Original Article

Influence of Rainfall and Logistic Factors on Dengue Hemorrhagic Fever Cases in Mountainous Areas in Yogyakarta, Indonesia

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ABSTRACT

Objective

This research aimed to reveal the environmental risk factors for dengue hemorrhagic fever (DHF) in the mountainous areas of Yogyakarta Province, Indonesia.

Materials and methods

Two mountainous areas were chosen: Gunungkidul (GK), a relatively dry mountainous area, and Kulon Progo (KP), a wet mountainous area. The area of settlement and shoreline distance were determined using Geographic Information System (GIS). Rainfall data and rainy days were obtained from the Local Climatology Agency. Data for DHF were obtained from the Regency Health Office. The correlation between DHF cases and independent variables was analyzed using the Spearman rank test.

Results

From 2015 to 2019, 2,796 cases of DHF occurred in GK, and 775 cases in KP. The highest incidences were in the two capital cities. DHF cases correlated with residential area in GK (p = 0.000, r 0.615) and KP (p = 0.000; r 0.426), altitude in GK (p = 0.000, r -0.321) and KP (p = 0.046, r 0.312), rainfall in GK (p = 0.000, r 0.505) and KP (p = 0.016, r -0.309), and rainy days in GK (p = 0.002, r 0.394) and KP (p = 0,032, r -0.277). DHF cases did not correlate with shoreline distance in either region (GK p = 0.911; KP p = 0.068).

Conclusion

The DHF risk factors in dry and wet mountainous areas were similar, but some had different directions. Settlement area was positively correlated with DHF. Rainfall and rainy days were positively correlated with DHF in dry mountainous areas but negatively correlated in wet mountainous areas. Altitude was positively correlated with DHF in wet but negatively correlated in dry mountainous areas. The incidence of DHF in mountainous areas was not affected by shoreline distance.

Keywords

dengue hemorrhagic fever; environment, hilly area; risk factors

INTRODUCTION

Dengue hemorrhagic fever (DHF) is a vector-borne disease that has rapidly spread globally from tropical to sub-tropical areas.[1] The factors that influence its incidence are climate, especially temperature, humidity, and rainfall;[2] settlement conditions;[3] altitude;[4] and population density.[5] Population mobility also plays a role in the geographical spread of DHF.[2]

The influence of climate on DHF varies in each region in Indonesia. In Jakarta[6] , Semarang,[7] Yogyakarta,[8] and Bandar Lampung,[9] temperature, humidity, and rainfall affect DHF. However, in Manado Municipality, only humidity and rainfall affect it. [10] This indicates that the effect of risk factors on the incidence of DHF is geographically local.

The Special Region of Yogyakarta, a tourist and education destination in Indonesia, is endemic to DHF, ranking 9th in Indonesia in 2020 with 3.6I8 cases.[11] Bantul Regency reported the

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most cases in 2017, followed by Sleman Regency, Yogyakarta City, Gunungkidul, and Kulon Progo.[12] Although Kulon Progo and Gunungkidul have few DHF cases, an alarming increasing annual trend has been noted. Kulon Progo and Gunungkidul have similar topography in terms of many mountains and hills, with different regional characteristics. Gunungkidul is a dry mountainous area, whereas Kulon Progo is a wet mountainous area. Kulon Progo has fewer DHF cases than Gunungkidul.[12]

The Indonesian government's 2020–2024 National Medium-Term Development Plan and Strategic Plan emphasize DHF as a potential outbreak. To control it, community empowerment and sanitation are prioritized.[13, 14] This study aimed to identify risk factors for DHF in Yogyakarta Province's mountainous areas, which can be used to develop new measures to prevent the disease in Gunungkidul and Kulon Progo Regencies.

MATERIALS AND METHODS

This was an analytic observational ecological study with a cross-sectional approach. The dependent variable was the incidence of DHF. The independent variables were the distance from the beach, altitude, area of settlement, average rainfall, and rainy days. Temperature and humidity could not be analyzed concerning the incidence of DHF because data were not available.

The incidence of DHF was taken as the number of cases in each village from 2015 to 2019. The distance to the shoreline was the distance between the centroid of the village and the nearest shoreline in kilometers (km). The settlement area was the land area occupied by clustered settlements (km^2). The altitude was the centroid height of each village in meters above sea level (masl). The average rainfall was the average monthly rainfall from 2015 to 2019 for each district in millimeters (mm). Rainy days were defined as the number of rainy days in a month.

Data on the incidence of DHF from 2015 to 2019 were obtained from the Regency Health Office. Data on the distance to the beach were obtained using the distance function in Geographic Information System (GIS) from a digital map. Data on the area of settlements were obtained from the Regency or City Statistical Bureau. Altitude data were obtained by interpolation, using the GIS from contour maps. Data on average rainfall and rainy days were obtained from the Meteorology, Climatology and Geophysics Council of Yogyakarta Province. Spearman rank test correlation analysis was used to determine each variable's risk factor for DHF.

RESULTS

Gunungkidul. Gunungkidul Regency is located between 7°46' and 8°09' south latitude and 110°21' to 110°50' east longitude. It is bordered by Klaten and Sukoharjo Regency of Central Java to the north, Wonogiri Regency of Central Java to the east, the Indonesian Ocean to the south, and Bantul, Sleman Regency, and Yogyakarta City to the west. The total area of Gunungkidul Regency is recorded as 1,485.36 km^2. Semanu is the largest sub-district, making up around 108.39 km^2 or 7.30% of the area of Gunungkidul Regency.

Gunungkidul Regency has a large population. Based on the 2010 Population Census estimate, the population in 2012 was 680,406, comprising 328,878 males and 351,528 females. Gunungkidul Regency consists of 18 sub-districts, 144 villages, 1416 hamlets, and 6,844 groups of neighborhoods. The sub-districts include Panggang, Purwosari, Paliyan, Saptosari, Tepus, Tanjungsari, Rongkop, Girisubo, Semanu, Ponjong, Karangmojo, Wonosari, Playen, Patuk, Gedangsari, Nglipar, Ngawen, and Semin. Of the 144 villages, 141 villages are classified as self-help, and three are self-sufficient.

Gunungkidul Regency is divided into three development zones based on topographical conditions. The North Zone, Batur Agung, is hilly and has groundwater sources at depths of 6–12 meters. The Central Zone, Ledok Wonosari, is dominated by red Mediterranean and black grumous soil with limestone parent material. The Southern Zone, Mount Seribu, is karst and has limestone base rock with conical hills and underground rivers. This area includes sub-districts in the central Ponjong and southern Semanu sub-districts.

Gunungkidul has a tropical climate and hilly karst topography, causing less fertile land conditions for agricultural cultivation. The region experiences an average rainfall of 1,954.43 mm/year, with 103 days of rain per year. The wet season is 7 months, and the

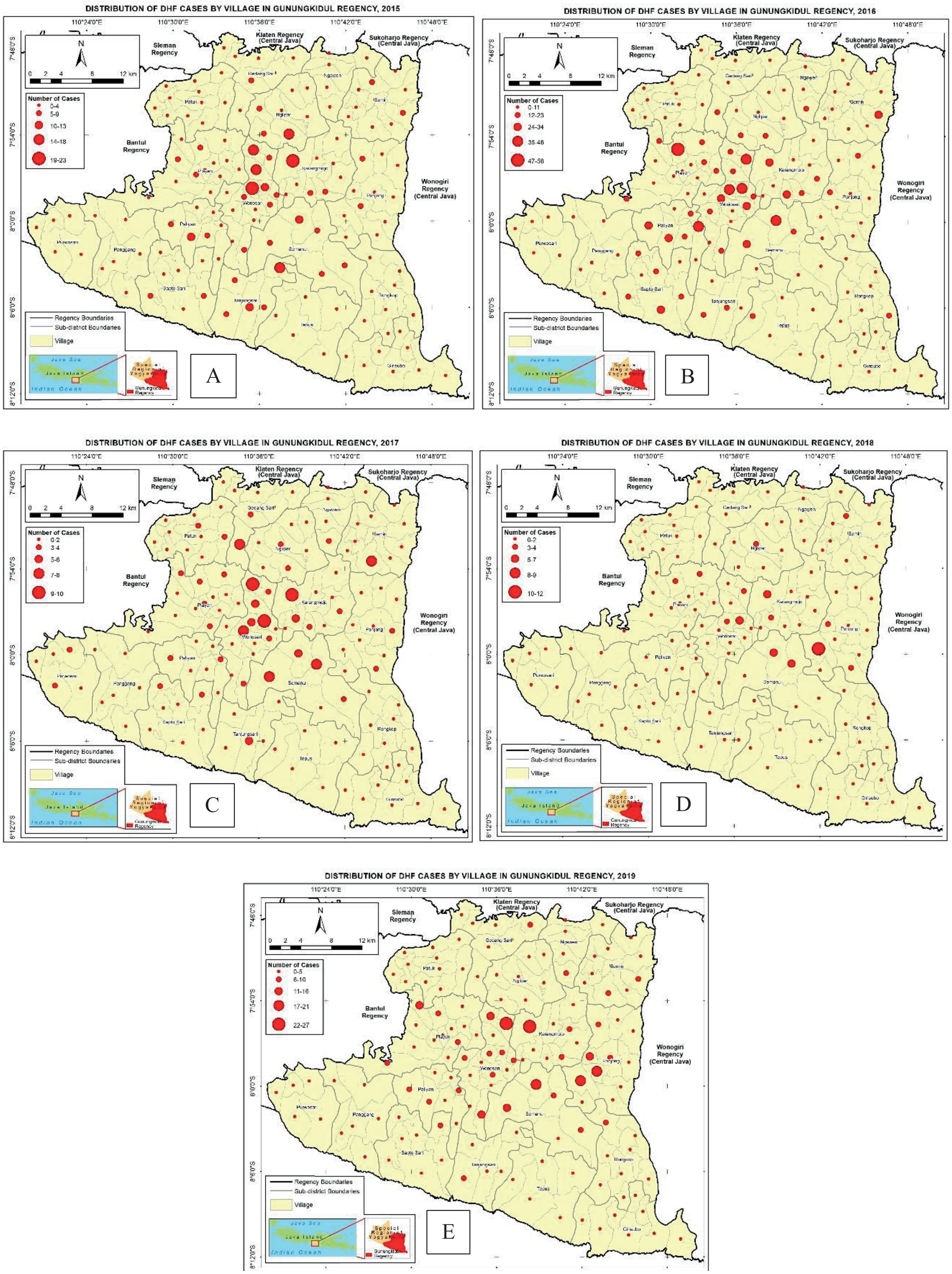

Figure 1A–E. Distribution of DHF in Gunungkidul, 2015–2019: A. 2015; B. 2016; C. 2017; D. 2018; E. 2019.

dry season is 5 months. The average daily temperature is 27.7°C, with relative humidity ranging from 80% to 85%.

Incidence of DHF. Data from the Regency Health Office showed that the total incidence of DHF from 2015 to 2019 was 2,796. The distribution description by sub-district is shown in Figures 1A–E. The incidence of DHF each year centered in the Central part of Gunungkidul, particularly Wonosari City and its surroundings.

4. FIGURES AND TABLES

Figure 2 shows that Wonosari had the highest DHF incidence, at more than twice the average sub-district incidence in Gunungkidul Regency. The development of cases from 2015 to 2019 is presented in Figure 3. The number of DHF cases in Wonosari (the capital city) was the highest among all sub-districts from 2015 to 2019, especially in 2016.

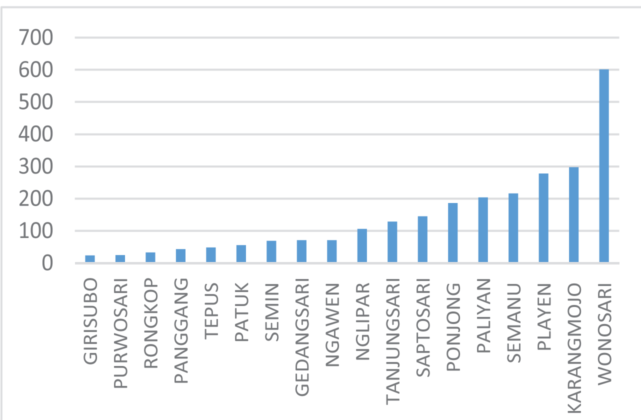

Figure 2. Distribution of DHF cases by sub-district in Gunungkidul Regency from 2015 to 2019.

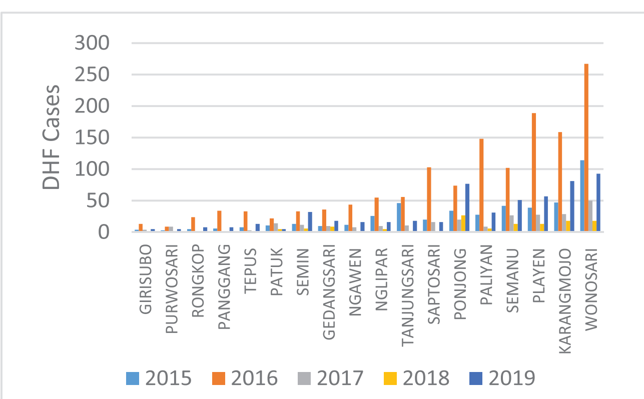

Figure 3. Development of DHF cases by sub-district in Gunungkidul Regency from 2015 to 2019.

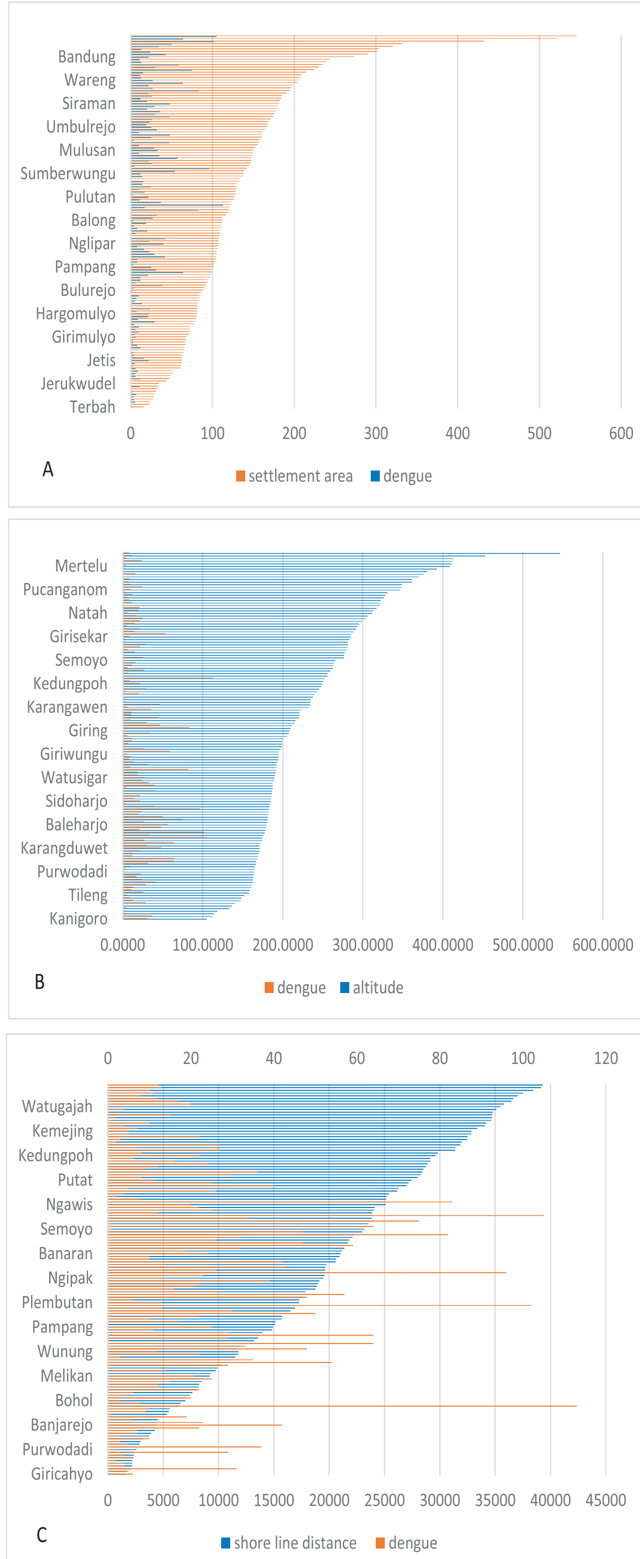

Figure 4. Relationships between DHF incidence and settlement (A), altitude (B), and shoreline distance (C) in Gunungkidul, 2015–2019.

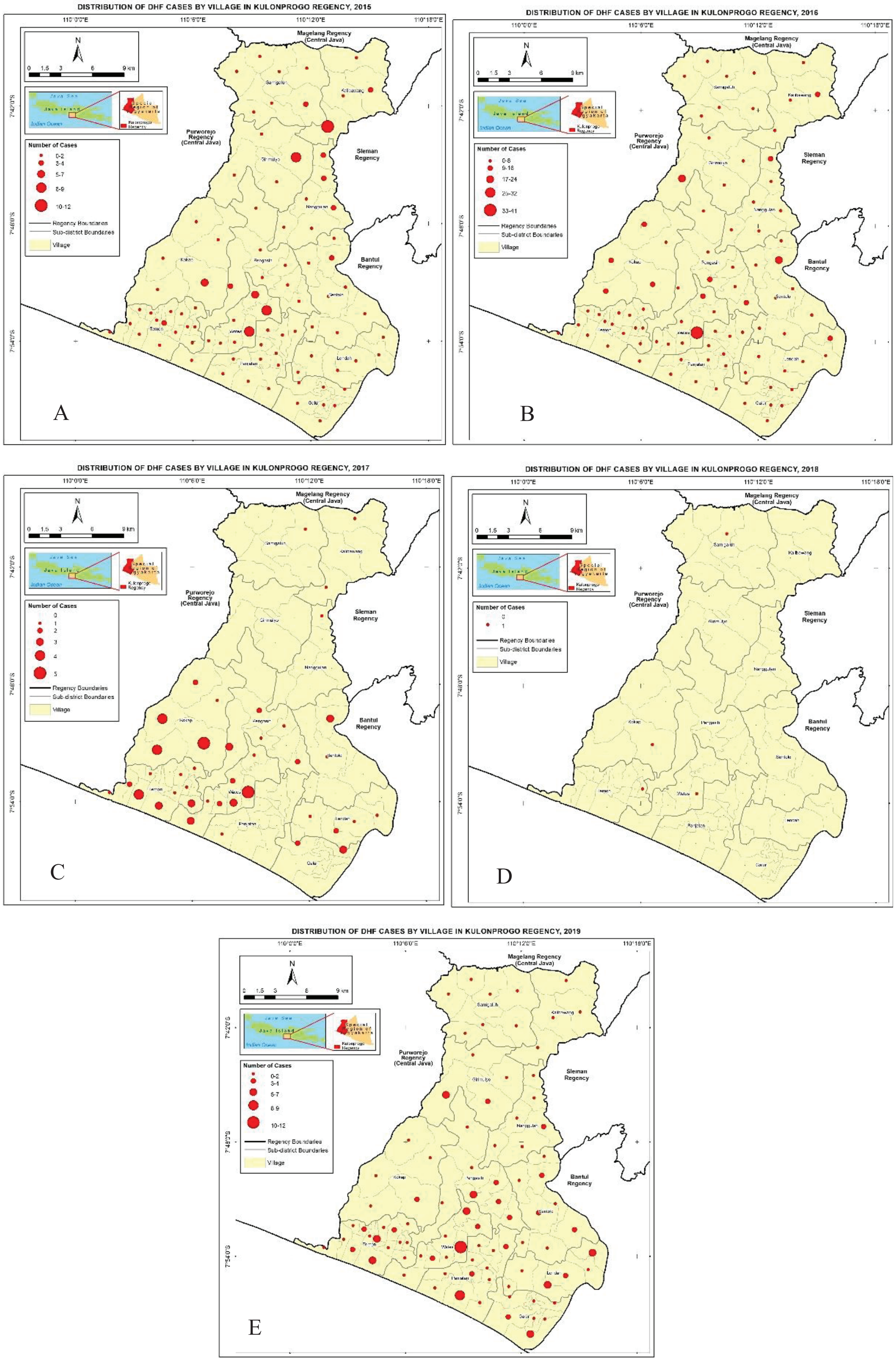

Figure 5A–E. Distribution of DHF in Kulon Progo Regency, 2015–2019: A. 2015; B. 2016; C. 2017; D. 2018; E. 2019.

Risk Factors: The study identified risk factors for DHF incidence in Gunungkidul Regency: altitude, settlement area, shoreline distance, rainfall, and rainy days. The results showed more cases in larger settlements and a significant relationship between altitude and DHF incidence (Figure 4 A–C; Table 1).

Table 1. Spearman rank test correlation between environmental risk factors and incidence of DHF in Gunungkidul.

Variable	p-value	Correlation coefficient (r)
Settlement area	**0.000**	**0.615**
Altitude	**0.000**	**-0.321**
Shoreline distance	0.911	0.009
Rainfall	**0.000**	**0.505**
Rainy days	**0.002**	**0.394**

Settlement area and altitude were linked to DHF incidence. Larger settlements had higher incidences, whereas higher altitudes had fewer cases. Rainfall and rainy days also affected DHF incidence. Shoreline distance did not significantly impact DHF incidence, suggesting that areas near and far from the coast had similar rates (Table 1).

Kulon Progo Regency: This western part of Yogyakarta, Indonesia, is bordered by Bantul, Sleman, Purworejo, Magelang, and the Indian Ocean. It covers 586.2754 km^2 and is divided into 12 sub-districts. The region has a varied topography, with altitudes ranging from 0 to 1,000 meters. The northern part includes the Menoreh highlands and hills, which are prone to landslides. The middle part is a transitional area from lowlands and hills, and the southern part is a lowland. The average annual rainfall is 2,150 mm, with 106 rainy days per year. The region includes seven springs, Sermo Reservoir, and the Progo River. The Progo River, Bogowonto River, and Glagah River help maintain groundwater conditions. The Sermo Reservoir and irrigation network are essential for agricultural and fishery production. The clean water needs of the community are managed by the Local Water Company.

Incidence of DHF: Data from 2015 to 2019 showed 775 cases of DHF in Kulon Progo, with a regional distribution as shown in Figure 5A–E. The incidence of DHF was consistently the highest in Wates, the capital city. In 2018, only four cases of DHF were recorded.

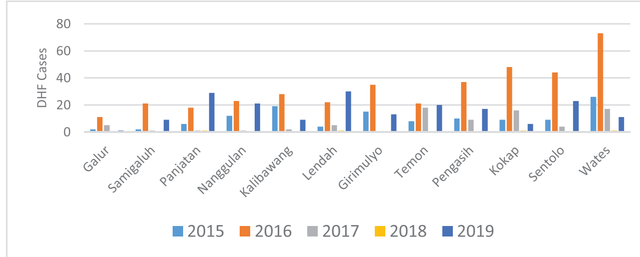

Figure 6 presents the incidence of DHF from 2015 to 2019. In 2016, Kulon Progo experienced a spike in cases in all regions, with the most cases in the city of Wates.

Figure 6. Development of DHF cases in Kulon Progo Regency by sub-district from 2015 to 2019.

Risk Factors: The relationship between several risk factors and the incidence of DHF is presented in Figure 7A–D. Altitude was positively correlated with the incidence of DHF, indicating that high-altitude areas had a higher incidence (Figure 7A). Figure 7B shows that in areas with a larger residential area, the incidence of DHF was higher. Figures 7C and 7D show that rainfall and rainy days in Kulon Progo were negatively correlated with DHF, indicating that areas with higher rainfall and more rainy days had a lower incidence of DHF. This is supported by the Spearman rank correlation test results, presented in Table 2.

Table 2 shows that only the shoreline distance was not significantly correlated with the incidence of DHF in the Kulon Progo Regency (p 0.068). Residential area, altitude, rainfall, and rainy days were correlated with moderate strength based on the correlation coefficient (r). Settlement area and altitude were positively correlated, whereas rainfall and rainy days were negatively correlated.

Table 2. Spearman rank correlation test results of risk factors for DHF incidence in Kulon Progo Regency.

Variable	p-value	Correlation coefficient (r)
Settlement area	**0.000**	**0.426**
Altitude	**0.046**	**0.312**
Shoreline distance	0.068	0.196
Rainfall	**0.016**	**-0.309**
Rainy days	**0.032**	**-0.277**

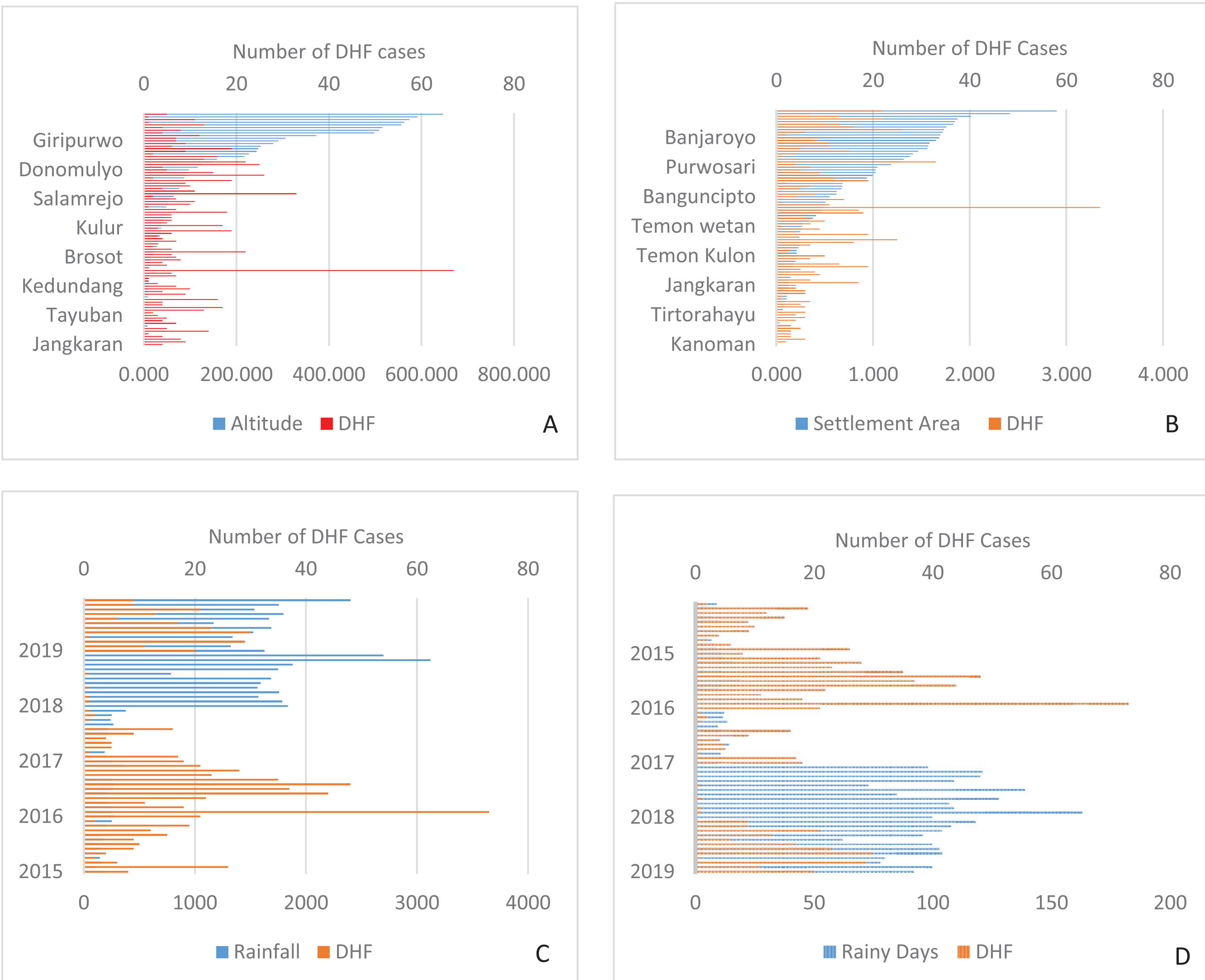

Figure 7A–E. Relationships between DHF cases and altitude (A), settlement area (B), rainfall (C), and rainy days (D) in Kulon Progo Regency, 2015–2019.

DISCUSSION

Gunungkidul. DHF in Gunungkidul Regency primarily occurs in Wonosari, the capital city, due to its high population density and many settlements. The city's government, trade, and education center contributes to a wider environment beneficial for *Aedes aegypti* life, increasing the risk of DHF transmission.[15–18]

The growth of settlements without adequate clean water facilities and sanitation can lead to puddles of clean water becoming breeding grounds for DHF.[19] Increased public knowledge and awareness are crucial for preventing DHF, with community behavior playing a significant role.[20–22]

Altitude negatively correlated with the incidence of DHF, with a moderate relationship. This is probably because the highlands in Gunungkidul Regency result in low temperatures. According to Purwantara (2015),[23] the higher the area is, the lower the environmental temperature will be. Climate data for Gunungkidul shows that the lowest temperature is 23.5 °C. At this temperature, the *Aedes aegypti* mosquito is less active in sucking blood, and its reproduction is slow.[24] The environmental temperature for peak transmission ranges from 26 °C to 29 °C, although in the laboratory, transmission can still occur at 18 °C.[25] No temperature data yet exists based on the altitude of the Gunungkidul area. Another possibility is the association between altitude and the presence of *Aedes* mosquitoes. The highest area in Gunungkidul Regency is 700 masl. Several studies have shown that the presence of *Aedes* is related to altitude, where it is more commonly found in the lowlands (22 masl), although it can still be found in the highlands (>1,000 masl).[26] Research in Wonosobo shows that *Aedes* species, mostly found in highland areas (500–1,000 masl), include *Aedes albopictus* (a secondary vector of DHF).[27] No study has examined the diversity of *Aedes* mosquitoes in Gunungkidul Regency by altitude. The altitude of an area can also affect the amount of inundation because, in the highlands, water flows smoothly, leading to few puddles. However, reducing stagnant water in the environment would reduce the breeding places for *Aedes* mosquitoes, especially *Aedes albopictus*, which mostly live outside the home,[27] thereby reducing DHF transmission in areas in the highlands of Gunungkidul.

Shoreline distance did not significantly impact DHF incidence in Gunungkidul compared to Bantul Regency. This difference may be due to the coast's lack of obstruction by mountains and karst hills, whereas Bantul's beaches are open and influenced by climate and winds. The study highlights the importance of environmental conditions in determining DHF incidence.[28] Rainfall and rainy days in Gunungkidul increased the incidence of DHF, with a moderately strong correlation, because standing water increases mosquito breeding and population. Rainwater also increases humidity, making the air suitable for mosquito life. Therefore, optimal humidity is required for mosquito resistance.

Kulon Progo**.** Like Gunungkidul, most cases of DHF occurred in the district capital of Kulon Progo. The problem of a high incidence of DHF in urban areas occurs in endemic areas worldwide. The densely populated environment and many settlements[16–18] are the main reasons for the many DHF cases in urban areas. Additionally, the availability of adequate clean water facilities and infrastructure,[19] community clean living behavior[20–22] and mobility, and large populations[29] affect the incidence of DHF in urban areas. Urban population mobility is linked to education and the economy, with urban residents seeking competitive secondary and tertiary education. Kulon Progo Regency has few quality schools, and Yogyakarta City, the capital, is endemic with many DHF cases. Children from Yogyakarta may spread the virus to Kulon Progo, highlighting the need for further investigation into population mobility's role in DHF incidence.

Very few DHF cases occurred in Kulon Progo Regency in 2016. This is unusual and needs to be studied further. Declines in other disease cases have been partly due to the success of vaccination or disease control programs, disruption of reporting systems, and quality of surveillance officers.[30] No effective vaccine for DHF exists so far. The DHF prevention program in Indonesia is also considered to have not been successful. This raises the possibility of disruption of the reporting or surveillance system that needs further investigation.

Altitude. In Kulon Progo, altitude positively correlated with DHF incidence, whereas in Gunungkidul, it negatively correlated with DHF incidence. Kulon Progo's hilly, shady, humid environment attracts *Aedes* mosquitoes due to large trees and water storage. Tourism development in Kulon Progo has increased DHF transmission. In Gunungkidul, barren and dry areas, with low *Aedes* mosquito population density and activity, reduce DHF transmission.

Rainfall and Rainy Days**.** Rainfall and rainy days correlated negatively with DHF incidence in Kulon Progo and positively in Gunungkidul, possibly due to higher environmental temperature conditions in the latter, with an average temperature of 27.7 °C (Kesetyaningsih et al., manuscript submitted to the Journal). Rainfall and rainy days also positively correlated with DHF incidence in Bantul Regency, with an average temperature of 30 °C.[31] Rainfall and rainy days are positively correlated with DHF incidence, increasing humidity, and breeding places, accelerating mosquito reproduction and DHF transmission in high-temperature areas.

The average temperature of Kulon Progo is 24 °C (23–25 °C), a range in which *Aedes* does not aggressively feed.[24] Low environmental temperatures suppress mosquito activity and prolong their reproductive cycle. High rainfall reduces the number of mosquito larvae in hilly and lowland areas, negatively affecting DHF incidence in Kulon Progo. The lowest incidence of DHF among DIY Province districts is due to the average temperature, which does not support *Aedes* feeding activity.

In general, this study shows that although both areas are mountainous, the influence of climate on the incidence of DHF may differ, depending on the level of drought in each area. In prediction modeling, rainfall can increase the number of DHF cases in dry mountainous areas but reduce the number of DHF cases in wet mountainous areas.

CONCLUSION

DHF was primarily found in urban areas, particularly wet and dry mountains. Residential areas were a risk factor. Altitude, rainfall, and rainy days affected DHF differently in wet and dry mountainous areas. Shoreline distance was not a risk factor. Regional governments in mountainous areas should consider the correlation between urban environments and DHF cases, with rainfall affecting the number of cases in dry and wet areas.

Conflict of interest

The authors report no conflicts of interest in this work.

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