Original Article

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Incidence Trend and Climate Influence on Dengue Fever in Banjarmasin, Indonesia: A Path Analysis Approach

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Abstract:

Objective: Dengue hemorrhagic fever (DHF) remains a significant global health burden, especially in tropical and subtropical regions. This study aims to determine climate trends and their influence on dengue incidence in Banjarmasin.

Material and Methods: DHF data were collected monthly from the health centers through the Health Office from 2016–2023. Climate data (temperature, humidity and rainfall) were obtained from the Banjarbaru Class II Meteorology and Geophysics Agency. Decomposition approach and path analysis were used in this study.

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Results: The results show that DHF cases exhibited a strong seasonal pattern, with the peak occurring in the first quarter of each year. The incidence of DHF in Banjarmasin has shown an increasing trend since 2016, with the highest incidence reported in 2023 (88 cases, 12.10 per 100,000 population). Temperature had the most significant direct impact on DHF cases, followed by rainfall and humidity. Humidity and temperature also indirectly affected dengue cases, as demonstrated in the path analysis (direct effect of rainfall: 0.269; indirect effect through temperature: -0.0643). These results underscore the influence of climate on the incidence of dengue fever.

Conclusion: Case trends can reveal the seasonal pattern of DHF cases. Mitigation efforts by local health authorities early in the year are essential to reducing morbidity and mortality from dengue fever in Banjarmasin.

Keywords: climate, dengue, incidence trend, Indonesia, path analysis

Introduction

Dengue hemorrhagic fever (DHF) remains a significant global health burden due to its rapid spread and lack of effective control measures, especially in tropical and subtropical countries[1,2]. DHF affects more than 100 countries worldwide, with the Asia-Pacific region being the area at the highest risk[3]. In Indonesia, DHF cases exceed 100,000 annually, spread across all provinces. As of mid-2020, Indonesia reported 95,893 DHF cases with 661 deaths, and by the end of the year, 73.35% or 377 districts/cities had an Incidence Rate (IR) of less than 49 per 100,000 population[4].

DHF is closely related to the epidemiological triangle theory, confirmed in various studies[5–7]. According to this theory, DHF is caused by 3 main factors: the host (related to characteristics, behaviors, and habits), the agent (related to the dengue virus), and the environment (including climate factors such as temperature, humidity, and rainfall)[4]. Several studies have established the relationship between climate and the epidemiology of mosquito-borne diseases, particularly concerning the abundance of Aedes mosquitoes, the vectors for transmitting DHF[4,8–12]. Climate plays an important role in shaping the life cycle, abundance, and biting behavior of mosquitoes, as well as the replication and transmission of viruses within their bodies. Temperature is a key determinant of mosquito development, affecting larval growth rates, adult longevity, and biting frequency. Temperature also significantly impacts mosquito populations since it directly impacts the number of breeding sites, the rate at which mosquitoes develop, reproduce, and survive, and the likelihood that diseases will be transmitted to humans. Warmer temperatures often accelerate virus replication in mosquitoes, reducing the extrinsic incubation period (the time it takes for the virus to become infectious) and increasing the likelihood of disease transmission[13]. However, extreme heat can sometimes suppress mosquito activity or reduce virus viability[14]. In addition, air humidity increases mosquito survival and activity, especially at humidity levels above 60%, where mosquitoes live longer and forage more frequently, which can increase disease transmission[15]. Rainfall creates breeding habitats, especially standing water, although excessive rainfall can wash away breeding sites[13]. This aligns with our research focus, which emphasizes understanding the influence of climate on the spread of DHF as a control and prevention measure, especially given the absence of a DHF vaccine in Indonesia.

Banjarmasin, a major city in South Kalimantan Province, Indonesia, has seen an increase in DHF cases and deaths since the onset of the coronavirus disease 2019 (COVID-19) pandemic. Despite a slight decrease in 2021, 2023 witnessed the highest number of DHF cases, with 88 cases resulting in 6 deaths. This trend underscores the need for effective preventive measures to manage future case surges. Banjarmasin, located on the eastern bank of the Barito River and bisected by the Martapura River, is known as the "City of a Thousand Rivers". The city's way of life revolves around rivers for transportation, tourism, fishing, trade, and daily activities. These rivers, influenced by the tides of the Java Sea, become salty during the dry season, reducing the availability of clean water. Consequently, the community stores rainwater during the dry season, creating breeding grounds for Aedes mosquitoes. Rainfall affects DHF occurrences, as stagnant rainwater provides breeding sites for Ae. Aegypti mosquitoes[12].

In the current era of climate change and global warming, rising surface temperatures can impact DHF by enhancing vector reproduction, particularly Aedes mosquitoes, which thrive in temperatures ranging from 25–27 °C up to a maximum of 40 °C. Additionally, increased rainfall can lead to the proliferation of rainwater puddles, creating breeding sites for mosquitoes. Climate change also affects average humidity levels, influencing ecosystems and diseases, especially those transmitted by mosquitoes sensitive to temperature, humidity, and environmental conditions[3,7].

Research on these climate variables is crucial, given the uneven distribution of temperature, humidity, and rainfall across Indonesia. This disparity can lead to variations in disease occurrence timing[7]. This study aims to analyze the influence of temperature, humidity, and rainfall on DHF in Banjarmasin, an endemic region for DHF in Indonesia. The novelty of our research lies in identifying the most influential variables that directly and indirectly impact DHF occurrences. Understanding these variables can be a crucial step in optimizing early prevention management and interventions in order to prevent future spikes in DHF cases and related deaths.

Material and Methods

Research location

Astronomically, Banjarmasin is located between 3°16'46" and 3°22'54" south latitude and 114°31'40" and 114°39'55" east longitude. The city encompasses a total area of 98.46 square kilometers, divided into 5 sub-districts: South Banjarmasin, East Banjarmasin, West Banjarmasin, Central Banjarmasin, and North Banjarmasin (Figure 1). The terrain is primarily swampy and level, with an average elevation of 0.16 meters below sea level, causing nearly the entire area to be submerged during high tide. Banjarmasin City hosts 395 integrated healthcare centers, 26 public health centers (PHCs), and 9 public hospitals, all of which provide essential healthcare services to its residents.

Data collection

DHF case data

Monthly DHF, dengue fever (DD), and dead data were obtained from health centers via the Banjarmasin Health Office. The data included geographical location (village or health center coverage area), age, sex, date of onset, and laboratory-confirmed diagnosis. The reports were compiled at the city level, verified at the provincial level, and submitted to the Ministry of Health.

Climate data

Climate data, including temperature, humidity, and rainfall, were collected from the Syamsudin Noor Meteorological Station, approximately 20 kilometers from Banjarmasin. These data were accessed through the Indonesian Agency for Meteorological, Climatological and Geophysics South Kalimantan Climatology Station official website (https://dataonline.bmkg.go.id/home).

Ethical approval

This study obtained ethical approval from the Health Research Ethics Committee of the National Research and

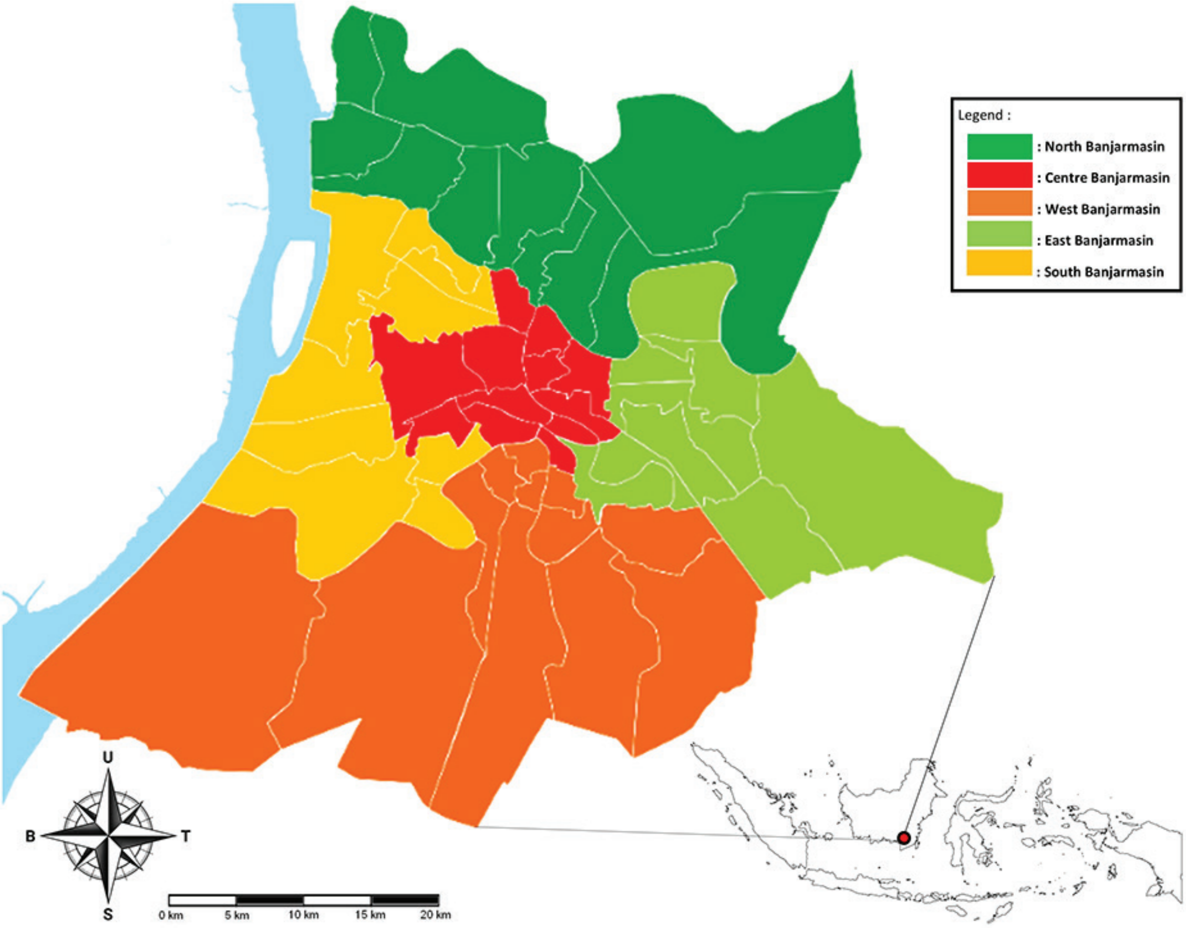

Figure 1 Map of research location, Banjarmasin, South Kalimantan, Indonesia

Innovation Agency, with approval number No: 076/KE.03/SK/04/2024.

Data analysis

An analysis was conducted retrospectively on Banjarmasin's dengue notifications between 2016 and 2023. Descriptive analysis was used to aggregate the number of cases by age group (≥55), gender, case category, and age range (<5, 5–9, 10–14, 15–54, and ≥55 years). The monthly incidence of dengue (Yt) was divided into 3 components using multiplicative seasonal decomposition analysis (SPSS version 21): a cumulative trend (Tt), a seasonal component (St), and an error or residual component (Et). Yt=Tt+St+Et is the connection between dengue incidence and the various decomposition terms.

This study sets villages as the spatial unit of analysis when more detailed spatial data are available. Univariate analysis was used to provide an overview of dengue disease distribution, rainfall fluctuations, humidity, and air temperature. To explain the mechanism of the causal relationship between rainfall, humidity, air temperature and dengue disease incidence, path analysis was conducted. Path analysis is an applied form of multiregression analysis that helps facilitate hypothesis testing of the relationships between variables that are quite complicated. In path analysis, the correlation between variables is associated with the parameters of the model expressed by a path diagram. This analysis model is used if, in theory, the researcher believes that the variables have a causal relationship pattern. SmartPLS Version 3 software is used in this analysis. Creating a thematic map of the research area using QGIS 3.36.0.

Results

Dengue cases in Banjarmasin fluctuate. Dengue hemorrhagic fever was reported in 58 cases in 2016, declined between 2017 and 2021, but surged again in 2022 (63 cases) and 2023 (88 cases); 2022 saw 63 cases, while 2023 saw 88 cases. Men outnumbered women in terms of gender. Age-wise, the age group with the highest number of cases, 69 in 2023—was 15–64 years old. In 2023, 12.10/100 was the highest incidence rate recorded. With a CFR of 6.8%, the highest incidence rate in 2023 was 12.10/100,000 people (Table 1).

January, May–June, and September see the highest average temperatures, while December has the lowest (Figure 2A). Humidity tends to rise between January and February, the start of the year, and November and December, the year's conclusion. Nearly the same amount of rainfall is seen every month, with January seeing the most (Figure 2C). Figure 3 shows the results of seasonal decomposition of dengue cases in Banjarmasin during the period 2016-2023, which reveals a consistent seasonal pattern, with peak cases occurring at the beginning of the year, particularly in January and February, and an additional increase in December. The long-term trend has shown an increasing trend of dengue cases from year to year, with the highest peak in 2023.

Table 1 Summary of dengue cases (category, gender and age): total population, incidence (per 100,000 people) and case fatalities, 2016-2023

Variable	Years								
	Total	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Case category									
Dengue fever (DF)	3,878	653	288	705	670	151	36	1,005	1,023
Dengue haemorrhagic fever (DHF)	272	58	16	28	41	42	11	63	88
Dead	12	1	1	2	1	2	0	3	6
Gender									
Man	182	30	13	21	26	21	7	43	51
Women	90	28	3	7	15	21	4	20	20
Age (years)									
<5	17	3	0	2	4	3	0,0	5	3
5-14	84	27	7	15	18	15	1,0	12	16
15-64	171	28	9	11	19	24	10,0	46	69
>64	0	0	0	0	0	0	0	0	0
Total	272	58	16	28	41	42	11	63	71
Total population	4,976,542	684,183	692,793	700,869	708,606	715,703	714,199	719,577	724,795
IR per 100.000 population	38.05477	8.48	2.31	4.00	5.79	5.87	1.54	8.76	12.10
CFR (%)	29,61914	1, 7	6, 3	7, 1	2, 4	4, 8	0, 0	4, 8	6, 8

IR=incidence rate, CFR=case fatality rate

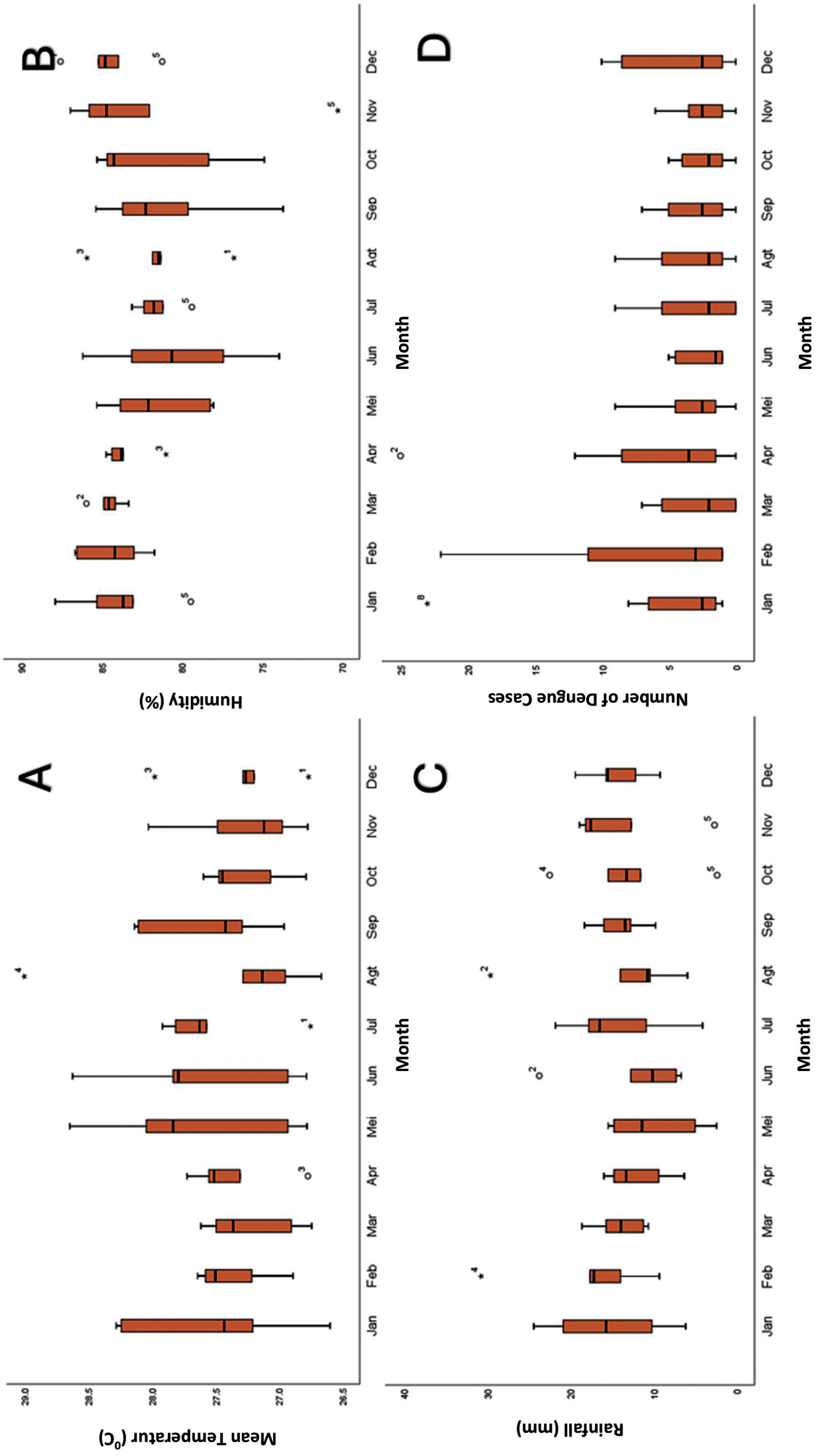

Figure 2 Boxplot graphs (2016-2023)
(A) Temperature, (B) Humidity, (C) Rainfall, and (D) Dengue case

Furthermore, a path analysis was conducted to determine the magnitude of the influence of climate change, which includes rainfall, humidity, temperature, and dengue incidence. Using this path analysis, the causal link mechanism between humidity (X1), temperature (X2), rainfall (X3), and dengue case (Y) was explained. Table 2 displays the route analysis of the relationship between temperature, humidity, rainfall, and dengue disease incidence. Table 2 shows that there is a direct relationship between X2→Y, X3→X2, X3→X2 and X3→Y (p-value<0.005).

Overall, the influence formed from climate variables is depicted in the path diagram in Figure 4. Rainfall affects humidity and air temperature. The indirect effect of X3 to Y through X2=-0.308x0.209=-0.0643, while the direct effect of X3 to Y is 0.269. In this model, rainfall and temperature affect dengue, while humidity has no effect.

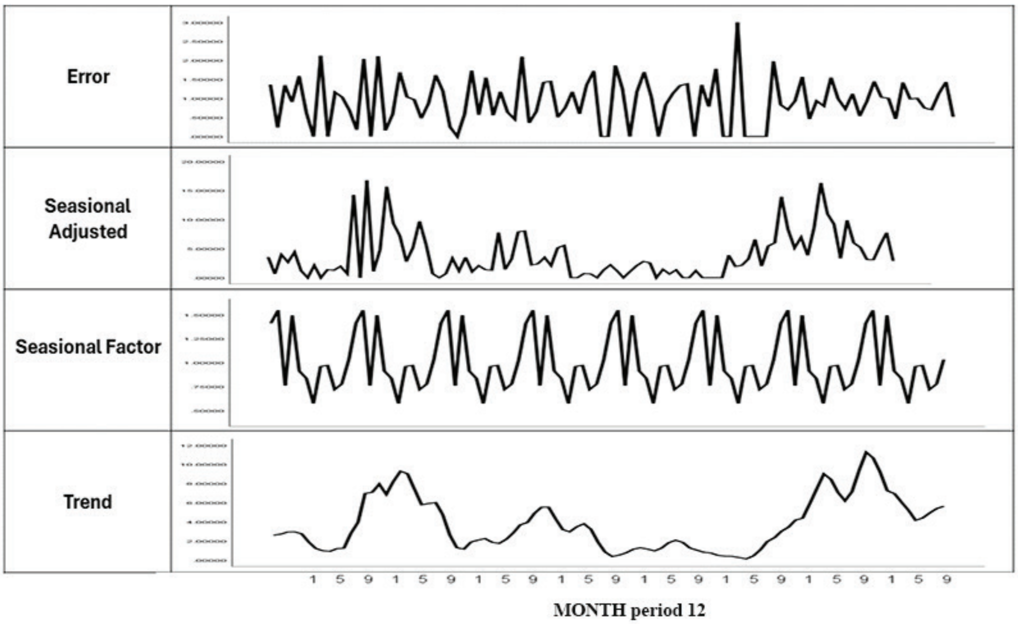

Figure 3 Seasonal trend decomposition plots of notified dengue incidence, 2016–2023

Table 2 The relationship predicting climate and dengue case factors

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	p-values
X1 -> Y	0.178	0.189	0.114	1.552	0.121
X2 -> X1	-0.189	-0.192	0.097	1.940	0.053
X2 -> Y	0.209	0.231	0.086	2.429	0.015*
X3 -> X1	0.503	0.506	0.094	5.349	0.000*
X3 -> X2	-0.308	-0.302	0.124	2.482	0.013*
X3 -> Y	0.269	0.285	0.132	2.033	0.042*

*significant

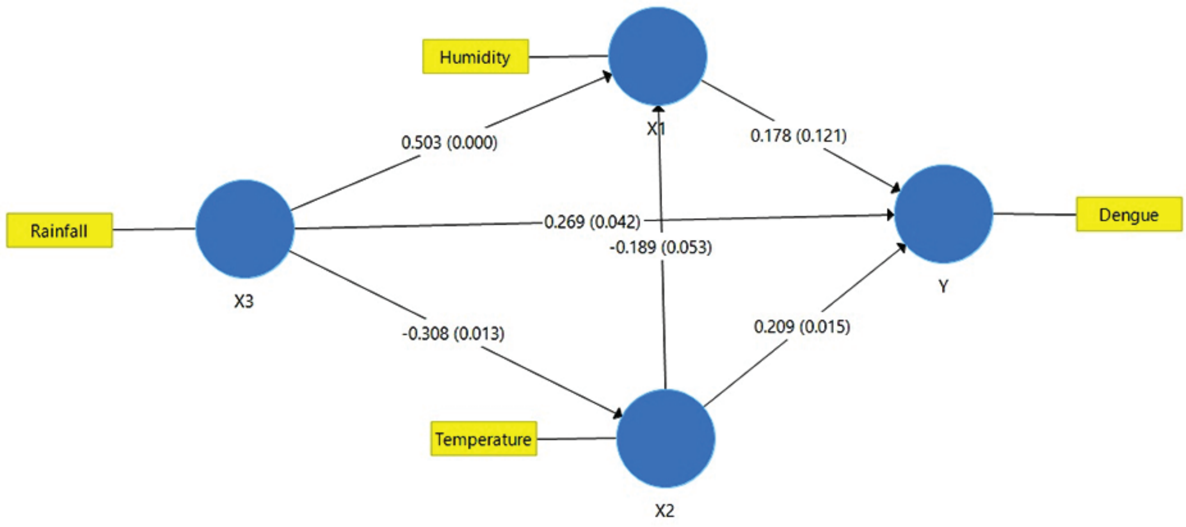

Figure 4 Path analysis climate variable and dengue

Discussion

Banjarmasin is astronomically located between 3°16'46" to 3°22'54" and close to the equator. The variation in the amount of sunlight received at a site due to the angle of the sunbeam was caused by latitudinal variances. The temperature will be comparatively more significant closer or nearer the equator and lower in the farthest region of the equator. Temperature significantly impacts mosquito populations since it directly impacts the number of breeding sites, the rate at which mosquitoes develop, reproduce, and survive, and the likelihood that diseases will be transmitted to humans. The idea that a warmer temperature will result in more mosquito populations and a rise in dengue transmission is supported by the adaptable behaviors of the mosquito[16]. All tropical and sub-tropical latitudes are home to the dengue virus, and Banjarmasin has a tropical environment. Geographically, Banjarmasin is a relatively flat, marshy landscape with an average elevation of 0.16 m below sea level. The area is frequently at high risk for dengue occurrence due to the preference of mosquitoes carrying the virus for locations with water[17]. The World Health Organization claimed that the increase in dengue incidence has been caused by the changing human ecology, demography, globalization, and climate change[17]. Climate change factors influencing dengue case transmission are temperature, rainfall[18], and humidity[19].

According to published research, the number of dengue cases increases as the daily mean temperature climbs beyond 28 °C, and it also increases when the mean temperature rises from 23 °C to 26 °C[18]. According to dengue vector biology, the ideal temperature range for breeding activities is between 26 and 30 degrees Celsius. Below 15 degrees Celsius, dengue vectors stop feeding, and their mortality rate rises. Then, between 25 °C and 28 °C is the ideal temperature for extrinsic incubation, or the infectious cycle of dengue virus multiplication and migration to female Aedes[18]. In Banjarmasin, temperature has the highest direct influence on dengue cases, apart from the indirect impact of rainfall and humidity. Monthly data on temperature in Banjarmasin shows lower dengue cases when the temperature reaches 28 °C in January, May, and September. However, dengue cases are almost equally distributed every month throughout the year. The same instances in Manado where the lowest dengue cases occurred when the temperature was higher by 28.4 °C[20].

The humidity has a direct and indirect influence on dengue cases in Banjarmasin. The maximum humidity was higher than 85% and occurred at the beginning and the end of the year (January, February, November, and December), which is related to the higher number of dengue cases in Banjarmasin. At 85% humidity, the female Aedes will live the longest—104 days—while the male will only live 68 days. Because of lower humidity, the mosquito's lifespan will be brief and there won't be enough time for the virus to move from the stomach to the salivary glands; the lowest limit of humidity and potential for Aedes to survive and become a vector is 60%[20,21]. Maximum humidity also increased larval populations[22].

Rainfall has a direct influence on dengue cases in Banjarmasin. The highest dengue cases occur at cumulative daily rainfall between 20 mm and 30 mm[18]. The rainfall in Banjarmasin tends to be low, under 20 mm, except in January, followed by an increase in dengue cases in February. There is a delay or lag time of around 3 weeks between an increase in rainfall and an increase in dengue cases from the start of the rainy season until the occurrence of a dengue fever incident[23]. Average temperature and relative humidity significantly influence dengue incidence across different lag periods. Studies have shown that higher temperatures at 2, 3, and 4 months lag can enhance dengue virus reproduction and accelerate the life cycle of Aedes aegypti mosquitoes, the primary vector of the disease. Furthermore, higher relative humidity, particularly at 4 and 5 months lag, supports mosquito growth and survival, thereby increasing the risk of dengue transmission[24].

El Nino and La Nina phenomena and their impact on dengue cases are intimately related to rainfall, temperature, and humidity levels. El Nino is negatively correlated with rainfall (less rainfall than usual). In most of India's northeastern states, the rainfall index was negatively correlated with the dengue case index[25]. That may be because heavy rains flush out Aedes larvae from outdoor breeding places, then reduce the abundance of Aedes vectors, and decrease dengue incidence. However, dengue transmission varies depending on the location. Dengue epidemics can be caused by little rainfall in one area and excessive rainfall in another[25]. In Indonesia, based on dengue cases from 2007 to 2017, strong El Nino and moderate La Nina were more influential in the increase of dengue cases, while the influence of moderate El Nino and strong La Nina on the dengue cases increased only in a small percentage of regions in Indonesia[23]. A strong El Nino occurred in 2015-2016 and 2023, marked by the high incidence of dengue cases in 2016 and 2023[23,26,27], while the strong La Nina in 2020-2021 28 was precisely marked by the decrease in dengue cases in Banjarmasin.

The strong El Nino has had a profound impact on dengue cases in Indonesia; it is related to the community's behavior of storing water in containers, which can become a high-risk breeding habitat for emerging dengue vectors[23]. It is the reason that the guarantee of a closed-water system or water-pipeline continuity becomes one of the socioeconomic factors of dengue control because it can decrease the existence of water storage by residents and decrease the habitat of the dengue vectors. Socioeconomic factors are also closely related to the growth and spread of dengue transmission, climate change, and globalization[29]. The other phenomenon of bionomic, during the hot days in El Nino that mosquitoes will seek out more suitable microclimates, like under leafy vegetation or inside drain pipes or housing, and the increases in water vapor will induce higher humidity that can decrease the negative impacts of global warming on mosquito survival[30]. Meanwhile, the dengue cases increase during La Nina, where rainfall is higher than usual, which can increase the number of dengue vector breeding habitats. Still, excessively high rainfall over a long time, especially during a strong La Niña, can cause flooding, eliminating breeding and decreasing the abundance of dengue vectors[18,23].

Data show that dengue tends to be higher in men than women in Banjarmasin. Previous research has also shown the same phenomenon; the difference in mobility between men and women is that men spend more time outside than women and thus have a higher risk of vector bites[31]. The public needs to be alerted and made aware of the presence of dengue vectors in public places: work locations like offices, markets, mosques, schools, and other public areas require attention, especially in vector control. Better public health measures against dengue are desperately needed in Banjarmasin due to the disease's geographical spread and growing number of cases. It is necessary to comprehend the present state of dengue, including the distribution of cases and vectors, as well as the evolving traits of Aedes and virus serotypes, to provide scientific recommendations for the disease's efficient prevention and control. In this study, among many factors affecting dengue incidence, only monthly average rainfall, temperature and humidity were studied. In future studies, other variables, such as population density, community behavior, and mosquito density, also need to be considered.

Conclusion

Climatic factors, particularly temperature, rainfall and humidity, significantly influence seasonal patterns, increasing the trend of dengue hemorrhagic fever cases with temperature being the most dominant factor. Dengue transmission in Banjarmasin is closely related to climate factors. Temperature has the highest direct influence on dengue cases, followed by rainfall and humidity. Additionally, both humidity and temperature have indirect effects on dengue incidence in Banjarmasin. Given the rise and peak of dengue cases in 2023, it is crucial to investigate the dengue vector: its bionomics, geographic distribution, and density. This research offers practical applications for dengue prevention and control, especially for local health authorities. By understanding the significant influence of climatic factors – particularly temperature, rainfall, and humidity – on dengue incidence, targeted interventions can be implemented during high-risk periods. Preventive measures such as intensified fogging, public education, and campaigns to eliminate mosquito breeding sites can be focused during the hotter months (January to March) and the beginning of the rainy season to reduce the upcoming dengue peak. In addition, this information can also support the development of a weather-based early warning system to identify high-risk areas, allowing for efficient resource allocation and timely action.

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Conflict of interest

We declare that there is no conflict of interest in this research.

References

1. Ramadhani SN, Latif MT. Impact of climate change on dengue hemorrhagic fever (DHF) in tropical countries: a literature review. J Kesehat Lingkung 2021;13:219-26. doi: 10.20473/jkl.v13i4.2021.219-226.
2. Pakaya R, Daniel D, Widayani P, Utarini A. Spatial model of dengue hemorrhagic fever (DHF) risk: scoping review. BMC Public Health 2023;23:2448. doi: 10.1186/s12889-023-17185-3.

3. Parveen S, Riaz Z, Saeed S, Ishaque U, Sultana M, Faiz Z, et al. Dengue hemorrhagic fever: a growing global menace. J Water Health 2023;21:1632-50. doi: 10.2166/wh.2023.114.
4. Pinontoan OR, Sumampouw OJ, Ticoalu JHV, Nelwan JE, Musa EC, Sekeeon J. The variability of temperature, rainfall, humidity and prevalance of dengue fever in Manado City. Bali Med J 2022;11:81-6. doi: 10.15562/bmj.v11i1.2722.
5. Ridha MR, Indriyati L, Juhairiyah J, Kusumaningtyas H. Malaria incidence trends and their association with climatic variables in East Kalimantan, Indonesia, 2014-2020. J Environ Health 2022;14:130–8. doi: 10.20473/jkl.v14i2.2022.130-138.
6. Ridha MR, Marlinae L, Zubaidah T, Fadillah NA, Widjaja J, Rosadi D, et al. Control methods for invasive mosquitoes of Aedes aegypti and Aedes albopictus (Diptera: Culicidae) in Indonesia. Vet World 2023;16:1952. doi: 10.14202/vetworld.2023.1952-1963.
7. Islam S, Emdad Haque C, Hossain S, Hanesiak J. Climate variability, dengue vector abundance and dengue fever cases in dhaka, bangladesh: a time-series study. Atmosphere (Basel) 2021;12:905. doi: 10.3390/atmos12070905.
8. Edillo F, Ymbong RR, Navarro AO, Cabahug MM, Saavedra K. Detecting the impacts of humidity, rainfall, temperature, and season on chikungunya, dengue and Zika viruses in Aedes albopictus mosquitoes from selected sites in Cebu city, Philippines. Virol J 2024;21:1-16. doi: 10.1186/s12985-024-02310–4.
9. Zaw W, Lin Z, Ko JK, Rotejanaprasert C, Pantanilla N, Ebener S, et al. Dengue in Myanmar: Spatiotemporal epidemiology, association with climate and short-term prediction. PLoS Negl Trop Dis 2023;17:1-25. doi: 10.1371/journal.pntd.0011331.
10. Kesetyaningsih TW, Fauzan RA. The relationship between climate factors and dengue hemorrhagic fever incidence in Sleman, Yogyakarta. Proceedings of the 4th International Conference on Sustainable Innovation 2020–Health Science and Nursing (ICoSIHSN 2020). 2021;33(ICoSIHSN 2020):614-9. doi: 10.2991/ahsr.k.210115.116.
11. Li Y, Dou Q, Lu Y, Xiang H, Yu X, Liu S. Effects of ambient temperature and precipitation on the risk of dengue fever: a systematic review and updated meta-analysis. Environ Res 2020;191:110043. doi: 10.1016/j.envres.2020.110043.
12. Monintja TCN, Arsin AA, Syafar M, Amiruddin R. Relationship between rainfall and rainy days with dengue hemorrhagic fever incidence in Manado City, North Sulawesi, Indonesia. Open Access Maced J Med Sci 2022;10:840-3. doi: 10.3889/oamjms.2022.8897.
13. Ehelepola NDB, Ariyaratne K, Buddhadasa W, Ratnayake S, Wickramasinghe M. A study of the correlation between dengue and weather in Kandy City, Sri Lanka (2003-2012) and lessons learned. Infect Dis Poverty 2015;4:1-15. doi: 10.1186/s40249-015-0075–8.
14. Bellone R, Failloux AB. The role of temperature in shaping mosquito-borne viruses transmission. Front Microbiol 2020; 11:584846. doi: 10.3389/fmicb.2020.584846.
15. Takken W, Verhulst NO. Host preferences of blood-feeding mosquitoes. Annu Rev Entomol 2013;58:433-53. doi: 10.1146/annurev-ento-120811–53618.
16. Edillo F, Ymbong RR, Bolneo AA, Hernandez RJ, Fuentes BL, Cortes G, et al. Temperature, season, and latitude influence development-related phenotypes of Philippine Aedes aegypti (Linnaeus): Implications for dengue control amidst global warming. Parasit Vectors 2022;15:1-17. doi: 10.1186/s13071-022-05186–x.
17. Nakano K. Future risk of dengue fever to workforce and industry through global supply chain. Mitig Adapt Strateg Glob Chang 2018;23:433-49. doi: 10.1007/s11027-017-9741-4.
18. Masrani AS, Rosmawati N, Husain N, Musa KI, Yasin AS. Prediction of dengue incidence in the Northeast Malaysia based on weather data using the generalized additive model. Hindawi BioMed Res Int 2021;2021:1-8. doi: 10.1155/2021/3540964.
19. Muhajir AR, Sutoyo E, Darmawan I. Forecasting dengue fever disease model in DKI Jakarta province using linear regression algorithm to determine the trend of predictor variable values towards increasing cases. Fountain Informatics J 2019;4:33. doi: 10.21111/fij.v4i2.3199.
20. Monintja TCN, Arsin AA, Amiruddin R, Syafar M. Analysis of temperature and humidity on dengue hemorrhagic fever in Manado Municipality. Gac Sanit 2021;35(Suppl 2):S330-3. doi: 10.1016/j.gaceta.2021.07.020.
21. Abdullah NAMH, Dom NC, Salleh SA, Salim H, Precha N. The association between dengue case and climate: a systematic review and meta-analysis. One Heal 2022;15:100452. doi: 10.1016/j.onehlt.2022.100452.
22. Hii YL, Zaki RA, Aghamohammadi N, Rocklöv J. Research on climate and dengue in Malaysia: a systematic review. Curr Environ Heal Reports 2016;3:81-90. doi: 10.1007/s40572-016-0078-z.

23. Indriyati L, Mahanani U. The effect of La Nina and El Nino on dengue fever and malaria in Indonesia. EnviroScienteae 2024;20:90-9. doi: 10.20527/es.v20i1.18877.
24. Aswi A, Cramb S, Duncan E, Hu W, White G, Mengersen K. Climate variability and dengue fever in Makassar, Indonesia: Bayesian spatio-temporal modelling. Spat Spatiotemporal Epidemiol 2020;33:100335. doi: 10.1016/j.gaceta.2021.10.063.
25. Pramanik M, Singh P, Kumar G, Ojha VP, Dhiman RC. El Niño Southern Oscillation as an early warning tool for dengue outbreak in India. BMC Public Health 2020;20:1-11. doi: 10.1186/s12889-020-09609–1.
26. Peng Q, Xie SP, A.Passalacqua G, Miyamoto A, Deser C. The 2023 extreme coastal El Niño: atmospheric and sea coupling mechanisms. Sci Adv 2024;10:4-11. doi: 10.1126/sciadv.adk 8646.
27. Marinho R dos SS, Duro RLS, Mota MT de O, Hunter J, Diaz RS, Kawakubo FS, et al. Environmental changes and the impact on the human infections by dengue, chikungunya and zika viruses in Northern Brazil, 2010–2019. Int J Environ Res Public Health 2022;19:1-11. doi: 10.3390/ijerph191912665.
28. Hasan NA, Chikamoto Y, Mcphaden MJ. The influence of tropical basin interactions on the double-dip La Niña. Front Clim 2022; 10:1-13. doi: 10.3389/fclim.2022.1001174.
29. Yue Y, Liu Q, Liu X, Zhao N, Yin W. Dengue fever in mainland China, 2005–2020: a descriptive analysis of dengue cases and aedes data. Int J Environ Res Public Heal 2022;19:1-13. doi: 10.3390/ijerph19073910.
30. Lahondère C, Bonizzoni M. Thermal biology of invasive Aedes mosquitoes in the context of climate change. Curr Opin Insect Sci 2022;51:100920. doi: 10.1016/j.cois.2022.100920.
31. Ishak NI, Kasman K. The effect of climate factors for dengue hemorrhagic fever in Banjarmasin City, South Kalimantan Province, Indonesia, 2012-2016. Public Heal Indones 2018;4: 121-8. doi: 10.36685/phi.v4i3.181.