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The variability of temperature, rainfall, humidity and prevalance of dengue fever in Manado City

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ABSTRACT

Background: Dengue hemorrhagic fever (DHF) was one of infectious diseases that is still a concern in Indonesia, especially the Manado city. This study aimed to analyze the variability of temperature, rainfall, humidity, and the incidence of DHF in Manado city 2011-2020.

Method: This ecological research used secondary data obtained from the Health Office and the Central Bureau of Statistics of the Manado City. The variables studied were air temperature, humidity, rainfall and the incidence of DHF in Manado city 2011-2020.

Result: in 2016 there were 567 cases of dengue fever and the highest was in the Malalayang sub-district and the lowest was in the Ranomut sub-district. In 2017 there was a significant decrease to 139 cases, the highest in Malalayang sub-district with 32 cases, and the lowest in Bunaken sub-district with 1 case. In 2018, there was an increase in cases by 294 cases, the highest was in the Malalayang sub-district. The air temperature continues to fluctuate where based on the trendline it is found that the air temperature tends to increase. Whereas, the humidity tends to decrease. The rainfall in the city of Manado continues to fluctuate, where based on the trendline it is found that rainfall tends to decrease. Mosquitoes are cold-blooded animals and their metabolic processes or life cycles depend on the environment's temperature. The DHF cases continue to fluctuate (up and down) where based on the trendline it is found that DHF cases tend to decrease

Conclusion: In the period 2011-2020 in Manado City, air temperature tends to increase but rainfall, humidity, and cases of DHF tend to decrease.

Keywords: climate, dengue haemorrhaghic fever, variability.
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BACKGROUND

Dengue hemorrhagic fever (DHF) is one of the public health problems that has not been successfully controlled for its spread. Based on data from the World Health Organization (WHO) in 2021, it shows that in 2020, DHF was attacked in several countries, with an increasing number of cases in Bangladesh, Brazil, Cook Islands, Ecuador, India, Indonesia, Maldives, Mauritania, Mayotte (Fr), Nepal, Singapore, Sri Lanka, Sudan, Thailand, Timor-Leste and Yemen. In 2021, DHF continued to attack Brazil, the Cook Islands, Colombia, Fiji, Kenya, Paraguay, Peru and the island of Reunion.[1]

The number of DHF cases reported has increased more than 8 time in the past two decades, from 505,430 cases in 2000 and decresed from 2.4 million in 2010 to 5.2 million in 2019. The deaths reported between 2000 and 2015 increased from 960 to 4032.[1] The number of DHF cases in Indonesia showed that DHF cases have spread to 472 districts/cities in 34 provinces. Mortality number of DHF occurred in 219 districts/cities. DHF cases until the 49th week of 2020 were 95,893 with 661 deaths. DHF data on November 30, 2020 there were 51 cases of illness and 1 case of death. A total of 73.35% or 377 regencies/ cities have reached an Incident Rate (IR) of less than 49/100,000 population.[2] Based on data from the North Sulawesi Provincial Health Office, the prevalence of dengue fever in 2015 was 1,546 cases and in 2019 there were 2,381 cases. This cases was increased of 835 cases (54%). In 2019, the highest cases occurred in the city of Manado with 597 cases and 10 deaths.[2] John Gordon's theory of the occurrence of disease was known as the epidemiological triangle. Based on this theory, the DHF caused by three factors: the host, the causative agent, and the environment. Host factors such as age, gender, disease history, behavior and others. The agent factor such as the dengue virus (nature of virus). Environmental factors such as air temperature, humidity, rainfall, vegetation and others.[3]

Several studies have shown that there are shift in rainfall patterns and the earth's average temperature, which is estimated to increase by 1-3,5°C. Changes in these environmental components will affect the species in the ecosystem group and the

distribution pattern of vectors and disease viruses. Climate can influence infectious disease patterns because disease agents (viruses, bacteria, or other parasites) and vectors (insects or rodents) are sensitive to temperature, humidity and other ambient environmental conditions. Weather and climate affect different diseases in different ways. Mosquito-borne diseases such as DHF, malaria and yellow fever are associated with warm weather conditions. In contrast, influenza was associated with cold weather conditions and meningitis was associated with dry environmental conditions.[4–6]

Physical environmental factors related to the incidence of DHF such as temperature, rainfall and humidity. Several studies have shown that at a temperature of 28-32oC with high humidity. In Indonesia, because the air temperature is not the same in every place, the time pattern of disease occurrence is somewhat different.[7–10] According to Lahdji (2017) rainfall and air temperature affect the incidence of DHF. Stagnant water caused by rain is a breeding ground for Ae. aegypti. Other studies have shown that the incidence of DHF is influenced by environmental factors such as temperature, rainfall and humidity.[11–14]

Global phenomena such as climate change affect to the incidence of DHF. Climate change caused an increase the air temperature. The increase in temperature can accelerate the breeding of mosquitoes, but to a certain extent the development slows down and eventually stops. Mosquitoes can develop optimally at 25-27oC, but can still adapt to 40oC. Above this temperature mosquito development stops. In addition, climate change causes an increase in rainfall. Increased rainfall can cause puddles of rainwater on shrubs and used goods (cans and plastic). The more water pond, the higher the breeding ground for mosquitoes.[15,16]

Manado city is the capital city of North Sulawesi province which is located on the coast. Manado City is the largest city in North Sulawesi and the second largest on the island of Sulawesi after Makassar City. The city of Manado has a tropical climate with an average temperature of 24-27°C. The average rainfall is 3,187 mm/year with the driest climate around August and the wettest in January. The average intensity of

sunlight is 53% and the relative humidity ± 84%. The results of the study from Tulandi et al (2020), show that the annual minimum and maximum values of the minimum temperature have increased.[17] The lowest minimum temperature was recorded on September 19, 1994 at 14,6°C, while the highest occurred in August 2002 at 29,9°C. The purpose of this study was analyzed the variability of temperature, rainfall, humidity and the incidence of DHF in Manado city 2011-2020.

METHODS

This is ecological research. This study used secondary data from the Manado City Health Office and Central Statistics Agency. The variables studied were air temperature, rainfall, humidity and the incidence of DHF. The data obtained were the average air temperature, rainfall, and humidity per month in the city of Manado from 2011-2020 while the data on the incidence of DHF is the prevalence (total cases) of DHF per month in the city of Manado from 2011-2020. The data described are the lowest, highest, interval and average values. In addition,

the trendline of data on air temperature, rainfall, humidity and the incidence of DHF.

RESULTS

The distribution of DHF in Manado city by sub-district can be seen in **Figure 1**.

Figure 1 showed that in 2016 there were 567 cases of dengue fever and the highest was in the Malalayang sub-district and the lowest was in the Ranomut sub-district. In 2017 there was a significant decrease to 139 cases, the highest in Malalayang sub-district with 32 cases and the lowest in Bunaken sub-district with 1 case. In 2018, there was an increase in cases by 294 cases, the highest was in the Malalayang sub-district.

Figure 2 shows that the air temperature continues to fluctuate (up and down) where based on the trendline it is found that the air temperature tends to increase. Mosquitoes are cold-blooded animals and their metabolic processes or life cycles depend on the temperature of the environment. Mosquitoes cannot measure their temperature against changes outside their body. Furthermore, the trendline of
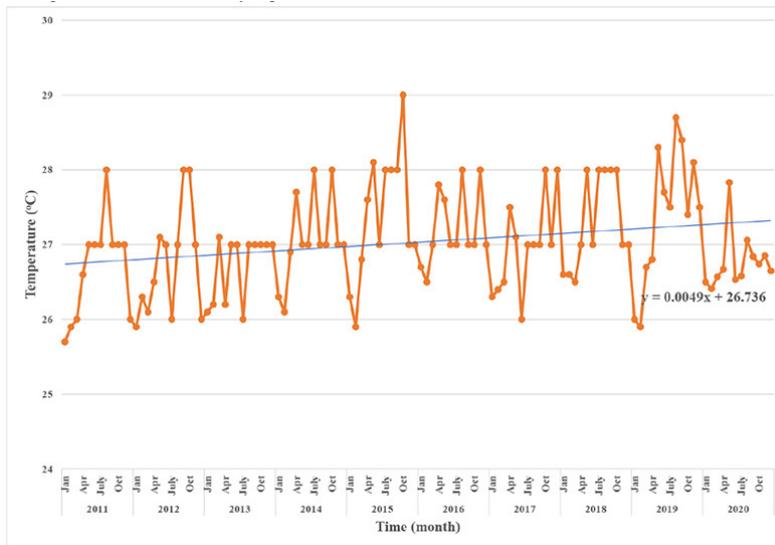

Figure 1. The distribution of DHF cases in Manado City 2016-2018
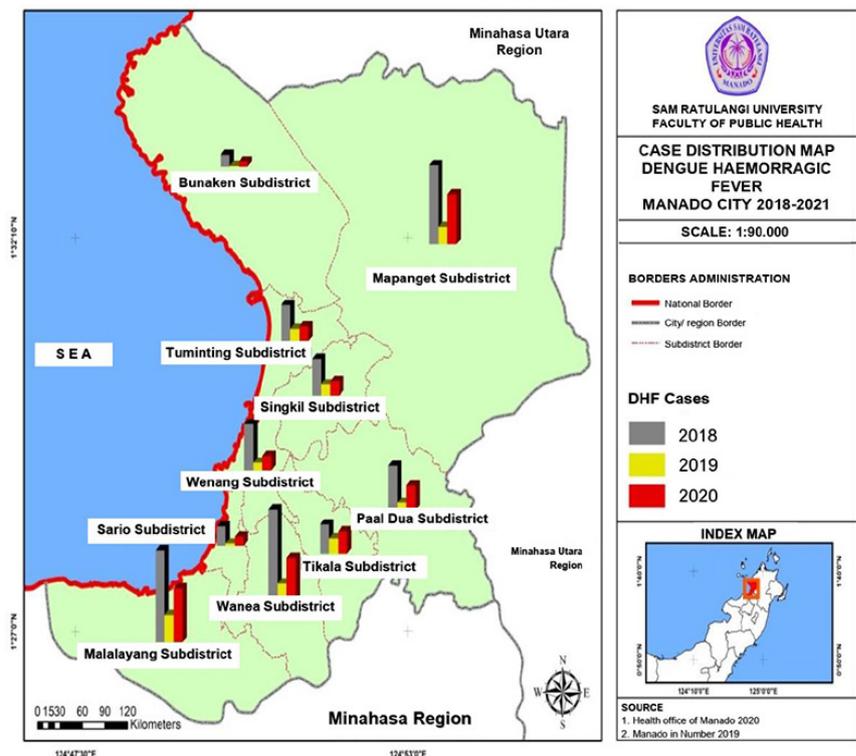
Figure 2. The air temperature in the city of Manado in 2011-2020
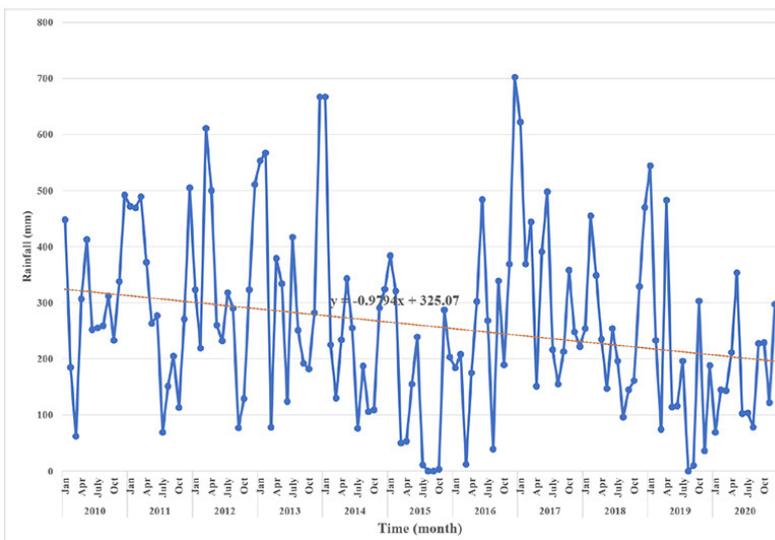

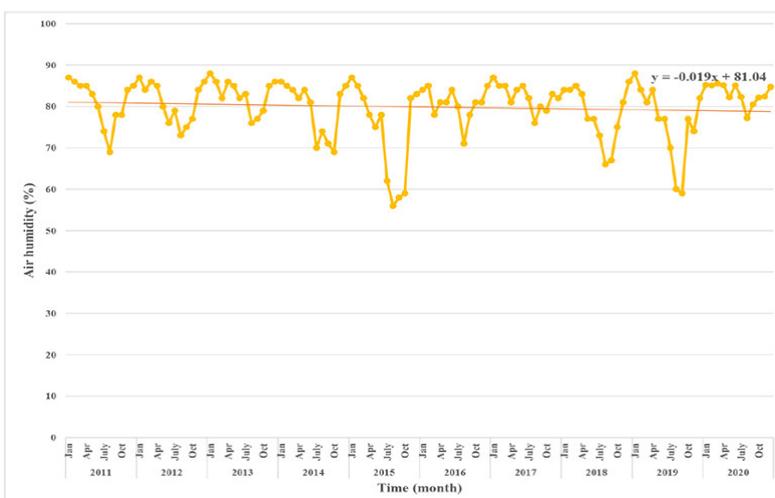**Figure 3.** Rainfall in Manado city in 2011-2020

Figure 4. Air humidity in the city of Manado in 2011-2020

rainfall in the city of Manado is explained in **Figure 3**.

Figure 1 shows that the rainfall in the city of Manado continues to fluctuate (experiencing up and down) where based on the trendline it is found that rainfall tends to decrease. The trendline of air humidity in the city of Manado is described in **Figure 4**.

Figure 4 shows that the humidity continues to fluctuate (up and down) where based on the trendline it is found that the humidity tends to decrease. Furthermore, the trendline of DHF cases in the city of Manado is explained in **Figure 5**. This graph shows that DHF cases continue to fluctuate (up and down) where based on the trendline it is found that DHF cases tend to decrease.

DISCUSSION

In 2016 there were 567 cases of dengue fever and the highest was in the Malalayang sub-district and the lowest was in the Ranomut sub-district. In 2017 there was a significant decrease to 139 cases, the highest in Malalayang sub-district with 32 cases and the lowest in Bunaken sub-district with 1 case. In 2018, there was an increase in cases by 294 cases, the highest was in the Malalayang sub-district. In general, it can be seen that the Malalayang sub-district has the highest cases and the lowest is in the Bunaken sub-district. According to Joy (2012), the high number of dengue cases in Malalayang sub-district is because there are several public places that are a gathering places for people from various regions such as public hospitals and health centers hotels, restaurants, schools (elementary schools to colleges). Malalayang District is also the border area of Manado City (urban and rural nature), and there are several urban villages located on the coast. Research by Butarbutar et al. (2019) showed the decrease in prevalence in 2009-2018 where in 2009 the prevalence of DHF was 1045 and in 2018 it was 294 cases.[18] The latest data from the Manado City Health Office in 2019 experienced a significant increase from 2018 with an incidence rate of 294 cases to 2,381 cases in 2019. Research by Musfanto et al. (2019) showed that the distribution of DHF cases in 2016-2018, the highest prevalence was found in 2016 in the
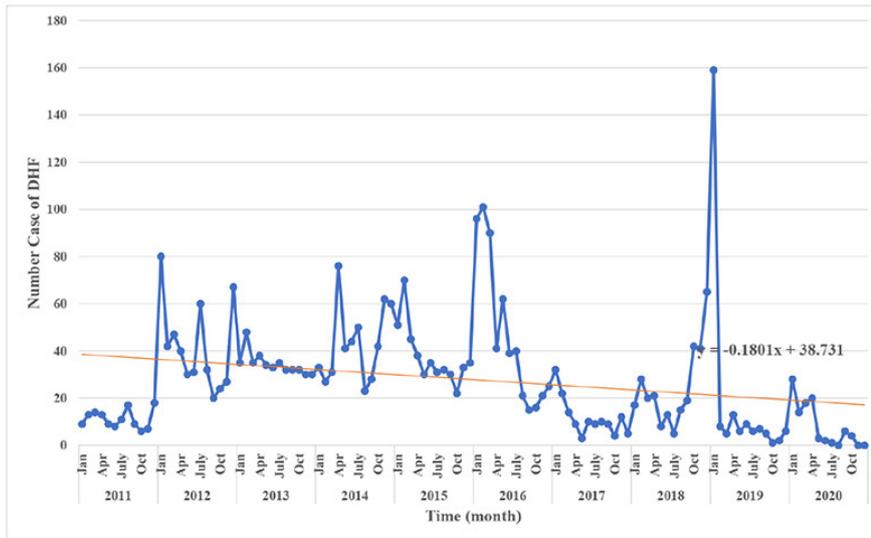
Figure 5. DHF cases in Manado city in 2011-2020

district of Malalayang.[19] Therefore, in an effort to reduce the prevalence of DHF, it is necessary to carry out health promotion efforts that emphasize climate factors and the behavior of the people of Manado.

Mosquitoes are cold-blooded animals and their metabolic processes or life cycles depend on the temperature of the environment. Mosquitoes cannot measure their temperature against changes outside their body. According to Pinontoan (2018), the average optimum temperature for mosquito growth is 25-27°C. Mosquito growth will stop completely at temperatures less than 10°C or more than 40°C.[20] The speed of development of mosquitoes depends on the speed of their metabolic processes which are partly regulated by temperature. Therefore, certain biological events such as the duration of immaturity, the rate of digestion of the sucked blood and maturation of the ovaries and the frequency of taking food or biting vary according to temperature and the length of time the virus has taken travels in the mosquito's body.

Several studies have shown the air temperature limit for *Ae. aegypti* activity is around 10°C where temperatures less than 10°C will cause mosquitoes to become paralyzed and unable to move. Rowley and Graham found that *Ae. aegypti* females are able to fly at a temperature of 15-32°C. At extreme temperatures (10°C and 35°C) will cause mosquitoes to fly in a short time. In general, the flight performance

of *Ae. aegypti* females will do better if it is below 27 °C. The maximum flight speed (34.1 m/min) was recorded at 32°C with 50% humidity. The temperature limit at which *Ae. aegypti* was found to stop biting at 15°C. Connor stated that Ae. aegypti is most active at 28°C. Marchoux *et al* found that female mosquitoes ate faster in a temperature range of 26-35°C compared to a temperature range between 19-25°C. The upper temperature limit of *Ae. aegypti* feed is 36°C, with a temperature of *Ae. aegypti* died at 40°C.[21]

Ambient temperature changes mosquito population dynamics by influencing egg, larval, and pupal stage development and reproduction. The lowest temperature threshold for *Ae. aegypti* develops at 16°C, and the highest temperature limit is 34°C. At lower temperatures such as 8°C, the larvae are immobile and die within a few days. Couret et al showed that food availability and mosquito density need to be considered to influence the rate of larval development and survival of this species when combined with temperature. Development time from hatching to maturity is shorter at higher temperatures. Bar-Zeev found that the time required for larvae to complete development was optimal at 32°C and death occurred at 14°C and 38°C.[21,22] There is a maximum temperature limit for mosquito vector life, according to Yang (2009), at temperatures above 30°C there will be an increase in adult mosquito mortality.[23] In addition,

increasing temperature can shorten the gonotrophic development of Aedes mosquitoes.[24,25]

Juwita (2020), who researched climate variability with the incidence of DHF in Tangerang City, showed a relationship between air temperature and the incidence of DHF.[26] Anwar et al (2014) showed that the several areas of South Sumatra which found that the highest number of *Aedes* mosquitoes. It was found in locations with an average air temperature of 28.0-28.2°C (87% of the total mosquitoes caught) and 27.5°C (13% of the total mosquitoes caught). Temperature is complexly related to the incidence of DHF by influencing the life of the Aedes mosquito.[27] The ideal temperature range for the survival of *Aedes* mosquitoes is between 20-30°C.[28] This causes the air temperature can affect the density of these mosquitoes in an area.

Rainfall is an important determinant of dengue transmission because it affects air temperature, affecting adult mosquitoes' survival. Furthermore, rainfall and temperature can affect mosquito feeding and reproduction patterns and increase population density.[29] Rainfall is very important for the survival of A. aegypti mosquitoes, rain will affect the increase in air humidity and increase the number of Aedes mosquito breeding places outside the house. Eggs laid by Aedes mosquitoes that have sucked the blood of a dengue patient or someone whose blood contains dengue virus at the end of the previous rainy season have the potential to be infected with dengue virus from their mother in the following rainy season. Hot temperatures cause the life cycle of arthropods to be shortened by shortening the incubation period of the pathogen, including the availability of water as a place to live for larvae. Many species with various types, including vectors with their pathogens, live in the tropics very well.[30]

Rain will affect the humidity and increase the number of natural mosquito breeding places. Natural mosquito breeding outside the house and dry garbage such as used bottles, cans, and pieces of bamboo as fences are often found in people's homes and leaves that allow collecting rainwater are good breeding places for Ae aegypti to lay eggs. According to Apriliana's research (2017),

rainfall will contribute to the availability of suitable habitats for vectors to breed, which impacts vector populations. The availability of vector habitats such as standing water as a breeding ground can lead to a vector population explosion that can increase the IR of dengue disease in an area. The effect of rainfall varies, depending on the amount of rain, the frequency of rainy days, geographical conditions, and the physical nature of the land or the type of habitat as a water reservoir for mosquito breeding.[31] Azhari et al.'s research (2017) in Pandeglang Serang Regency found a significant relationship between rainfall and the incidence of dengue fever in Pandeglang Serang Regency from 2011 to 2016 with a p-value (0.018).[32]

Rainfall can increase the number of vector breeding places or eliminate breeding places. However, if the rain is very heavy and continuous, then the mosquito breeding place outside the house will be damaged because the water will continue to spill and flow out, so eggs and larvae will also be carried out. Rainfall can also affect air temperature and humidity.[33] According to Cahyati (2006), rainfall of 140 mm/week can inhibit the breeding of mosquitoes. Heavy rainfall causes the vector breeding sites to be clean because they are carried away by the flow of water which causes the death of mosquito larvae.[34] Air humidity is associated with the incidence of DHF. The humidity rate in Indonesia can reach 70%. This is because Indonesia is an archipelagic country whose oceans are wider than the land, so the air contains more water. The average humidity for mosquito growth is 60-70%. Humidity affects mosquito age, flight distance, breeding speed, biting habits, rest, and others.[30] Irawan et al (2021) who examined meteorological factors and the incidence of DHF showed that air humidity was related to the incidence of DHF. Humidity indicates the amount of water vapor in the air. The amount of water vapor in the air is only a small part of the entire atmosphere. Meanwhile, relative humidity is the ratio of water vapor in the air to the amount of water vapor when the air is saturated with water vapor at the same temperature and pressure. If the relative humidity reaches 100%, the air is saturated with water vapor. The daily variation of relative humidity is opposite to temperature, which is maximum in the morning and minimum in the afternoon.[30]

Research from Irawan et al (2021) based on the correlation test results using a simple regression correlation between the humidity variable and the incidence of DHF shows that the incidence of DHF will increase when humidity increases. We found a significant weak relationship between humidity and the incidence of DHF in Pekanbaru City in 2013-2017 at 72-85% humidity conditions (r = 0.254; p-value = 0.050).[30] Apriliana (2017) also found a relationship between humidity and the incidence of dengue fever in Bandar Lampung City, where an increase of 1% humidity will increase the incidence of DHF by 4 cases with humidity conditions of 71% - 84%.[31] Arghintha's research (2016) in the lower area of Semarang City found that there was a relationship between humidity and the incidence of DHF in humidity conditions of 61% - 90%.[35]

Research by Alizkan (2017) showed that on the analysis of the correlation of air humidity to the dengue fever epidemic in Serang Regency and City shows that air humidity has a relationship with the incidence of DHF in Serang Regency.[36] Research from Azhari et al. (2017) on the study of correlation between climatic factors and the incidence of DHF in 2011-2016 shows a weak relationship with a positive direction between air humidity and the incidence of DHF.[32] In general, it can be seen that since 2011-2020, air temperature tends to increase but rainfall, humidity and cases of DHF tend to decrease. Temperature is one environmental factor that affects the incidence of DHF, especially in mosquito behavior. In January 2019, Manado City Health Office reported that this outbreak involved the highest number of cases in the past 10 years. Initial observations by local clinicians revealed an increasing number of children with severe dengue admitted to hospitals. The Indonesian Health Ministry reported a sudden spike in DHF cases in eight regions in Indonesia and declared an emergency in Manado, North Sulawesi.[37]

Research by Ariati and Musadad (2013) showed that temperature was the dominant factor affecting the number of DHF cases in the rainy season period from January to March. An increase in temperature of 1oC would reduce the number of dengue cases by 18. While in the dry season period from April to July humidity and rainy days were the dominant factors affecting the number of DHF cases. An increase of 1 point of moisture was found to increase the number of DHF cases by 2.4. However, 1 day of rain decreased the number of DHF cases by as much as 2. In the rainy season from August to December, the dominant factors were humidity and rainy days. An increase of 1 point in the humidity was found to increase 13.6 point the number of cases. However, an increase of 1-point in the rainy days was found to reduce 7 points in DHF cases.[38]

CONCLUSION

That can be concluded in the period 2011-2020 in Manado City, air temperature tends to increase but rainfall, humidity and cases of DHF tend to decrease. Based on this result, it is necessary to conduct research that examines the relationship between climate and the incidence of dengue fever in the city of Manado.

CONFLICT OF INTEREST

All authors declared that there is no conflict of interest regarding this publication

AUTHOR CONTRIBUTION

All authors contributed equally in the writing of this article

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ETHIC APPROVAL

This study had been ethically approved by ethical commission of RSUP Prof. dr. R.D. Kandou Manado with approval letter number 087/EC/KEKP-KANDOU/VI/2021

REFERENCE

1. World Health Organization (WHO). Dengue and severe dengue [Internet]. 2021. Available from: who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue

2. Kementerian Kesehatan RI. Data Kasus Terbaru DBD di Indonesia [Internet]. 2021. Available from: sehatnegeriku.kemkes.go.id/baca/umum/20201203/2335899/data-kasus-terbaru-dbd-indonesia/

3. Pinontoan O., Sumampouw O., Nelwan J. Epidemiologi Kesehatan Lingkungan. Deepublish. 2019;

4. Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Beagley J, Belesova K, et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. Lancet. 2021;397(10269):129–70. Available from: http://dx.doi.org/10.1016/s0140-6736(20)32290-x

5. Gloria-Soria A, Armstrong PM, Powell JR, Turner PE. Infection rate of Aedes aegypti mosquitoes with dengue virus depends on the interaction between temperature and mosquito genotype. Proceedings Biol Sci. 2017;284(1864):20171506. Available from: https://pubmed.ncbi.nlm.nih.gov/28978730

6. ANWAR A, ANWAR S, AYUB M, NAWAZ F, HYDER S, KHAN N, et al. Climate Change and Infectious Diseases; Evidence from Highly Vulnerable Countries. Iran J Public Health. 2020; Available from: http://dx.doi.org/10.18502/ijph.v48i12.3549

7. Purwani NPA, Swastika IK. Efektivitas ekstrak ethanol daun kemangi (Ocimum sanctum) sebagai insektisida terhadap nyamuk Aedes Aegypti. E-Jurnal Med Udayana. 2018;7(12):1–4.

8. Marsaulina I, Siregar FA. Pengaruh Lingkungan Fisik dan Perilaku Masyarakat terhadap Kejadian Demam Berdarah Dengue di Wilayah Kerja Puskesmas Kota Juang Kabupaten Bireuen Provinsi Aceh Tahun 2017 [Internet]. 2018. Available from: http://repositori.usu.ac.id/handle/123456789/6527

9. Sunarno RP, Wahyuningsih NE, Budiharjo A. Studi Faktor Suhu di dalam Rumah dan Kejadian Demam Berdarah Dengue Di Semarang Tahun 2017. J Kesehat Masy. 2017;5(5):807–14.

10. Indriyati L, Andiarsa D, Hairani B. VEKTOR MALARIA BARU DI KABUPATEN KOTABARU, PROVINSI KALIMANTAN SELATAN, INDONESIA. Vektora J Vektor dan Reserv Penyakit. 2017;9(1). Available from: http://dx.doi.org/10.22435/vk.v9i1.4522.1-8

11. Dompas BE, Sumampouw OJ, Umboh JM. Apakah Faktor Lingkungan Fisik Rumah Berhubungan dengan Kejadian Demam Berdarah Dengue? Indones J Public Heal Community Med. 2020;1(2):011–5.

12. Komaling D, Sumampouw OJ, Sondakh RC. Determinan Kejadian Demam Berdarah Dengue di Kabupaten Minahasa Selatan Tahun 2016-2018. Indones J Public Heal Community Med. 2020;1(1):1–10.

13. Oroh MY, Pinontoan OR, Tuda JB. Faktor Lingkungan, Manusia dan Pelayanan Kesehatan yang Berhubungan dengan Kejadian Demam Berdarah Dengue. Indones J Public Heal Community Med. 2020;1(3):35–46.

14. Rompis CL, Sumampouw OJ, Joseph WB. Apakah Curah Hujan Berpengaruh terhadap Kejadian Demam Berdarah Dengue? Indones J Public Heal Community Med. 2019;1(1):12–8.

15. Fadly R, Kaunang WP, Pandelaki A. Pemetaan Kasus Demam Berdarah Dengue di Kabupaten Minahasa Utara. 2015.

16. Rasmanto MF. Model Prediksi Kejadian Demam Berdarah Dengue (DBD) Berdasarkan Unsur Iklim Di Kota Kendari Tahun 2000-2015. J Ilm Mhs Kesehat Masy. 2017;1(3):1–10.

17. Tulandi DA, Tumangkeng J V, Bororing E V. Temperatur Dan Hujan Ekstrim Di Bandara Sam Ratulangi Manado Tahun 1987--2017. JSME (Jurnal Sains, Mat Edukasi). 2020;8(2):143–52.

18. Butarbutar RN, Sumampouw OJ, Pinontoan OR. Trend Kejadian Demam Berdarah Dengue Di Kota Manado Tahun 2009-2018. Kesmas Natl Public Heal J. 2019;8(6):1–10.

19. Musfanto CP, Sumampouw OJ, Pinontoan OR. Sebaran Kejadian Demam Berdarah Dengue di Kota Manado Tahun 2016-2018. Kesmas Natl Public Heal J. 2019;8(6):1–10.

20. Pinontoan O. Pengendalian Vektor. Unstrat Press. 2018.

21. Reinhold JM, Lazzari CR, Lahondère C. Effects of the Environmental Temperature on Aedes aegypti and Aedes albopictus Mosquitoes: A Review. Insects. 2018;9(4):158. Available from: https://pubmed.ncbi.nlm.nih.gov/30404142

22. Couret J, Dotson E, Benedict MQ. Temperature, larval diet, and density effects on development rate and survival of Aedes aegypti (Diptera: Culicidae). PLoS One. 2014;9(2):e87468–e87468. Available from: https://pubmed.ncbi.nlm.nih.gov/24498328

23. YANG HM, MACORIS MLG, GALVANI KC, ANDRIGHETTI MTM, WANDERLEY DM V. Assessing the effects of temperature on the population of Aedes aegypti, the vector of dengue. Epidemiol Infect. 2009;137(8):1188–202. Available from: http://dx.doi.org/10.1017/s0950268809002040

24. Goindin D, Delannay C, Ramdini C, Gustave J, Fouque F. Parity and longevity of Aedes aegypti according to temperatures in controlled conditions and consequences on dengue transmission risks. PLoS One. 2015;10(8):e0135489–e0135489. Available from: https://pubmed.ncbi.nlm.nih.gov/26258684

25. Delatte H, Gimonneau G, Triboire A, Fontenille D. Influence of Temperature on Immature Development, Survival, Longevity, Fecundity, and Gonotrophic Cycles ofAedes albopictus, Vector of Chikungunya and Dengue in the Indian Ocean. J Med Entomol. 2009;46(1):33–41. Available from: http://dx.doi.org/10.1603/033.046.0105

26. Juwita CP. Variabilitas Iklim dengan Kejadian Demam Berdarah Dengue di Kota Tangerang. Gorontalo J Public Heal. 2020;3(1):8. Available from: http://dx.doi.org/10.32662/gjph.v3i1.914

27. Anwar C, Lavita R., Handayani D. Identifikasi dan Distribusi Nyamuk Aedes Sp . Sebagai Vektor Penyakit Demam Berdarah Dengue di Beberapa Daerah di Sumatera Selatan. Maj Kedokt Sriwij. 2014;46(2):111–7.

28. Brady OJ, Johansson MA, Guerra CA, Bhatt S, Golding N, Pigott DM, et al. Modelling adult Aedes aegypti and Aedes albopictus survival at different temperatures in laboratory and field settings. Parasit Vectors. 2013;6:351. Available from: https://pubmed.ncbi.nlm.nih.gov/24330720

29. World Health Organization (WHO). Panduan Lengkap Pencegahan dan Pengendalian Demam Berdarah Dengue. 2012.

30. Sucipto C. Vektor Penyakit Tropis. Yogyakarta: Gosyen Publishing; 2011.

31. Apriliana. Pengaruh Iklim terhadap Kejadian Demam Berdarah Dengue di Kota Bandar Lampung, Provinsi Lampung. Cermin Dunia Kedokt. 2017;44(3).

32. Azhari AR, Darundiati YH, Dewanti NAY. A Studi Korelasi antara Faktor Iklim dan Kejadian Demam Berdarah Dengue Tahun 2011-2016. HIGEIA (Journal Public Heal Res Dev. 2017;1(4):163–75.

33. Soegijanto S. Aspek Imunologi Penyakit DBD dalam DBD: Tinjauan dan Temuan Baru di Era 2003. Surabaya: Airlangga University Press; 2004. 27–33 p.

34. Cahyati WH. Dinamika Aedes Aegypti sebagai Vektor Penyakit Kesehatan Masyarakat. 2006. 40–50 p.

35. Argintha WG, Wahyuningsih NE, Dharminto D. Hubungan keberadaan breeding places, container index dan praktik 3M dengan kejadian DBD (studi di kota semarang wilayah bawah). J Kesehat Masy. 2016;4(5):220–8.

36. Alizkan U. Analisis Korelasi Kelembaban Udara Terhadap Epidemi Demam Berdarah yang Terjadi Di Kabupaten dan Kota Serang. Gravity J Ilm Penelit dan Pembelajaran Fis. 2017;3(1).

37. Tatura SNN, Denis D, Santoso MS, Hayati RF, Kepel BJ, Yohan B, et al. Outbreak of severe dengue associated with DENV-3 in the city of Manado, North Sulawesi, Indonesia. Int J Infect Dis. 2021;106:185–96. Available from: http://dx.doi.org/10.1016/j.ijid.2021.03.065

38. Perwitasari D, Ariati Y. MODEL PREDIKSI DEMAM BERDARAH DENGUE DENGAN KONDISI IKLIM DI KOTA YOGYAKARTA. J Ekol Kesehat. 2016;14(2). Available from: http://dx.doi.org/10.22435/jek.v14i2.4667.124-135