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Analysis of cumulonimbus cloud evaporation in the tropospheric layer and the potential for high rainfall in Serang regency

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ABSTRACT

Rain occurs after passing through several stages of the process, which becomes a repetitive cycle; the stages passed are evaporation (evaporation), condensation, and precipitation. Clouds are an element that becomes a factor that affects weather changes, and their shape can change depending on the type. The type of cloud that can cause bad weather is the Cumulonimbus cloud. This research aims to review the volume of rainfall in the Serang Regency area, which can be used as material to predict the steps that must be taken to prevent an event. This research uses data from the Geospatial Information Agency and CHIRPS, which is then processed in ArcGIS 10.8 software. And also based on previous research literature. The data obtained is then analyzed in the ArcGIS application by overlaying one data with other data to find the areas that experience high rainfall. It was found that the average high rain occurred in the western region of Serang Regency.

Keywords: Arcgis, cumulonimbus clouds, rainfall

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INTRODUCTION

According to Kamus Besar Bahasa Indonesia, rain can be interpreted as water points falling in the air due to the cooling process. Rain occurs after passing through several stages of the process, which becomes a repetitive cycle; the stages passed are evaporation (evaporation), condensation, and precipitation. Evaporation is the process of evaporating water from a body of water into water vapor, which is influenced by pressure differences and the surface of the evaporation field (Jesiani et al., 2019). Condensation is the process of rising water vapor from evaporation into the atmosphere; this process occurs due to temperature differences based on the height of clouds in the air. Precipitation is the process of changing the form of water from vapor originating from the condensation process, which then descends to the earth's surface, which is caused by low air temperatures and condensation clouds that have reached the earth (Salsabila & Nugraheni, 2020). Rain is also related to rainfall. Rainfall is the average amount of water that falls to the earth's surface, measured daily, monthly, and annually in millimeters

(mm) (Rahmabudhi, 2024). Rainfall is influenced by topography, wind direction, temperature, and humidity. Indonesia has only two seasons (dry season and rainy season). Rainfall is expected to be very high during the rainy season, which usually lasts about six months (Susanto et al., 2020). Based on research conducted by Agustiarini et al. (2022), the rainy season occurs in November - April, when rainfall levels are very high.

Clouds are an element that becomes a factor that affects weather changes, and their shape can change depending on the type. The type of cloud that can cause bad weather is Cumulonimbus clouds. Cb clouds form when the sun intensively heats moist air in convergent areas and troughs (Abidin et al., 2023). Cumulonimbus clouds are shaped like large, heavy clumps consisting of cloud drops, large raindrops, and ice crystals on top. Cumulonimbus clouds are one of the causes of heavy rain accompanied by lightning, thunder, and storms (Salsabila & Nugraheni, 2020). Cumulonimbus clouds can reach temperatures of -100°C with the base of the cloud in the range of 100-600 meters, with a peak that can reach a height of 15 km or at the level of the troposphere (Nugroho & Fadlan, 2018). The troposphere is the lowest layer in the atmosphere and is where all changes in weather, temperature, wind, pressure, and humidity that we can feel take place (Yani et al., 2023). This research aims to find out how the formation of Cb clouds can lead to the potential for extreme weather, such as high rainfall accompanied by storms that can cause wet hydrometeorological disasters. In this research, calculations are also carried out related to the potential for high rainfall, which can be used as a reference in a preventive effort to prevent hydrometeorological disasters in certain areas.

Serang Regency is one of the regencies in Banten Province with an area of 1,467.35 km^2 (Raharjo, 2021). It has an area with lowlands and mountains with an altitude between 0-1,778 meters above sea level (Naryanto & Zahro, 2020). The Serang Regency area has diverse geographical conditions; hills, rice fields, and waters are scattered across several regions. Because of this condition, the Serang Regency is prone to floods, earthquakes, landslides, fires, tornadoes, and droughts. The Badan Penanggulangan Bencana Daerah (BPBD) of Serang Regency recorded that 2023 natural disasters were dominated by extreme weather with 34 incidents, floods with nine incidents, and land movements with six incidents (Administrator, 2023). Areas predicted to be prone to disasters include Cinangka District and Kopo District. An increase in the frequency of extreme weather events can potentially cause drought in the dry season, flooding in the rainy season, and increased rain intensity (Simanjuntak & Safril, 2020). Mapping areas with high rainfall using Geographic Information Systems (GIS) is carried out to analyze and estimate regions with high rainfall. GIS can process, combine, overlay, and store spatial and non-spatial data (Raharjo, 2021). The final results of GIS can be used as a basis for making preventive efforts against the occurrence of wet hydrometeorological disasters, such as floods (Breinl et al., 2021; Christian et al., 2020), landslides (Wahyuni & Susanti, 2023), extreme weather (Simbolon et al., 2023), and tornadoes caused by extreme weather in the form of high rainfall in certain areas (Suwarno & Niam, 2024).

RESEARCH METHODS

This research was conducted in Serang Regency, which is located between 5°50'00 "and 6°20'00" south latitude and 105°00'00 "and 106°22'00" east longitude with an area of 1,467.35

$km^{2,}$ which is divided into 29 sub-districts (BPS Kab. Serang, 2024).

In this research, the data used comes from sub-district administrative boundary data from the Geospatial Information Agency, which is spatial data, CHIRPS (Climate Hazards Group InfraRed Precipitation with Station Data) rainfall data for the 2016-2023 rainy season, which is temporal data, and literature review on the relationship between cumulonimbus clouds and high rainfall. Data analysis is obtained by processing rainfall classification based on data from the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) (Ruqoyah et al., 2023), which is then used as a reference in classifying rainfall spatially in ArcGIS 10.8 software. Rainfall classification is shown in Table 1.

Table 1. Rainfall Classification

Description	Average Rainfall (mm/day)
Very high	>400
High	301-400
Medium	101-300
Low	<100

Source: Muzaki et al., 2022; Pattipeilohy et al., 2021

Based on the rainfall classification in Table 1, if an area is declared to have an average rainfall exceeding a very high classification level, then the area can experience extreme rain, which has the potential for hydrometeorological disasters (Setiawan, 2021). Furthermore, based on the range of rainfall data used in the 2016-2023 rainy season, a prediction of the potential for high rainfall can be made, which can be used as a preventive effort to deal with hydrometeorological disasters in the Serang Regency area.

Data processing in ArcGIS 10.8 software is done by layering some of the data that has been obtained, such as regional data and rainfall data obtained from CHIRPS, then making a rainfall map using the Inverse Distance Weighted (IDW) interpolation technique followed by the reclassifying technique, where the use of these two techniques can create a map of the distribution of rainfall areas based on the classification given by BMKG.

In terms of determining the potential for high rainfall, the Mononobe equation is used to determine the intensity of precipitation in units of time (Meldiana et al., 2021).

$$I_t = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad (1)$$

It is the rainfall intensity for rainfall duration t (mm/h), t is the duration in hours, and R_{24} is the maximum rainfall for 24 hours (mm). This is done by converting daily rainfall data to hourly, and then hourly rainfall intensity is determined within 15, 30, 60, 90, 120, 180, 240, and 360 minutes.

High-intensity rain usually occurs over a short period and covers a limited area. Rain that covers a large area rarely occurs with high intensity but can last long. A combination of high rain intensity and long duration is rare. The strength of rain intensity varies from region to region. The strength of rain is related to the length of rain in short periods, such as 5 minutes, 30 minutes, 60 minutes, and hours. This short-term rainfall data can only be obtained through

automatic rain recording devices (Sofia & Nursila, 2019).

RESULTS AND DISCUSSION

CHIRPS rainfall data was used from the Climate Hazards Group as rainfall data from the 2016 to 2023 rainy season, which occurs from November to April, and then processed into an annual rainfall map of Serang Regency.

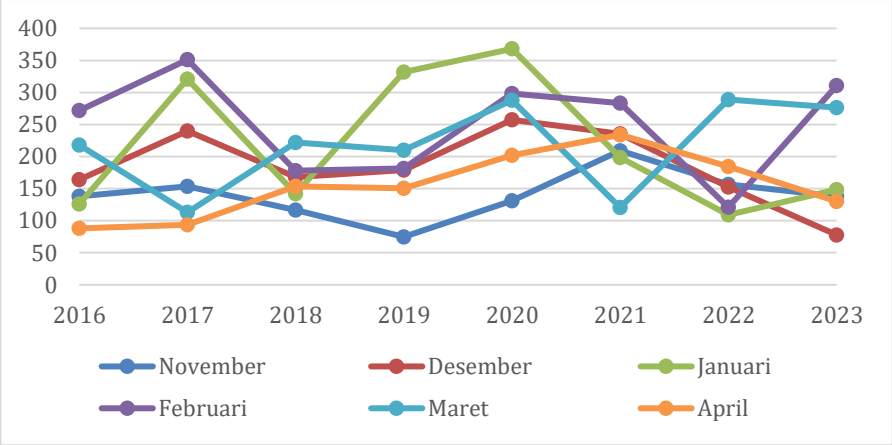

Figure 1. Rainfall Chart November-April 2016-2023

Based on Figure 1, it was found that in 2016, the highest rainfall occurred in February. In 2017, the highest rainfall occurred in February as well. Meanwhile, in 2018, high rainfall occurred in March. In 2019 and 2020, the highest rainfall occurred in the same month, namely January. In 2021, the highest rainfall again occurred in February. In 2022, the highest rainfall occurred in March. Then, in 2023, the highest rainfall again occurred in February. Overall, it was found that the highest rainfall in the November-April rainy season period 2016-2023 occurred in January 2020.

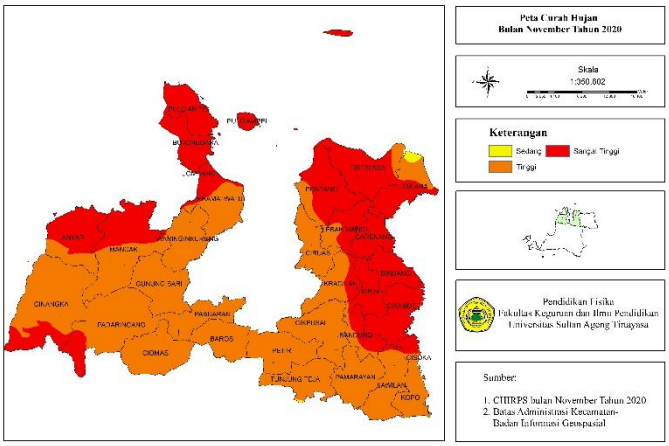

Figure 2. January rainfall area map in 2020

Based on the January 2020 rainfall data processed in ArcGIS 10.8 software, the resulting data shows that the Serang Regency area is divided into three parts based on rainfall levels: areas with moderate, high, and very high rainfall levels. Part of the Tanara sub-district and a

small part of the Tunjung Teja sub-district are classified as areas with moderate rainfall levels at 250-325 mm/day. Meanwhile, areas with high rainfall levels are located in parts of the Tanara sub-district, parts of the Tirtayasa sub-district, parts of the Pontang sub-district, parts of the Lebak Wangi sub-district, parts of the Kragilan sub-district, parts of Bandung sub-district, parts of Kramatwatu sub-district, parts of Mancak sub-district, parts of Anyar sub-district, part of Padarincang sub-district, part of Cinangka sub-district, part of Jawilan sub-district, part of Waringin Kurung sub-district, Ciruas sub-district, Cikeusal sub-district, Pamarayan sub-district, Tunjung Teja sub-district, Petir sub-district, Baros sub-district, Pabuaran sub-district, Ciomas sub-district, and Gunung Sari sub-district are at the high rainfall classification level with an average rainfall of 325-400 mm/day. Some areas are at the very high rainfall level with average rainfall reaching >400 mm/day, namely part of Tanara sub-district, part of Tirtayasa sub-district, part of Pontang sub-district, part of Lebak Wangi sub-district, part of Kragilan sub-district, part of Bandung sub-district, a small part of Jawilan sub-district, part of Kramatwatu sub-district, part of Mancak sub-district, a small part of Waringinkurung sub-district, part of Anyar sub-district, part of Cinangka sub-district, part of Padarincang sub-district, Pulo Ampel sub-district, Bojonegara sub-district, Jombang sub-district, Carenang sub-district, Binuang sub-district, Kibin sub-district, and Cikande sub-district. High rainfall is caused by factors such as physiographic conditions, wind patterns, climate (Supriyanti et al., 2024), and convective cloud conditions. Convective clouds are clouds that have an important role in the atmosphere. They can cause moderate to high-intensity rain, which can cause hydrometeorological disasters (Ninggar et al., 2023).

Based on the areas described, it is evident that the Serang Regency area experienced the highest average level of rainfall in January 2020 during the November-April rainy season period 2016-2023 (Ruhiat, 2022). Based on data provided by (Bidang Pengelolaan Data dan Sistem Informasi (PDSI), Pusdatinkom, 2024), in January 2020, there were 15 cases of hydrometeorological disasters in the form of floods, extreme weather, and landslides which were the result of the high rainfall that occurred. Efforts are needed to handle the annual disasters that often occur in the Serang Regency area. The government must collaborate with residents to make preventive efforts (Faradiba & Zet, 2020). Disasters due to low or high rainfall cannot be controlled. Even so, preventive efforts to prepare for disasters must be made to reduce the number of material and non-material victims (Faradiba, 2021b).

Rainfall is related to cumulonimbus clouds that can trigger thunder, lightning, heavy rain, and strong winds (Akhirta et al., 2023). Cumulonimbus clouds are a type of cloud that extends upwards, as they generate strong winds at the highest levels of the atmosphere. These clouds can also reach all layers with an area of 60,000 feet and have the highest position of all cloud types (Nugraheny, 2017). Cumulonimbus clouds have a life cycle that is not uniform in size and growth process, so in the tropics, these clouds are not always the same every day (Janwar & Munandar, 2015).

An analysis is carried out to predict the potential for high rainfall based on repeated events obtained from rainfall data that can form a pattern of repeated events (Djuraidah et al., 2019). Based on the analysis that has been done, Serang Regency is mostly classified as moderate to very high or extreme rainfall. After analyzing the potential for high rain in Serang Regency,

forecasts can be made for very heavy rainfall, which has the potential for hydrometeorological disasters, which will occur from January to February (Faradiba, 2021a).

CONCLUSION

The highest rainfall based on data obtained in the 8 years during the rainy season (November-April) was in January 2020, with average monthly rainfall reaching >350 mm. Areas at the very high rainfall classification level occur in the southwest, northwest, north, northeast, and east of Serang Regency. High rainfall can trigger potential hydrometeorological disasters in the Serang Regency area. The clouds that arise when extreme weather occurs are Cb clouds, which can trigger thunder, lightning, heavy rain, and strong winds. This research still needs further study because there are still limitations in the data obtained. In the next research, validation related to the prediction of the potential for high rainfall in the Serang Regency area can be carried out.

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