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SPATIOTEMPORAL DISTRIBUTION PATTERNS OF THE DENGUE EPIDEMIC IN THE BADULLA DIVISIONAL SECRETARIAT DIVISION OF SRI LANKA

[1]*S.M.N.S. Senanayaka and [2]Dr. E.M.S. Ranasinghe

[1,2]Department of Geography, Faculty of Arts, University of Colombo, Sri Lanka.

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***Corresponding Author**
S.M.N.S. Senanayaka
Department of Geography, Faculty of Arts, University of Colombo, Sri Lanka.

ABSTRACT

Dengue is the most rapidly emerging mosquito-born viral infection in tropical and sub-tropical countries, including Sri Lanka. Accordingly, this study aimed to analyze the spatiotemporal distribution patterns of the dengue epidemic in the Badulla Divisional Secretariat Division (DSD) in the Badulla district of Sri Lanka. Both primary and secondary data were used for the study. Primary data were collected from 102 dengue-affected families in the DSD for the year 2019. Data on the reported dengue cases in the study area was obtained from the secondary sources of the Medical Officer of Health (MOH) in Badulla for the years 2015-2019. ArcGIS 10.1 software was used to portray the spatial and temporal distribution of the dengue epidemic in the study area. The Average Nearest Neighbour Analysis method and Kernel Density Estimation were applied to analyze the spatiotemporal distribution patterns of the dengue epidemic in the study area. Results of the study showed that the dengue epidemic is widely recorded in the urban divisions of the study area, including Higurugamuwa, Badulla Central, Badulla South, Badulla East, and Badulupitiya, which represent 70% of the dengue cases. Among them, the Higurugamuwa division is reported as having the highest number of dengue cases in the years 2017, 2018, and 2019. The spatial distribution of the dengue cases in 2019 showed a clustered pattern in the western half of the study area, which represents the urban GNDs, that are accompanied by a high population. The study further revealed that the hotspots of the epidemic are mainly concentrated in the northwestern and southwestern parts of the study area. Finally, the study suggested that high population and improper solid waste disposal methods in the urban segment are the major factors of the vulnerability of the dengue epidemic in the Badulla DSD, therefore vigorous prevention actions should be taken to eliminate mosquito breeding sites, especially for the municipal council area.

KEYWORDS: Average Nearest Neighbour Analysis, Dengue Epidemic, Hotspots, Spatial Distribution, Temporal Distribution.

1. INTRODUCTION

According to the reports of the World Health Organization, the dengue epidemic is common in more than 110 countries in the world (Senanayaka, 2018). Being a tropical country, the epidemic is also rapidly spreading in Sri Lanka too, seems as a nationwide and year-round epidemic in the country and Badulla district is one of the most highly vulnerable districts of the epidemic. According to the statistics of the Dengue Control Unit in Sri Lanka, from 2010 to 2022, a total of 171,657 cases were reported in the country, and annually more than 25,000 cases were reported. The highest number of 186,101 dengue cases were reported in 2017 and death tolls were 440. With this background, the research focused on analyzing the temporal and spatial distribution of the dengue epidemic in the Badulla Divisional Secretariat Division (DSD) in the Badulla district in Sri Lanka. According to the statistics of the Medical Officer of Health (MOH) in Badulla, each year a significant number of dengue cases are reported in Badulla DSD. In year 2018, 90 dengue cases were reported in the DSD and it had increased six times in 2019 and reported 635 cases. In most of the research on the dengue epidemic in Sri Lanka, only urban areas have been focused. However, it is vital to investigate the characteristics of the epidemic considering both the urban and rural areas due to its widely spreading behavior. Hence, altogether, 29 GNDs of the Badulla DSD were considered for the study, and among them, 13 GNDs are urban areas governed by the Badulla Municipal Council. The remaining 16 GNDs are rural and governed by the Badulla Pradeshiya Sabha. Therefore, this study focused on both the urban and rural GNDs of the Badulla DSD as a geographical perspective study and could also be considered a timely important topic to analyze.

2. LITERATURE SURVEY

Dengue is the most common and important arthropod-borne viral (arboviral) illness for humans (Smith, et al., 2022). It is also known as breakbone fever due to the severity of muscle spasms and joint pain, dandy fever, or seven-day fever because of the usual duration of symptoms (Schaefer, et al., 2022). World Health Organization estimates that dengue puts at risk the health of more than 2.5 billion people in the world. Dengue fever occurs at high rates in tropical and subtropical areas of the world. These areas are susceptible to heavy rainfall and subsequent atmospheric humidity making them an ideal breeding ground for Aegypti mosquitoes (Lubin, 2023). Before 1970, major dengue epidemics erupted only in nine countries. According to Manna, et al., (2022), more than 100 nations in the world are burdened with the dengue disease, and the Asian region accounts for 70% of the reported cases. As the reports of the World Health Organization, dengue fever is one of the top ten global health threats and it's also the most rapidly spreading disease. There has been a 30-fold increase in global incidence over the past 50 years (World Mosquito Program, 2023).

In Sri Lanka, dengue cases have been reported since 1960. There are about 140 species of mosquitoes in Sri Lanka. Out of them, *Aedes aegypti* and *Aedes albopictus* mosquitoes transmit the dengue virus to humans. These two types of mosquitoes can be differentiated by using the markings on their bodies (National Dengue Control Unit in Sri Lanka, 2019). There are four types of dengue viruses D1, D2, D3 & D4, and all four types are presented in Sri Lanka in different proportions (Jayatilaka, 2012). In Sri Lanka, the disease shows seasonal transmission characteristics, which are marked by two peaks in June and July and in October and December due to monsoon rains. Most of the cases are reported between June and July during the southwest monsoon season. At present, almost all districts in the country are reporting dengue cases (National Dengue Control Unit in Sri Lanka, 2019).

Both local and foreign researchers have been focused on different perspectives of the dengue pandemic. When considering foreign research, Majid, et al. (2019) evaluated the distribution patterns of dengue cases in the Seremban district in Negeri Sembilan, Malaysia in 2008 and 2009 and found that dengue cases in both years clustered in the west of the Seremban district. Moreover, they observed that the population in the region frequently migrates and rapidly urbanizes, which may be contributing factors in the emergence of the centered dengue epidemic in the west of the Seremban district. Wu, et al. (2022) pointed out that dengue incidence has gradually increased in China in the recent past decades and has become a serious public health in recent years. Almost all provinces in China have reported dengue infection for all four serotypes of viruses. The researchers further revealed that the dengue virus has been circulated over the winter season in China and also they have recommended different strategies for reducing dengue prevalence in the country; including public awareness, a national reporting system of infection diseases and public health emergencies, vector mosquito control, personal protection, and improved environmental sanitation. According to Shabbir, et al. (2020), in Pakistan, Sindh and Khyber Pakhtunkhwa are two main vulnerable areas for the spread of dengue fever in the years 2006-2017. They pointed out that climate factors, such as rainfall and average maximum temperatures play a significant role in the spread of dengue fever in Pakistan. Their further conclusions were that the lack of proper hospital units is a highly significant factor in the spread of dengue fever. Also, areas most affected in Pakistan have large populations and higher population densities. Therefore, the research has suggested that the situation must be improved and awareness programs are needed to control the dengue epidemic in remote and less developed regions in the country.

In the field of concurrent local research on dengue, Jayarajah, et al. (2017) have conducted preliminary laboratory testing and revealed that the dengue virus serotype 2 (DENV-2) was the predominant circulating strain during the 2017 epidemic. Although all four DENVs have been co-circulating in Sri Lanka for more than 30 years, dengue virus serotype 2 is known to be associated with increased virulence and atypical clinical presentations. Another research (Pathirana, et al., 2009) has investigated the potential risk of dengue disease outbreak in the western province of Sri Lanka using GIS and statistical modeling and revealed that there are temporal and spatial correlations between post-rainfall seasons and dengue disease outbreaks. Edirisinghe (2018) found out that there is a high trend of spreading the dengue vectors in the Municipal Council in the Matara District, especially during the Southwest monsoon season. The researcher further emphasized that the distribution of the disease was mainly caused by environmental factors. Also, high population density and lack of a properly maintained drainage system have been identified as major physical factors for the rapid transmission of the disease.

The aforementioned foreign and local studies focused on different aspects of the dengue disease and suggested various strategies to control the epidemic. However, most tropical countries still suffer from this arthropod-borne viral illness which has become a year-round epidemic. Therefore, more studies are needed in this regard, especially considering micro-level study areas. When it comes to the Sri Lankan situation, although several studies focused on analyzing the spatiotemporal patterns of the disease, those research have been confined to limited study areas. Considering this research gap, the present study determined to analyze the spatiotemporal distribution patterns of the dengue epidemic in the Badulla DSD. Accordingly, this research would be important in planning local-level controlling measures and prevention strategies for the dengue epidemic.

3. OBJECTIVES

The main objective of this study was to analyze the spatiotemporal distribution patterns of the dengue epidemic in the Badulla DSD, Sri Lanka.

Specific objectives

- To analyze the temporal distribution pattern of the dengue epidemic in the Badulla DSD during the years 2015-2019.

- To analyze the characteristics of the spatial distribution pattern of the dengue epidemic in the Badulla DSD in the year 2019.

4. STUDY AREA

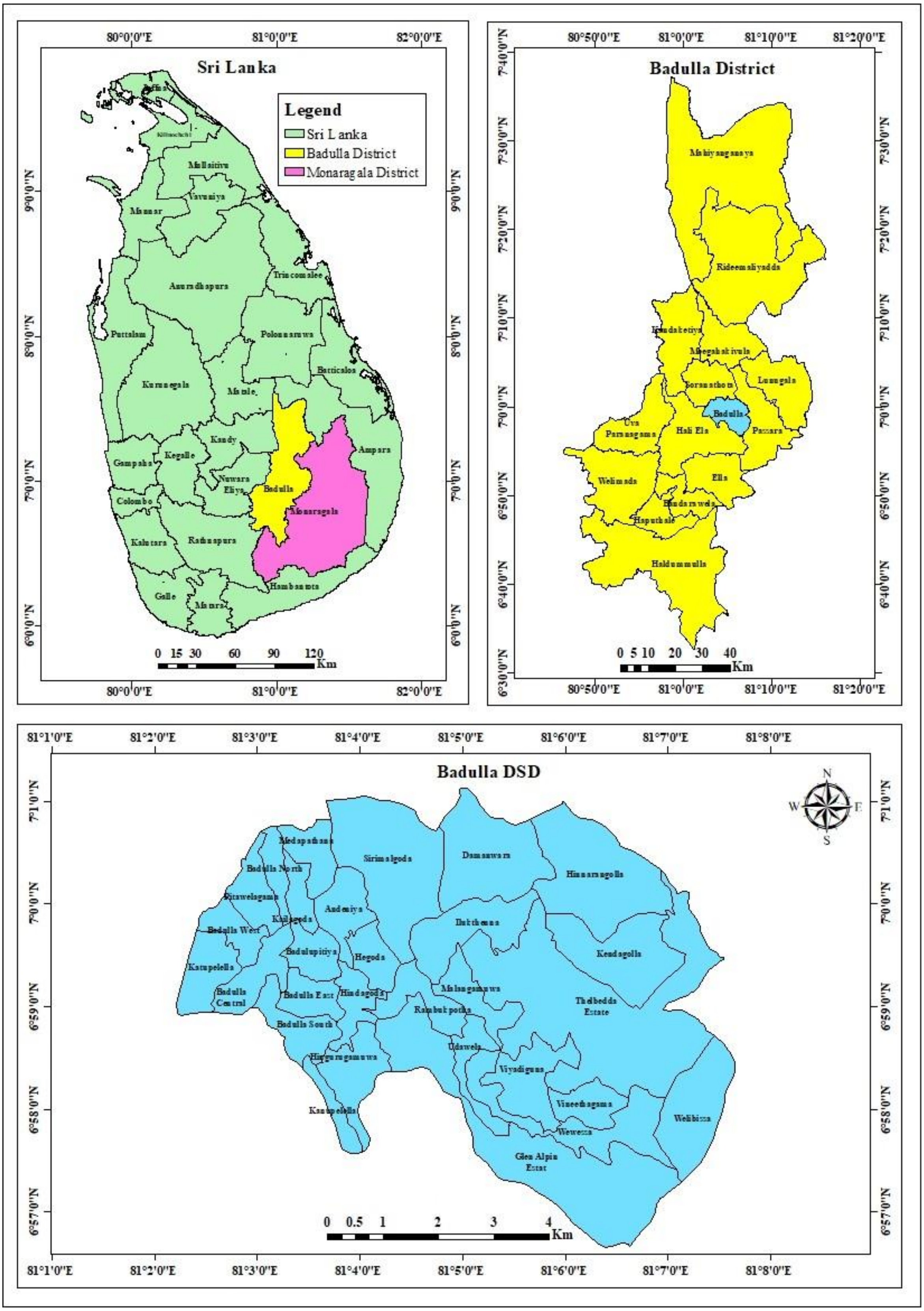


Fig. 1: Location Map of the Badulla DSD in the Badulla District.

Source: Prepared by the Authors using ArcGIS 10.8 software.

Out of the nine provinces of Sri Lanka, Badulla, and Monaragala districts belong to Uva province. Among them, the Badulla district is situated in the eastern part of the central highland of Sri Lanka and it can be described as an area with separate geographical features. The absolute location of the Badulla DSD is 6° 56' - 7° 01' North latitude and 81° 02' - 81° 08' East longitude. Its relative location is bordered from the North by the Soranathota DSD, South and East by the Passara DSD, and West by the Hali-Ela DSD. The DSD consists of 29 GNDs (Figure 1).

5. MATERIALS AND METHODS

Both primary and secondary data were considered for the study. Reported dengue cases of the 29 GNDs of the Badulla DSD were obtained from the secondary sources of the Medical Officer of Health (MOH) Badulla, covering the years 2015-2019 to achieve the first objective of the study. Within the considered years, a total of 2008 dengue cases were reported and those data were used to analyze the spatiotemporal distribution patterns of the dengue epidemic in the study area. The percentage method and the Least Square method of the time series analysis were applied to identify the temporal changes in the dengue cases. ArcGIS 10.8 software was used to portray the spatiotemporal distribution of dengue cases in the study area during the years 2015 to 2019. In that manner, the number of dengue cases was classified manually considering the class limits, and graduated colors were assigned. The symbology tool in ArcGIS 10.8 was used in this classification. In addition, the spatial distribution of the population size and the population density in the study area were portrayed using ArcGIS 10.8 software. The ArcGIS 10.8 software has also been used to analyze the association between reported dengue cases and the population density in the GNDs.

To fulfill the second objective of the study, the X and Y coordinates of the affected household locations were used as primary data to identify the characteristics of the spatial distribution pattern of the dengue epidemic in the study area in 2019. A total of 255 families were reported in the DSD as affected by dengue fever in 2019. Among them, 102 families were selected for the study sample using the stratified random sampling method, which is 40% of the total number of cases in the year.

Accordingly, A hotspot analysis was applied using the Kernel Density Estimation method to identify the concentration of the dengue cases in the study area in 2019. The Average Nearest Neighbor Analysis method in ArcGIS 10.8 was used to detect the pattern of the distribution of the epidemic in the Badulla DSD in 2019.

6. RESULTS AND DISCUSSIONS

6.1.Temporal Distribution Patterns of the Dengue Epidemic in the Badulla DSD

Figure 2 shows the reported annual total number of dengue cases in the Badulla DSD from 2015 to 2019. According to Figure, every considered year, a significant number of dengue patients were reported in the DSD. Compared to the number of cases in 2015 (118) with the number of cases in 2016 (286), it was increased by 59%. The most remarkable feature that could be seen in the area is that the reported dengue cases in 2017 were 86 % higher than the reported cases in 2016, and it represented 44% of the total cases of all the considered years. The number of reported cases decreased to 90 in the year 2018. However, another significant increase could be detected in 2019, reported 635 cases which was 86% higher than the records in 2018. Further, the year 2019 became the second highest, which represented 32% of the total cases during the years 2015-2019.

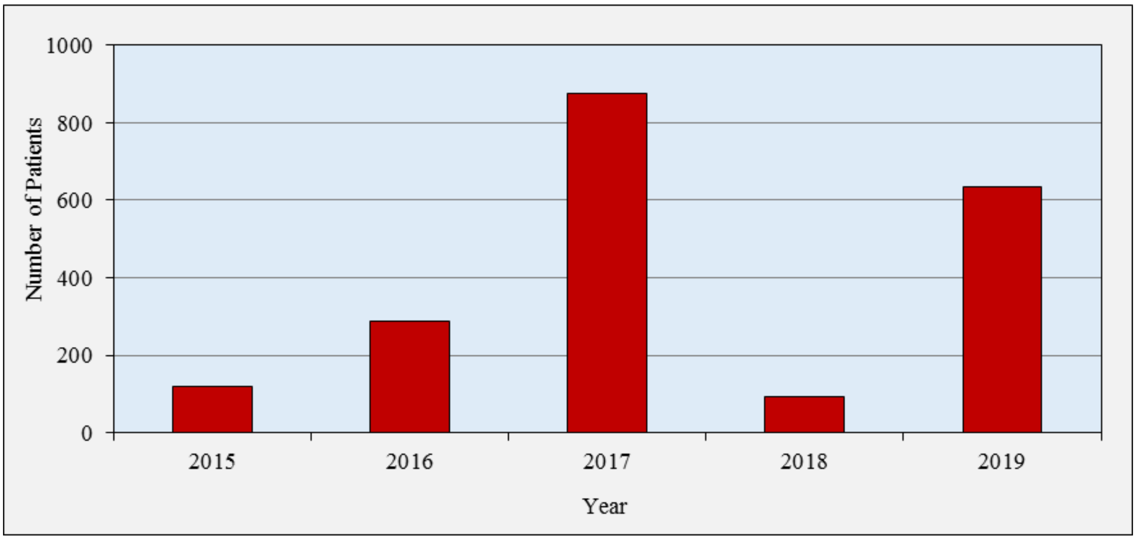


Fig. 2: Number of Dengue Cases in the Badulla DSD During the Years 2015-2019.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

The Least Square method of the time series analysis was used to identify the trend of the monthly dengue cases for the years 2015-2019 in the Badulla DSD and the relevant graphical representation is shown in Figure 3.

As per the result of the analysis, figure 3 represents a positive trend, which means that during the considered years, dengue cases increased with time and the trend value is 0.706 and is statistically significant at the 99% confidence level.

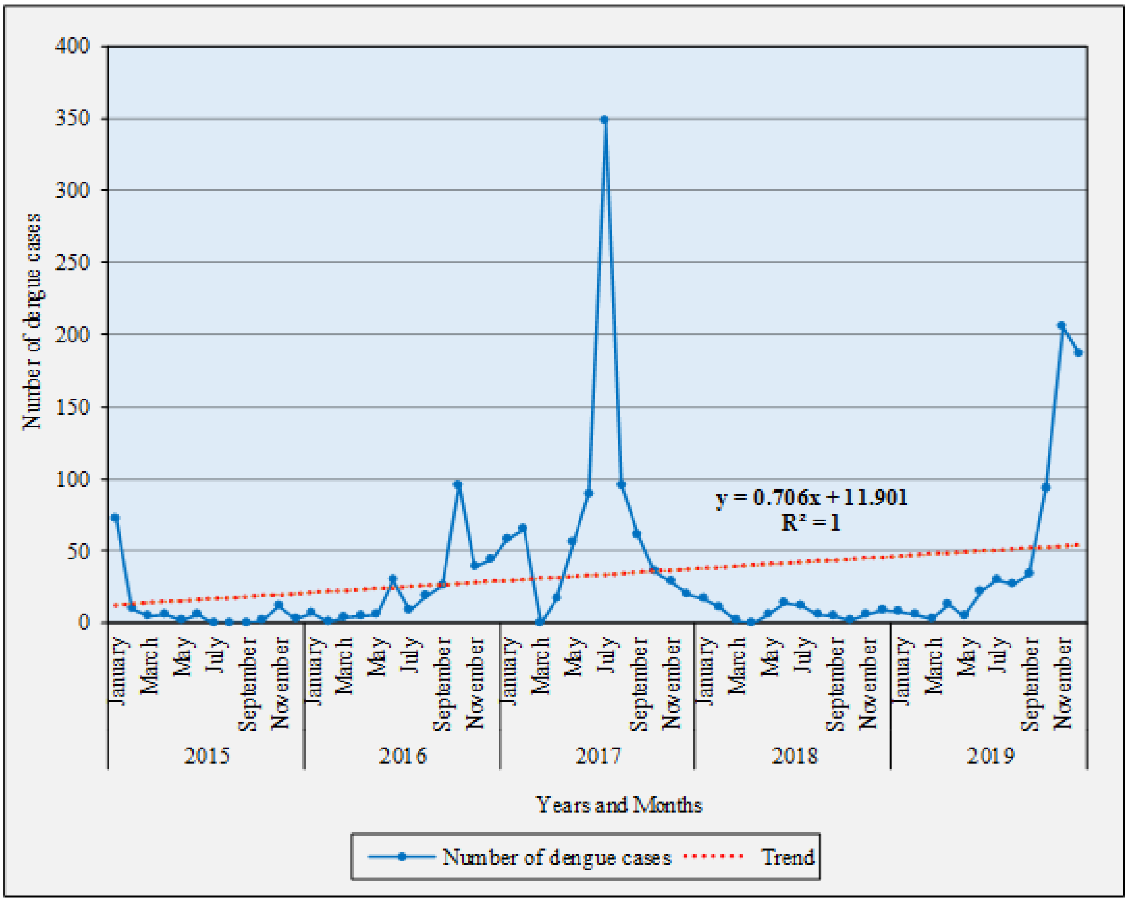


Fig. 3: Temporal Distribution of Dengue Cases during the Years 2015-2019.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

Figure 4 shows the GND-wise spatiotemporal distribution of the dengue epidemic in the Badulla DSD during the years 2015-2019. As seen in the Figure, the urban divisions are located in the Western half of the DSD and are represented by the serial numbers 1-13. The rural divisions are mostly located in the Eastern half of the DSD and are represented by serial numbers 14-29. As the Figure, except for the GND of Damanwara (17), which represented the highest number of dengue cases in 2019, almost all the other GNDs represented the highest number of dengue cases in the year 2017. Figure 5 shows the year-wise spatial distribution of the dengue epidemic in the Badulla DSD in 2015-2019.

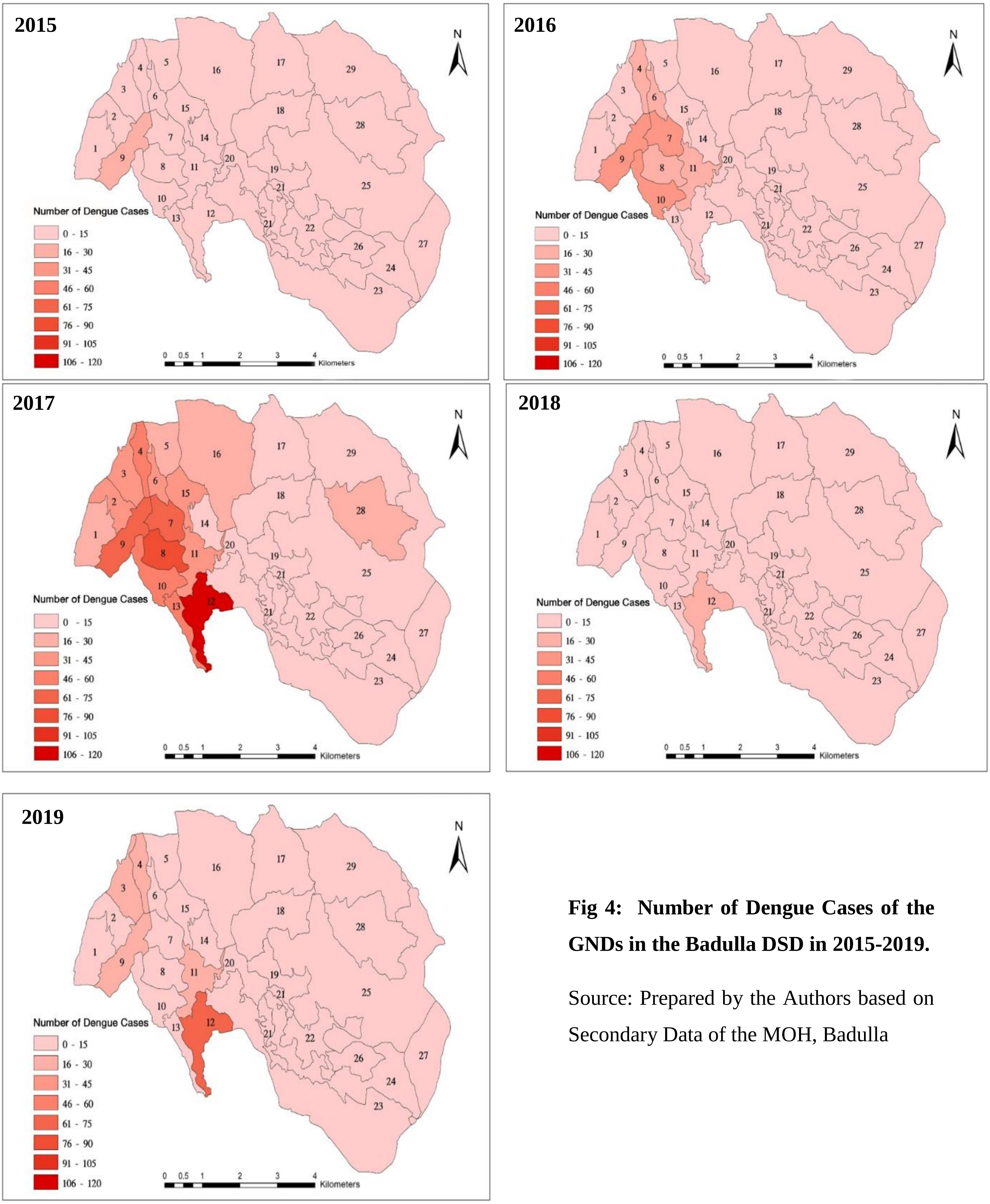
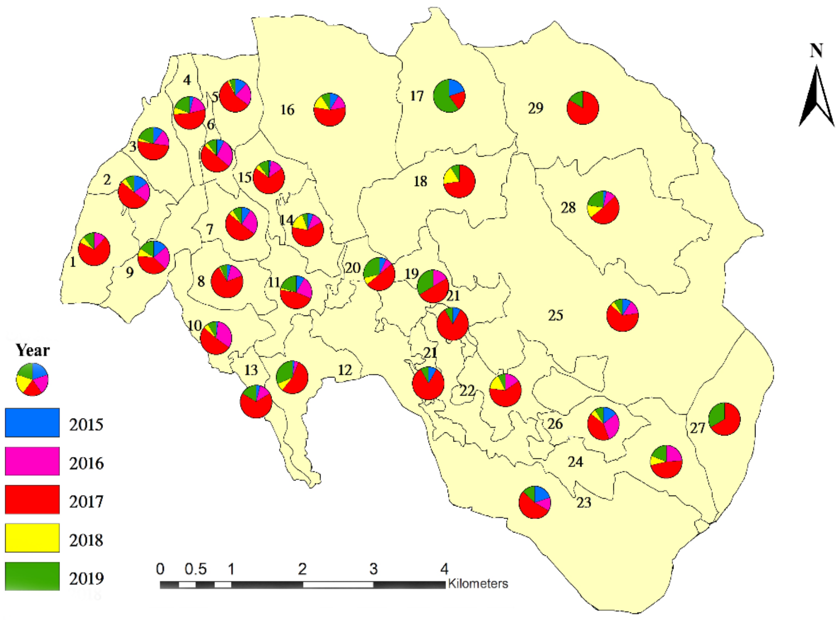


Fig 4: Number of Dengue Cases of the GNDs in the Badulla DSD in 2015-2019.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla



Rural/Urban	GN Divisions			
Urban	1 - Katupelella	2 - Badulla West	3 - Pitawelagama	4 - Badulla North
	5 - Medapathana	6 - Kailagoda	7 - Badulupitiya	8 - Badulla East
	9 - Badulla Central	10 - Badulla South	11 - Hindagoda	12 - Hingurugamuwa
	13 - Kanupelella			
Rural	14 - Ilegoda	15 - Andeniya	16 - Sirimalgoda	17 - Damanwara
	18 - Ilukthenna	19 - Malangamuwa	20 - Rambukpotha	21 - Udewela
	22 - Viyadiguna	23 - Glen Alpin Estat	24 - Wewessa	25 - Thelbedda Estate
	26 - Vineethagama	27 - Welibissa	28 - Kendagolla	29 - Hinnarangolla

Fig. 5: Year-wise Spatial Distribution of the Dengue Epidemic in Badulla DSD in 2015- 2019.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

As shown in Figure 5, altogether, 81% of the reported dengue cases in 2015 were identified in the urban GNDs (1-13). Among them, the highest number of dengue cases were reported in the Badulla Central GND (9), which represented 19% of the total cases in the year. The remaining GNDs were noticeable for reporting less than 13 dengue cases in the year. The spatial distribution of the dengue epidemic in 2016 shows that 85% of the total number of dengue cases were reported in the urban divisions. A similar feature to the year 2015 could also be seen in 2016, the highest number of dengue cases were reported in the Badulla Central GND, which represented 13% of the total dengue cases in the year. The second highest dengue cases have been reported in the Badulla South (10) and Badulupitiya (7) urban divisions. The remaining 26 GNDs were identified as reporting less than 22 dengue cases in the year.

As seen in Figure 5, in 2017, the highest number of dengue cases in Badulla DSD were reported in the Higurugamuwa (12) urban division, which represented 13%, of the total dengue cases in the year. The second highest was the Badulla East (8) urban division, responsible for 10% of the total dengue cases in 2017. The third highest number of dengue cases were reported from Badulla Central and Badulupitiya urban divisions. Thus, 80% of the total number of reported dengue cases in 2017 could be seen in the urban divisions in the Badulla DSD. Accordingly, within the year, more than 60 dengue cases have been reported in the urban divisions.

Among the 90 dengue cases that were reported in 2018, the highest number of cases have been identified in the Higurugamuwa urban division, representing 18% of the total dengue cases. While less than 15 dengue cases have been reported from the remaining 28 GNDs. Altogether 71% of the total number of reported dengue cases in 2018 were noticed from the urban divisions.

Though the MOH records show 635 total dengue cases in the Badulla DSD in 2019, only 255 dengue cases could be categorized according to the GNDs. Therefore, only those 255 dengue cases were considered for mapping the spatial distribution of dengue cases in 2019. In the years 2017 and 2018, also in 2019, the highest number of dengue cases were reported from the Higurugamuwa urban division, which represented 25% of the dengue cases in the year. The second highest number of dengue cases was reported from Badulla Central, representing 10% of the dengue cases in the year. Badulla North (4) and Hindagoda (11) urban divisions had become the third highest. Apart from that, the remaining 25 GNDs were noticed as reporting less than 18 dengue cases in 2019. About 82% of the total number of reported dengue cases in 2019 were reported from urban divisions.

6.2. Association between population characteristics and the distribution of dengue cases in the Badulla DSD in 2019

Two characteristics of the population in the Badulla DSD were taken into account to investigate the association between population and the distribution of dengue cases in the Badulla DSD in 2019, that is population size and population density.

When comparing the population size between GNDs in the DSD (Figure 6), except Thelbedda, the rest of the rural divisions could be seen as having relatively low populations. On the other hand, urban divisions (From 1-13) and Thelbedda (25) GNDs could be identified as having high populations. According to Figure 6 (a), the highest population can be seen from the Badulupitiya urban division, which is 5608. Likewise, the lowest population can be identified from the Welibissa rural division, which is 1126. Also, Badulla North, Badulla South, Badulupitiya, Higurugamuwa, and Badulla East urban divisions represent a relatively high population in the area. The association between population size and the spatial distribution of the dengue epidemic in the Badulla DSD in 2019, showed that the highest number of dengue cases that were reported from the urban divisions [as depicted in Figure 6 (a)] is aligned with the high population of the area [Figure 6 (b)].

The study further investigated the association between reported dengue cases and the population density in the Badulla DSD in 2019 [Figures 6 (a) and 6 (b)]. As depicted in Figure 6 (a), the high population density in the area in 2019 is seen in the urban segment of the DSD. However, as in Figure 6 (b), the highest number of dengue cases did not match the highest population density in the urban segment of the DSD.

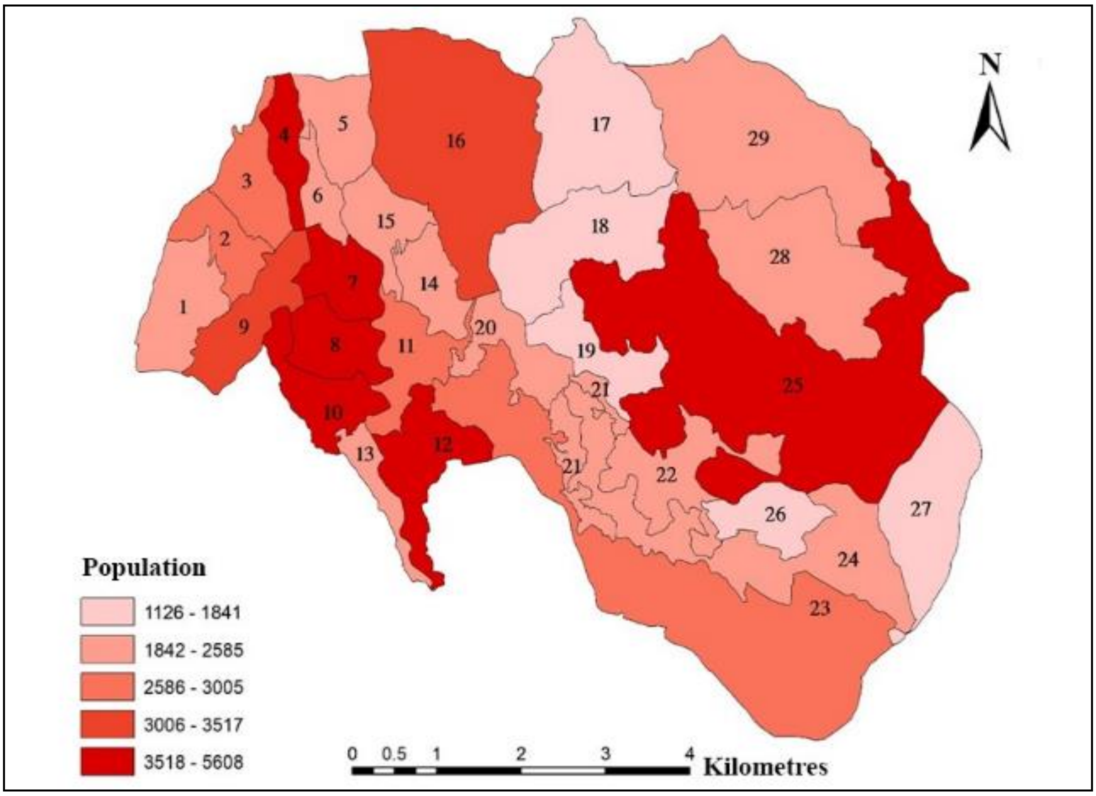


Fig. 6 (a): Distribution of the population in Badulla DSD in 2019.

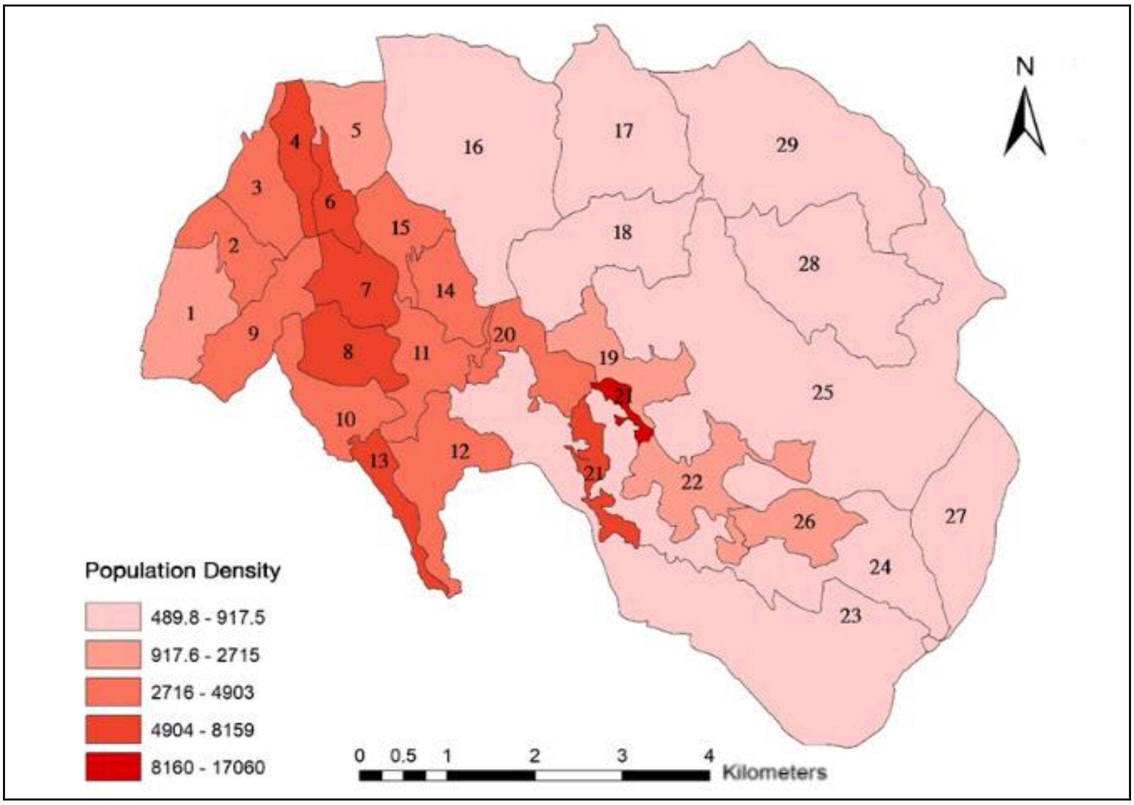


Fig. 6 (b): Population density of the Badulla DSD in 2019.

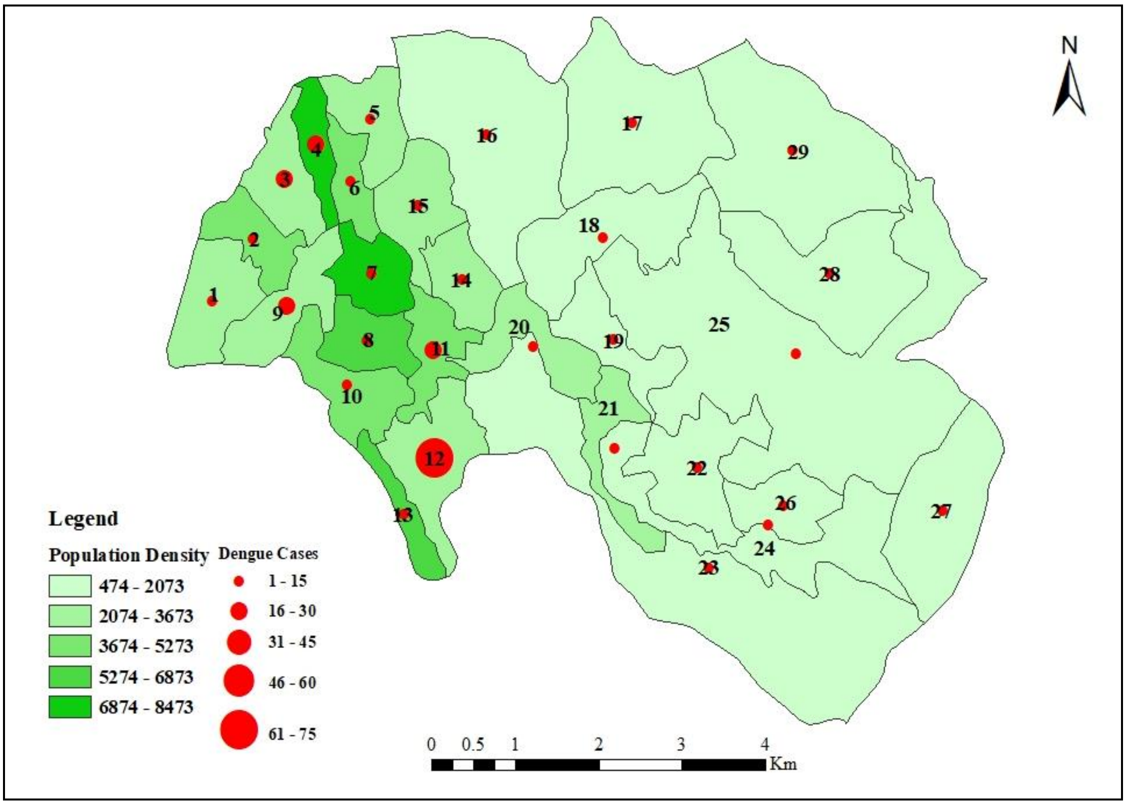


Fig. 6 (c): Number of Dengue Cases and population density in Badulla DSD in 2019.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

6.3. Characteristics of the Spatial Distribution Pattern of Dengue Epidemic in the Badulla DSD in 2019

As mentioned in the methodology of the study, 102 families were selected as the sample of the study using the stratified random sampling method to identify the characteristics of the spatial distribution pattern of the dengue epidemic in the Badulla DSD in 2019. In that manner, as the first step, the geographic locations of the selected families were plotted using a scatter dot map and shown in Figure 7. As the Figure, it is clear that the highest concentration of dengue cases could be seen in the northwestern, western, and southwestern parts of the DSD, which is in the urban segment of the study area.

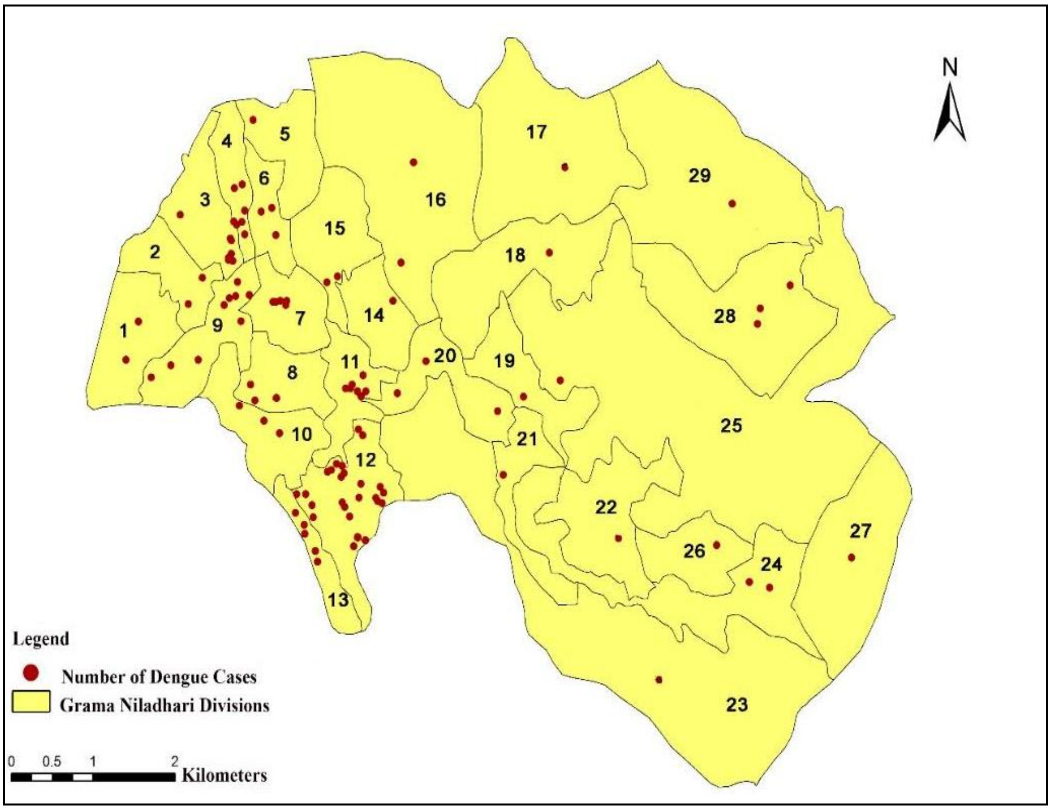


Fig. 7: Selected households to identify the spatial distribution pattern of the dengue epidemic in Badulla DSD in 2019.

Source: Prepared by the Authors based on Primary data.

According to the Kernel Density Estimation method (Figure 8), the hotspots of the epidemic in the year 2019 are mainly concentrated in the northwestern and southwestern parts of the DSD, representing the Hingurugamuwa, Hindagoda, Pitawelagama, Kailagoda, Badulupitiya, and Badulla South, Badulla East, and Badulla central urban domains.

These results are comparable with the results and discussion that were evidenced in sections 6.1, 6.2, and 6.3.

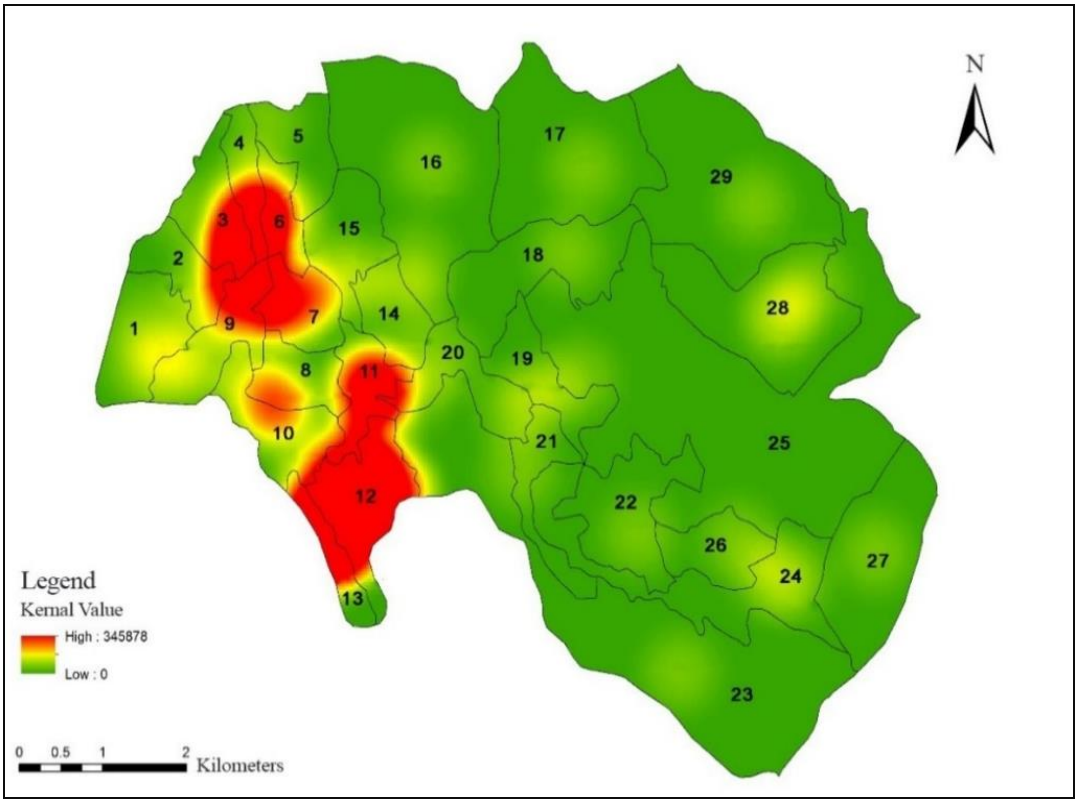


Fig. 8: Spatial Distribution of Dengue Cases in 2019 in the Badulla DSD.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

Further, the Average Nearest Neighbour Analysis method was applied in this study to determine whether the identified distribution is clustered, random, or regular and the result of the analysis is displayed in Figure 8. The Z-score in Figure 9 shows that the index is less than 1%. According to the Average Nearest Neighbour Analysis method theory, when the index (average nearest neighbor ratio) is less than 1, the pattern shown is clustered. Hence, the analysis of the study revealed a clustered pattern of the dengue households of the Badulla DSD in 2019 and it was statistically significant at the 99% confidence level.

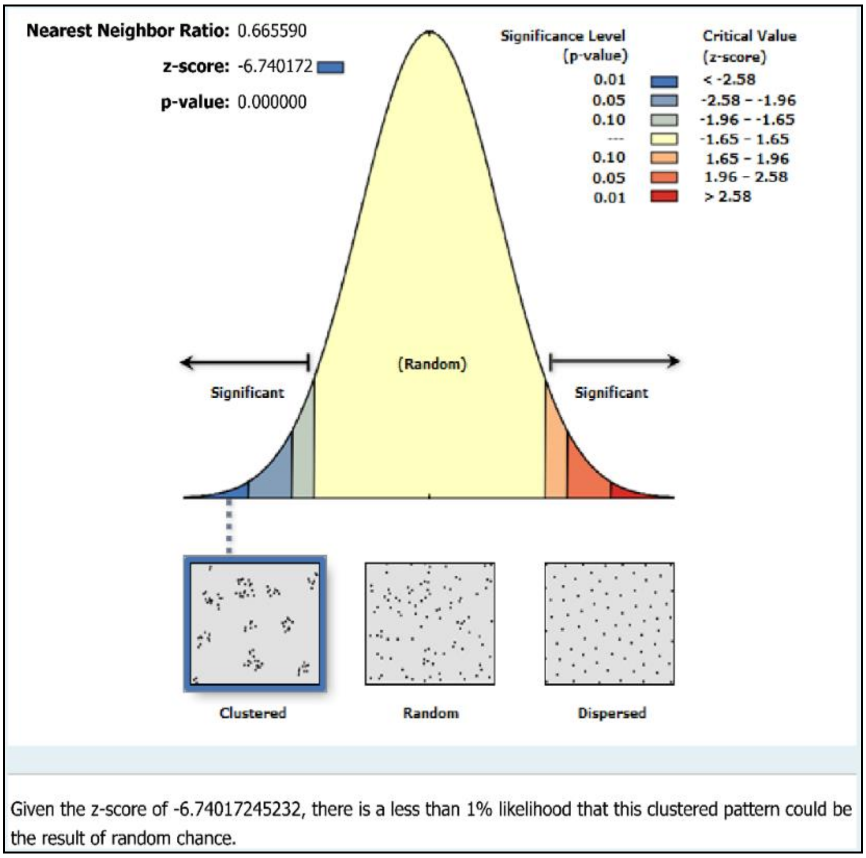


Fig. 9: Results of the Average Nearest Neighbor Analysis.

Source: Prepared by the Authors based on Secondary Data of the MOH, Badulla.

7. CONCLUSION AND RECOMMENDATIONS

The study concluded that, during the years 2015-2019, the highest number of dengue cases were reported in 2019 and the lowest number of cases were reported in 2018. It is evident that the urban GNDs in the Badulla DSD are mostly affected by the epidemic and among them, Badulla Central and Higurugamuwa were the most vulnerable GNDs. Higurugamuwa, Badulla Central, Badulla South, Badulla East, and Badulupitiya represented 70% of the reported dengue cases. Among them, the Higurugamuwa division is reported as having the highest number of dengue cases in the years 2017, 2018, and 2019. The monthly temporal distribution of the dengue cases in the Badulla DSD during the years 2015-2019 showed an increasing trend and the trend value (0.708) is statistically significant at the 99% confidence level. GND-wise reported dengue cases in the year 2019 were positively aligned with the population size of the GNDs in the same year. However, the highest number of dengue cases did not match the highest population density. According to the spatial distribution pattern of the dengue epidemic in the Badulla DSD in 2019, the western half of the study area, which is the urban segment could be identified as the hotspot area of the epidemic. As identified in the

Average Nearest Neighbour Analysis, the spatial distributions of the households of the dengue patients represent a statistically significant clustered pattern.

High population and improper solid waste disposal methods in the urban domains are the major factors of the vulnerability of the dengue epidemic. Therefore, the research suggests vigorous dengue prevention methods, especially in the municipal council area including proper solid waste disposal methods, breeding predators of mosquitoes (butterflies, dragonflies, etc.), releasing mosquito-eating Elephant mosquitoes into the environment, applying insect screening in houses, maintain a hotline service that needs to be activated as soon as dengue mosquito breeding places are noticed, educating people about waste management practices and organize continuous community awareness programs in the study area.

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REFERENCES

1. Edirisinghe, G., Emerging factors dengue epidemic in Matara district in Sri Lanka. World Journal of Engineering Research and Technology, 2018; 6(1): 102-117.
2. Guo, R.-n.et al., The Prevalence and Endemic Nature of Dengue Infections in Guangdong, South China: An Epidemiological, Serological, and Etiological Study from 2005–2011. Plos One, 2014; 9(1).
3. Jayarajah, U., Faizer, S., Zoysa, I. M. D. & Seneviratne, S. L., 2017. A Large Dengue Epidemic Affects Sri Lanka In. International Journals of Sciences and High Technologies, 2017; 6: 84-86.
4. Jayatilaka, K. D. P., Mosquito-Borne Diseases in Sri Lanka, Prevention and Control. 1st ed. Sri Lanka: Published by Author, 2012.
5. Lubin, M. D., Dengue Fever in South and Southeast Asia, 2023. [Online] Available at: https://ballardbrief.byu.edu/issue-briefs/dengue-fever-in-south-and-southeast-Asia [Accessed 7 March 2023].
6. Majid, N. A., Distribution and Spatial Pattern Analysis on Dengue Cases in Seremban District, Negeri Sembilan, Malaysia, Malaysia: Institute for Environment and Development, 2019.

7. Manna, S., Satapathy, P., Bora, I. & Padhi, B. K., Dengue outbreaks in South Asia amid Covid-19: Epidemiology, transmission, and mitigation strategies. Infectious Diseases: Epidemiology and Prevention, 2022.
8. Manna, S., Satapathy, P., Bora, I. & Padhi, B. K., Dengue outbreaks in South Asia amid Covid-19: Epidemiology, transmission, and mitigation strategies. Infectious Diseases: Epidemiology and Prevention, 2022.
9. Messina, J. P. et al., The Current and future global distribution and population at risk of dengue, 2019; 1508-1515.
10. Noordeen, F. et al., Distribution of dengue vectors, Aedes aegypti and Aedes albopictus, in a few selected semi-urban areas of the Central Province of Sri Lanka. Sri Lankan Journal of Infectious Diseases, 2018; 8(1): 36-39.
11. Pathirana, S., Kawabata, M. & Goonatilake, R., Study of the potential risk of dengue disease outbreak in Sri Lanka using GIS and statistical modeling. Journal of Rural and Tropical Public Health, 2009; 8: 8-11.
12. Rahman, M. S. et al., Mapping the spatial distribution of the dengue vector Aedes aegypti and predicting its abundance in northeastern Thailand using a machine-learning approach. One Health, 2021; 13.
13. Saita, S., Maeakhian, S. & Silawan, T., Temporal Variations and Spatial Clusters of Dengue in Thailand: Longitudinal Study before and during the Coronavirus Disease (COVID-19) Pandemic. Tropical Medicine and Infection Disease, 2022; 7.
14. Sanyaolu, A. et al., Global Epidemiology of Dengue Hemorrhagic Fever: An Update. Journal of Human Virology & Retrovirology, 2017; 6.
15. Schaefer, T. J., Panda, P. K. & Wolford, R. W., 2022. Dengue Fever. [Online] Available at: https://www.ncbi.nlm.nih.gov/books/NBK430732/ [Accessed 2 February 2023].
16. Senaratne, T. & Noordeen, F., Diagnosis of dengue in Sri Lanka: Improvements to the existing state of the art in the island, 2014; 686.
17. Sirisena, P. D. N. N. & Noordeen, F., Evolution of dengue in Sri Lanka changes in the virus, vector, and climate. International Journal of Infection Disease, 2014; 9: 6-12.
18. Shabbir, W., Pilz, J. & Naeem, A., 2020. A spatial-temporal study for the spread of. BMC Public Health.
19. Smith, D. S., Mariano, D. J. & Trautwein, M. L., 2022. Dengue. [Online] Available at: https://emedicine.medscape.com/article/215840-overview [Accessed 3 January 2023].

20. Sun, W., Xue, L. & Xie, X., Spatial-temporal distribution of dengue and climate characteristics for two clusters in Sri Lanka from 2012 to 2016. Springer Nature, 2017; 7.
21. Tavodova, M., Dengue fever. South Sudan Medical Journal, 2012; 5: 14.
22. Tissera, H. A. et al., 2020. Severe Dengue Epidemic Sri Lanka. Journal of Emerging Infection Disease, 2017; 26.
23. Warkentien, T. & Pavlicek, R., Dengue Fever: Historical Perspective and the Global Response. Journal of Infection Disease and Epidemiology, 2016; 2(2): 1-6.
24. Wu, T., Wu, Z. & Li, Y. P., Dengue fever and dengue virus in the People's Republic of China. Reviews in Medical Virology, 2022; 32(1).