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Dengue hemorrhagic fever incidence in Indonesia using trend analysis test and spatial visualization

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ABSTRACT

Dengue hemorrhagic fever (DHF) caused a public health risk in many developing countries, so understanding their incidence trend is needed to prepare for early warning prevention. The multi-year DHF trend analyses with spatial analysis are necessary but have not been accomplished in Indonesia. Therefore, this study aimed to present the current and future trends of DHF disease incidence in Indonesia during 2007-2022. This study examined the trends using yearly data of DHF for all provinces. The total number of DHF cases (DHF cases), the total death associated with DHF (TDC), case fatality rate (CFR), and infection rate (IR) are utilized. Univariate forecasting model, trend analysis test, and spatial visualization were developed. The results per province showed a declining trend of DHF cases and TDC in Java Island. There was an increasing trend outside Java Island. For the CFR and IR, most provinces had decreasing trend except for Gorontalo, North Kalimantan, and Maluku. Overall, trend analysis showed a continually decreasing trend of DHF, TDC, CFR, and IR that shows the positive results of the eradication program over 16 years. The findings highlighted the high-risk areas and need control strategies for DHF incidences.

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1. INTRODUCTION

The tropical and subtropical region is the highest vulnerability area for dengue hemorrhagic fever (DHF) transmission [1], [2]. Dengue disease is affected by the dengue virus (DENV). The dengue virus is divided into four types: DENV 1, DENV 2, DENV 3, and DENV 4, and the DENV types 2 and 3 are typically found in tropical regions [3]–[5]. In general, *Aedes aegypti* and *Aedes albopictus* mosquitos' bites are the leading cause of DHF disease with an incubation phase of 4-10 days. In the worst case, infection contributes to plasma leakage and organ damage [6], [7].

Currently, DHF is a critical public health problem in developing countries with tropical climates [8]. Many factors influence their transmission, such as meteorological and socioeconomic factors [9], [10]. In previous studies, meteorological and socioeconomic factors, such as air temperature, humidity, and rainfall, type of house, people density, built environment, socioeconomic status, demographic, and human mobility, have been found as a trigger of the transmission of dengue virus [11]–[15].

Indonesia is an example of a tropical climate country facing the DHF endemic for many years [16]. Several studies related to DHF has been conducted in Indonesia, including risk factors of DHF outbreak in North Sumatera [17], local factors that influence DHF transmission in Java [18], predicting DHF incidence rate in Jakarta [16], mapping epidemiology of DHF in Indonesia [19], [20]. However, the limitation of previous studies is the missing analyses of the current DHF incidence trend in Indonesia. In the earlier studies, and infection rate (IR) and case fatality rate (CFR) of DHF have been studied in Indonesia [20], [21], but no updated data has been since 2017. Furthermore, to provide early preventive information, the prediction of the future trends on DHF disease is needed to develop the control strategies for the disease. However, there is no current study that tackle this issue. Therefore, there is urgently need a study that explains the presents the current and the future trends of DHF disease incidence in Indonesia.

The spatiotemporal analysis is one of the promising methods that can help monitor vector-borne diseases such as dengue disease. The spatiotemporal study combines spatial and time aspects to determine the local differences and geographic disease risk. This investigation can display the exact location of an object or event identified in a particular coordinate system on the earth's surface. Many researchers have shown the advantages of using spatiotemporal analysis to explain DHF incidence, such as the spatial analysis of DHF in Putrajaya, Malaysia [22]. They showed the incidence of DHF arises in clusters with a typical radius of 264 meters. Moreover, a study in Taiwan displayed spatial clustering of DHF cases commonly occurring in metropolitan areas [23]. In Queensland, Australia, the incidence of DHF is also grouped around Cairn's location in the autumn season [24]. The spatial analysis of the DHF in Guangdong, China, displayed the incidence of clustered outbreaks in the Yuexiu District and spread to some nearby districts [25]. Thus, several spatial research shows the promising of this method to identify the area of distribution and timing of DHF disease incidence. Therefore, this study proposes to use trend analysis and spatiotemporal analysis to explain the current and future trends of the distribution of DHF disease in Indonesia during the 2007-2022 years. The key contributions of this paper are listed as follows: i) This study presents a spatiotemporal analysis to explain the recent update on the distribution of DHF disease incidence in Indonesia, where no study update has been since 2017. This analysis could provide helpful information to identify the current situation or areas with a high risk of DHF disease in Indonesia; ii) This study presents the future trends in DHF occurrence up to 2022 in spatial visualization. This information about the future trends in DHF occurrence can be helpful to the development of endemic prevention and control strategies in Indonesia.

The disease surveillance database from the Central Agency on Statistics of Republic Indonesia is analyzed to describe the DHF incidence in Indonesia. Linear regression univariate forecasting model constructed on the data up to 2019 predicted the future trends in the disease's occurrence up to 2022. After that, the Mann-Kendall trend analysis test is utilized to quantify the disease trend over 16 years. Lastly, it categorizes the results of the trend analysis test into spatial mapping to visualize the distribution of DHF disease.

2. RESEARCH METHOD

2.1. Materials and data

The secondary data on DHF cases were obtained from Indonesia's national statistical yearbook of The Central Agency on Statistics of Republic Indonesia [26]. The data was used from 2007 until 2019 (N=14 observation years+ three years' prediction). The DHF data was divided into four sub-datasets, including DHF cases, total death associated (TDC), CFR, and IR for 34 provinces in Indonesia. The experiments were performed in Python v.3.7 environments, and the Linear Regression and Mann-Kendall Trend Analysis model was developed with the Keras and Python library. The spatial visualization was performed using QGIS Desktop 3.14.15. While the experiment was conducted in the Windows 10 platform, 256 GB SSD storage, Core i7 processor 1.80 GHz, and 8 GB RAM.

2.2. Method

The available data was only for 2007 until 2019, and the linear regression algorithm was conducted to predict the DHF cases, TDC, CFR, and IR for 2020, 2021, and 2022 years as shown in Figure 1. The Mann-Kendall analysis test [27] was applied to explain the DHF incidences (Increasing or decreasing trend of DHF cases, TDC, CFR, and IR). The value of the positive tau of the Mann-Kendall shows a rising trend, and the negative tau shows a declining trend. Finally, the Jenk Natural Break algorithm [18] was performed based on trend analysis results to cluster and visualize the province with the significant DHF incidences.

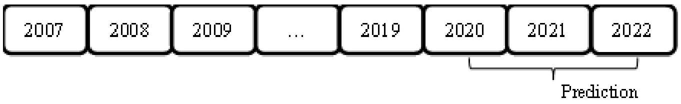

Figure 1. Predicted years' value from 2020 to 2022

2.3. Data definition

The yearly IR of DHF was calculated by dividing the total number of new DHF cases by the number of the specific year population (the total Indonesian population). The annual Indonesian population is used by the official the Indonesian Central Bureau of Statistics. The CFR was determined as the number of total deaths related to DHF (TDC) divided by the total number of DHF cases. The IR was used the number of cases per 100,000 person-years, while the CFR was indicated as a percentage (%). The DHF cases were expressed as a total number of cases, while TDC was stated as the total number of dead people related to DHF.

3. RESULTS AND DISCUSSION

The results were divided into three sections. The first section explains trend analysis per province (16 years) and spatial visualization of trend analysis per province. The last section presents trend analysis for Indonesia data (16 years).

3.1. Trend analysis per province (16 years period)

The result of trend analysis of DHF cases is depicted in Figure 2. Several provinces had significant increasing trends such as Bangka Belitung, Bengkulu, Gorontalo, Jambi, Kalimantan Tengah, Nusa Tenggara Barat, Papua, Riau, Maluku, Sulawesi Barat, and Sulawesi Tenggara, indicating an increasing DHF cases over 16 years. On the contrary, the significant decreasing trends were found in Banten, West Java and Central Java.

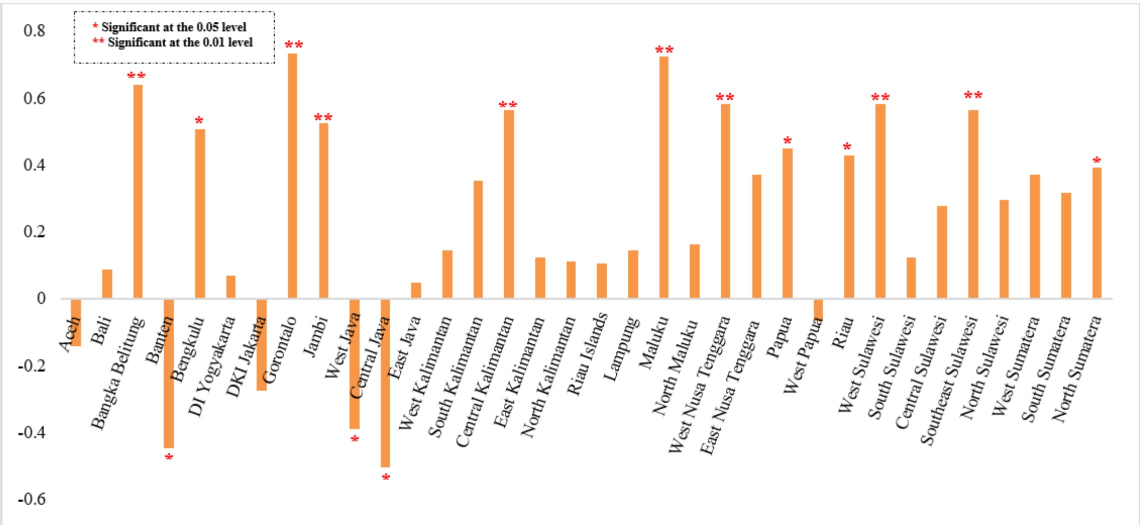

Figure 2. Trend analysis of DHF cases for 34 provinces in Indonesia

The trend analysis of TDC associated with DHF over 16 years is showed in Figure 3. Six provinces had the significant increasing trend in incidence death (Sumatera, Kalimantan, Sulawesi, and Maluku Island), particularly in Bengkulu, Gorontalo, Central Kalimantan, North Kalimantan, Maluku, and West Sulawesi provinces. On the other hand, the significant decreasing trend was found in Aceh, Banten, West Java, Central Java, Lampung, and North Sumatera.

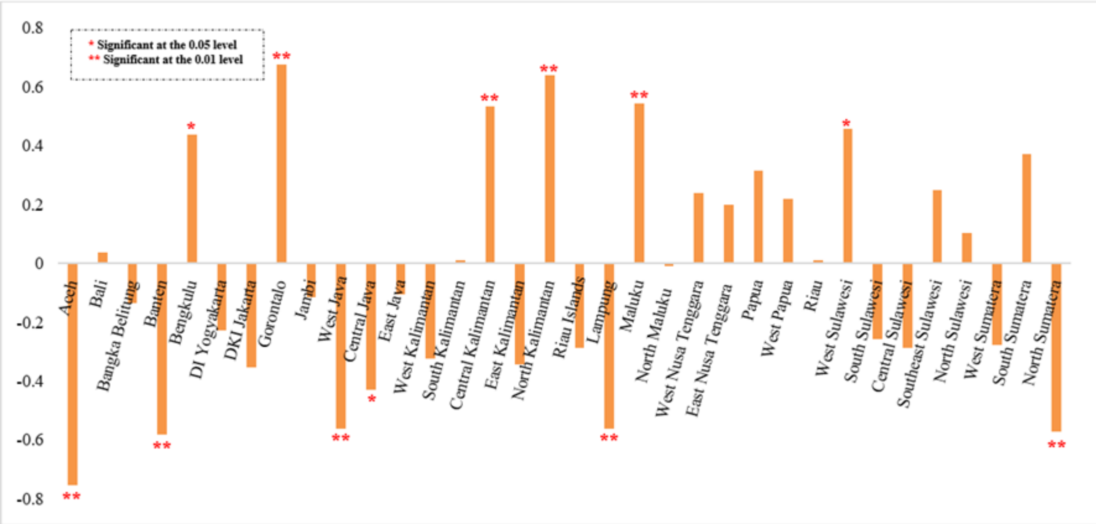

Figure 3. Trend analysis of TDC for 34 provinces in Indonesia

The trend analysis results of CFR are displayed in Figure 4. Only two provinces had significant increasing trend in CFR such as North Kalimantan, and South Sumatera. While, the significant decreasing trend was found in 15 provinces including Aceh, Bangka Belitung, Banten, Jambi, West Java, West Kalimantan, South Kalimantan, East Kalimantan, Riau Islands, Lampung, East Nusa Tenggara, Riau, Southeast Sulawesi, South Sumatera, and North Sumatera.

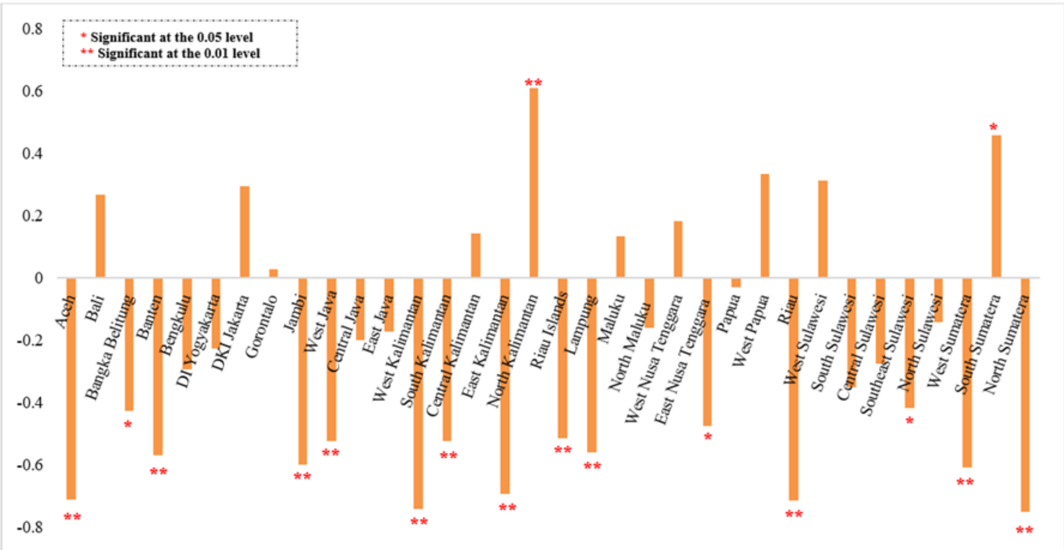

Figure 4. Trend analysis of CFR for 34 provinces in Indonesia

For IR of DHF disease, Gorontalo, North Kalimantan, and Maluku provinces had a significant increasing IR trend as shown in Figure 5. On the contrary, a negative value or significant decreasing trend was found in 14 provinces across Indonesia's continent. The provinces, such as Banten, DKI Jakarta, West Java, Riau Islands, North Maluku, South Sulawesi, and Central Sulawesi, had the lower tau level, meaning a decreasing trend of IR in these provinces. Furthermore, trend analysis results of DHF incidences were clustered and visualized using the Jenk Natural Break algorithm, including tau DHF cases, total TDC, tau CFR, and tau IR. The results were divided into 3 clusters (i.e., a significant increase, no trend, and significant decrease) that show the increasing, decreasing, and no trend of the disease incidence over 16 years in the specific province.

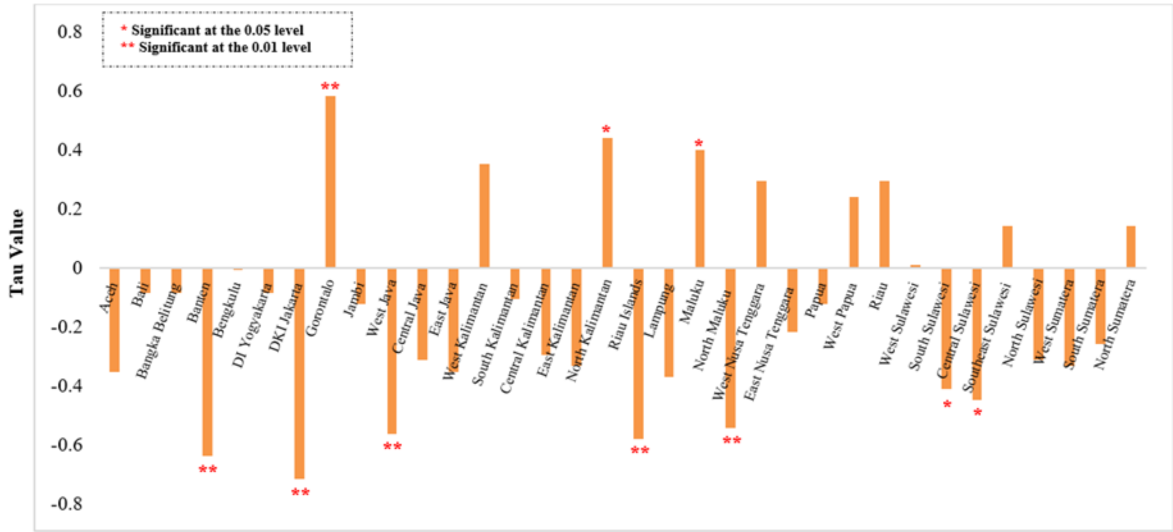

Figure 5. Trend analysis of IR for 34 provinces in Indonesia

Figure 6 illustrates the spatial distributions of DHF cases in 34 provinces. A total 12 province shows a significant upward trend in DHF cases. Several provinces, such as Gorontalo, Maluku, Bangka Belitung, Jambi, Bengkulu, West Nusa Tenggara, Central Kalimantan, Southeast Sulawesi, West Sulawesi, North Sumatera, Riau, and Papua, had the highest tau value for DHF cases. On the contrary, no trend was found in 19 provinces. While the tau of DHF cases significantly decreased in 3 provinces in Java Island (West Java, Central Java, and Banten).

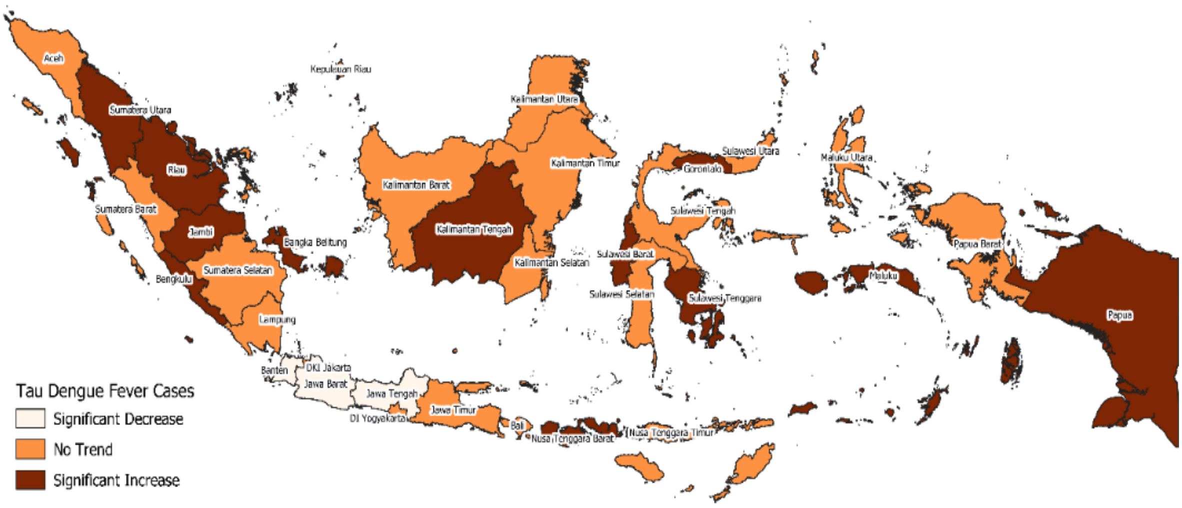

Figure 6. Spatial distribution of DHF cases for 34 provinces in Indonesia

Figure 7 displays the spatial distribution of TDC. Significant upward trends are clearly seen for Bengkulu, Central Kalimantan, North Kalimantan, West Sulawesi, Gorontalo, and Maluku provinces. While several big provinces, such as Aceh, North Sumatera, Lampung, West Java, Banten, Central Java, had a significant decline trend. Figures 8 and 9 show the results of the spatial distribution of tau CFR and IR. Only two provinces (South Sumatera and North Kalimantan) had significant increasing trend of CFR, while in IR, there were four provinces had the significant increasing trend, including North Kalimantan, Gorontalo, Maluku and Riau Islands.

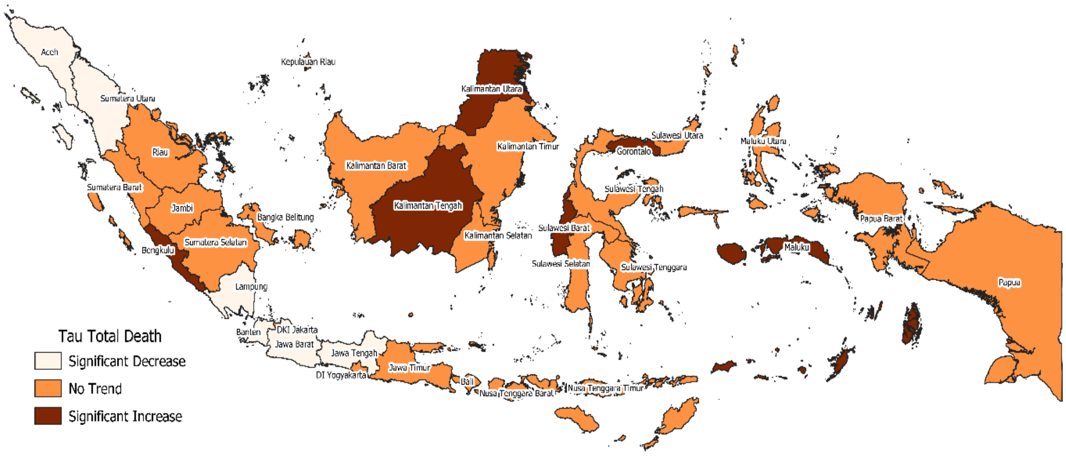

Figure 7. Spatial distribution of TDC for 34 provinces in Indonesia

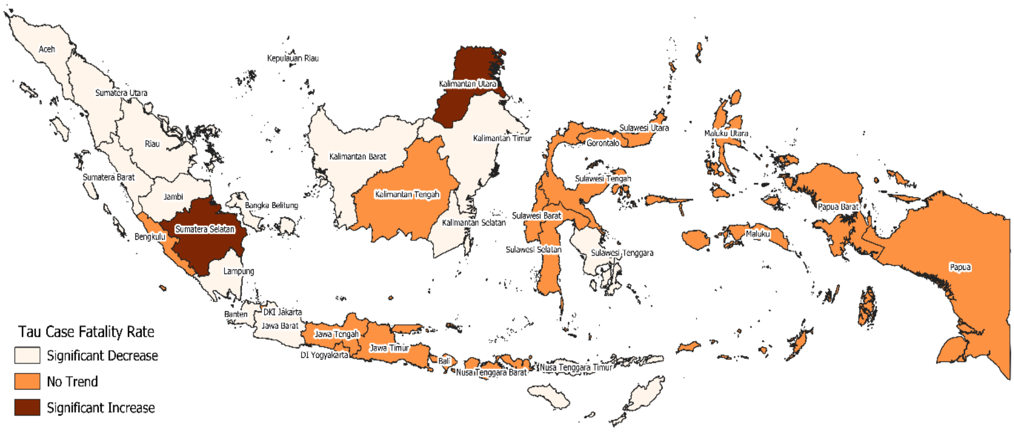

Figure 8. Spatial distribution of CFR for 34 provinces in Indonesia

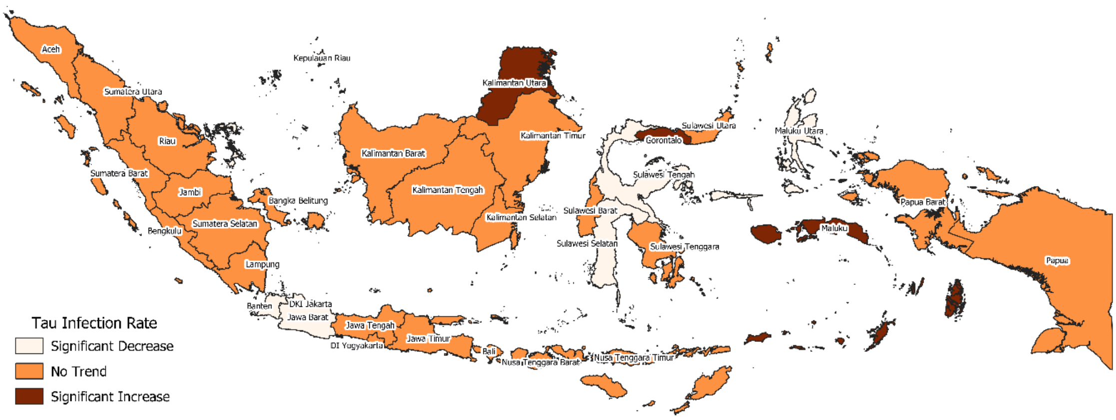

Figure 9. Spatial distribution of IR for 34 provinces in Indonesia

3.2. Trend analysis for Indonesia data (16 years period)

Trend analysis over 16 years period is displayed in Figure 10. There was a decreasing trend in the yearly of DHF cases (tau=-0.123), TDC (tau=-0.352), CFR (tau=-0.495; p<.01), and IR (tau=-0.31429) in Indonesia. Overall, all indicators displayed a declining trend over the period.

In Figure 11, the detailed data for each year of DHF cases, TDC, and IR showed repeated patterns, with the first peaks occurring in 2009. That peaks occurred in 2009, 2016, and 2019. The highest peak was achieved in 2016. The data showed 78.85 % per 100,000 person-years of IR, 0.78 % CFR, 204.171 DHF cases, and 1,598 TDC in Indonesia. Although the annual DHF cases, and TDC, showed a cyclic pattern over 16 years, the yearly IR and CFR displayed a declining trend over the period. As of 2022, the CFR is predicted to be just 0.75%, and the IR is expected to be just 0.4 % as presented in Figure 12.

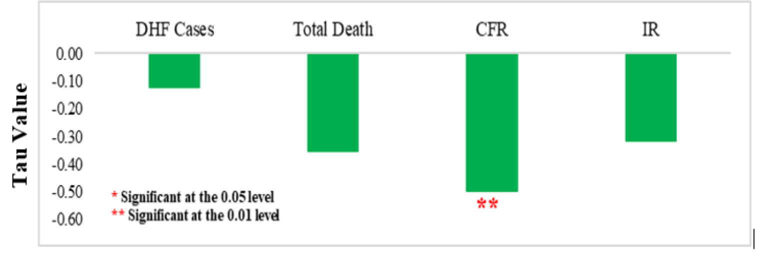

Figure 10. Trend analysis of DHF cases, TDC, CFR, and IR of Indonesia

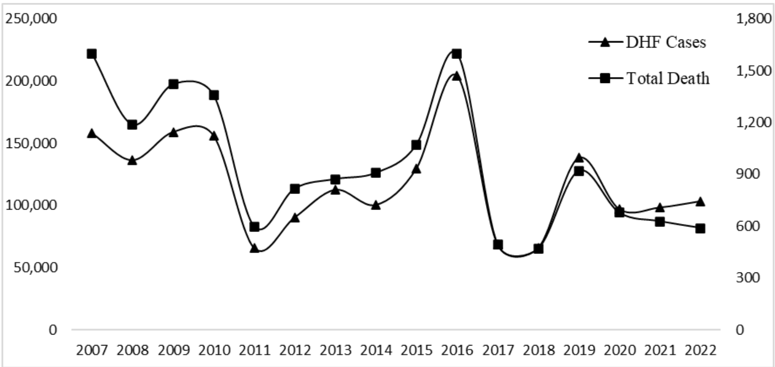

Figure 11. DHF cases and TDC in Indonesia from 2007 to 2022

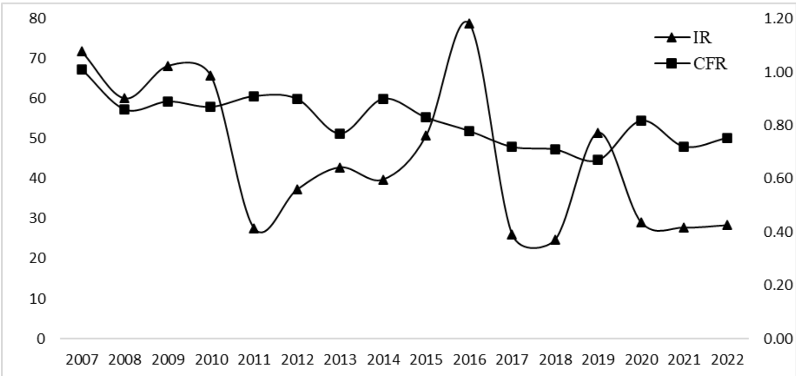

Figure 12. CFR (%) and IR (per 100,000 person-years) in Indonesia from 2007 to 2022

4. DISCUSSION

Trend analysis results per province showed a declining trend of DHF cases and TDC in Java Island, and there was an upward trend in provinces outside Java Island as shown in Figure 2 and Figure 3. According to previous works, Java Island (West Java, Central Java, East Java, DKI Jakarta, and Banten) supplied the highest number of DHF cases between 1968 and 2017 [20], so they may always have the highest average number of DHF cases and TDC each year. Contrary, our trend analysis results for DHF and TDC (West Java, Central Java, Java Timur, DKI Jakarta, Banten, except for Java Timur on DHF cases) showed a continually decreasing trend each year as presented Figure 2 and Figure 3. West Java, Central Java, and Banten identified the highest declining trend. These results may show the success of their local government intervention to control the disease. The potential reasons are that the massive eradication program has focused on preventing disease (DHF and Malaria) since 2004 by the Ministry of Health of Republic Indonesia. The eradication program, such as the socialization program of clean and healthy living behavior (PHBS/*perilaku hidup bersih dan sehat*) and the 3M method (Eradication of Mosquito Nest) [28] and the disease's health management controls [29], [30], may the cause of that decreasing trends. Furthermore, the provinces on Java Island had the highest number of healthcare facilities, healthcare workers, and human development index in Indonesia. So, it may ease the socialization and implementation of eradication programs (see Appendix A). According to the previous findings, the data from 1968 to 2017 [20], the previous study showed that Maluku, North Maluku, Gorontalo, Bali, and Kalimantan Timur had the highest CFR and IR. Our current trend analysis revealed slightly different results; South Sumatera, North Kalimantan, Gorontalo, and Maluku showed an increasing trend for CFR and IR as shown in Figures 4 and 5. The Indonesian government has to be concerned, especially for North Kalimantan province their CFR and IR showed a significant increasing trend over the years.

Overall trend analysis for Indonesia data showed a continually declining trend over 16 years as shown in Figure 10. This condition indicates the positive results of the eradication program to reduce DHF over 16 years, from 158,115 cases in 2007 to approximately 103,322 cases in 2022. Despite the fluctuation trends, such as the highest peak in 2016 and the lowest peak in 2018, were still found. Generally, all indicators indicated a significant declining trend which means the positive results of the eradication program to minimize the morbidity and mortality rate of DHF cases in Indonesia.

5. CONCLUSION

This study presented the current and future trends of DHF disease incidence in Indonesia during 2007-2022. The trend analysis and spatial visualization are used to explain the DHF disease in Indonesia. Trend analysis results per province showed a declining trend of DHF cases and TDC in Java Island, and there was an upward trend in provinces outside Java Island. Furthermore, our current trend analysis revealed that South Sumatera, North Kalimantan, Gorontalo, and Maluku showed an increasing trend for CFR and IR. The Indonesian government has to be concerned, especially for Kalimantan Utara province, that their CFR and IR have led to a significant increasing trend over the years.

Despite that, the overall results show a positive impact that their trend analysis showed a continually declining trend in DHF cases, TDC, CFR, and IR over 16 years in Indonesia. The knowledge gained from this study offers essential information on the spatial distribution of DHF incidences. It highlights the need for preventive and control strategies for several provinces with the increasing trend of DHF cases. In future works, this study suggests that it should discover the cause of the increasing or decreasing trend of DHF incidences for each province in Indonesia.

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APPENDIX A.

1. Total population and population density per province in Indonesia*

Province	Total population	Population desnity per Km2
West Java	49,316,712	139,400
East Java	39,698,631	83,045
Central Java	34,718,204	105,846
North Sumatera	14,562,549	19,954
Banten	12,927,316	133,783
DKI Jakarta	10,557,810	1,590,008
South Sulawesi	8,851,240	18,946
South Sumatera	8,470,683	9,248
Lampung	8,447,737	24,399
Riau	6,971,745	8,011
East Nusa Tenggara	5,456,203	112
West Sumatera	5,441,197	12,951
Aceh	5,371,532	9,268
West Nusa Tenggara	5,070,385	27,301
West Kalimantan	5,069,127	3,441
Bali	4,336,923	75,032
South Kalimantan	4,244,096	10,954
DI Yogyakarta	3,842,932	122,654
East Kalimantan	3,721,389	2,883
Jambi	3,624,579	7,241
Papua	3,379,302	1,059
Central Sulawesi	3,054,023	4,938
Central Kalimantan	2,714,859	1,768
Southeast Sulawesi	2,704,737	7,105
North Sulawesi	2,506,981	18,046
Riau Islands	2,189,653	26,697
Bengkulu	1,991,838	100
Maluku	1,802,870	3,843
Bangka Belitung	1,488,792	9,065
West Sulawesi	1,380,256	8,222
North Maluku	1,255,771	3,926
Gorontalo	1,202,631	10,683
West Papua	959,617	932
North Kalimantan	742,245	984

2. Health workers (i.e., doctor, nurse, etc.) and healthcare facilities (i.e., hospital, healthcare centers, drug shop, etc.)*

Province	Total number health workers	Total number of healthcare facilities
East Java	58,966	1,980

Central Java	54,854	1,966
West Java	44,518	659,058
South Sulawesi	15,916	860
South Sumatera	14,291	619
DKI Jakarta	14,060	1,423
Banten	12,740	1,112
Aceh	11,670	531
Lampung	11,105	668
Bali	10,882	369
DI Yogyakarta	10,625	1,306
West Sumatera	10,067	598
Riau	9,720	469
West Nusa Tenggara	8,246	338
South Kalimantan	7,773	331
West Kalimantan	7,505	398
East Kalimantan	7,479	522
Jambi	7,273	371
East Nusa Tenggara	7,267	559
Central Kalimantan	6,398	393
Central Sulawesi	6,316	317
Southeast Sulawesi	6,067	387
North Sumatera	5,845	1,827
Papua	5,436	477
North Sulawesi	5,033	269
Bengkulu	4,600	269
Riau Islands	4,496	367
Maluku	4,014	258
Bangka Belitung	3,788	165
Gorontalo	2,602	113
West Papua	2,510	252
North Maluku	2,386	155
North Kalimantan	1,936	64
West Sulawesi	463	112

3. Human development index in Indonesia (HDI)*

Province	2020
DKI Jakarta	80.77
DI Yogyakarta	79.97
East Kalimantan	76.24
Riau Islands	75.59
Bali	75.50
North Sulawesi	72.93
Riau	72.71
Banten	72.45
West Sumatera	72.38
West Jawa	72.09
Aceh	71.99
Indonesia	71.94
South Sulawesi	71.93
Central Jawa	71.87
North Sumatera	71.77
East Jawa	71.71
Bangka Belitung	71.47
Southeast Sulawesi	71.45
Bengkulu	71.40
Jambi	71.29
Central Kalimantan	71.05
South Kalimantan	70.91
North Kalimantan	70.63
South Sumatera	70.01
Lampung	69.69
Central Sulawesi	69.55
Maluku	69.49
Gorontalo	68.68
North Maluku	68.49
West Nusa Tenggara	68.25
West Kalimantan	67.66
West Sulawesi	66.11
East Nusa Tenggara	65.19
West Papua	65.09

*Based on 2019 data from The Central Agency on Statistics of Republic Indonesia