areas with low rainfall intensity are depicted in green, while those with relatively low intensity are indicated by yellow. As the intensity increases to a moderate level, the map transitions to a dark yellow hue. Higher precipitation levels are represented by orange for quite high intensity and red for the highest rainfall intensity. This color gradation allows for an intuitive interpretation of the precipitation patterns and spatial trends across the different regions of Serang City.

The spatial heterogeneity of rainfall in Serang City, as evidenced by the higher intensities in the western districts such as Taktakan, highlights the significant role of local geomorphological factors. This phenomenon is primarily driven by the orographic effect, where the hilly topography forces moist air masses to ascend, triggering adiabatic cooling and enhanced localized precipitation. In contrast, the northern coastal characteristics of Kasemen District contribute to lower saturation levels compared to inland regions, a pattern that mirrors findings by (Afghani et al., 2023) regarding coastal inland precipitation gradients.

A critical finding of this study is the rainfall peak observed at Station Meteorologi Class 1 Serang in the city center. This intensification suggests that beyond natural topography, anthropogenic modifications to the urban landscape specifically the Urban Heat Island (UHI) effect act as a secondary convective driver. The increased surface roughness and thermal storage of urban structures likely induce stronger localized convection, resulting in higher accumulation than the more rural landscapes of Sawah Luhur and Ciruas. This observation aligns with the UHI-rainfall nexus theorized by (Mukti & Halide, 2026) and (Ninggar et al., 2023), confirming that urban centers in Indonesia are increasingly becoming "rainfall hotspots."

Comparing these results to broader tropical climatology studies, such as (Yulihastin et al., 2021), it is evident that Serang City exhibits a non-uniform rainfall distribution governed by a complex interplay between topography and urban micro-climates. While regions under the BPTPH Sawah Luhur and BRMP Ciruas stations show more stabilized accumulation, the dense Isohyet gradients near the city center indicate high risk zones for pluvial flooding. Consequently, these findings necessitate a shift in urban infrastructure management from generalized drainage standards to location-specific runoff mitigation. Strengthening drainage capacity in these high-intensity hotspots is not merely a technical requirement but a critical adaptive strategy for resilient urban planning under intensifying extreme weather conditions.

CONCLUSION

The findings indicate that rainfall distribution in Serang City is spatially variable, with the highest accumulation concentrated in the central urban area around the Class 1 Serang Meteorological Station. Kolmogorov–Smirnov test results show p-values ranging from 0.010 to 0.150, suggesting that not all datasets fully meet the normality assumption. However, the data remain suitable for spatial interpolation analysis. These results imply that rainfall patterns may be influenced by urbanization processes, particularly in densely developed areas. Therefore, it is recommended that the Serang City Government prioritize improving drainage capacity in the city center to mitigate potential flood risks associated with increased rainfall intensity.

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