ORIGINAL RESEARCH ARTICLE

# Spatial Distribution and Cluster Analysis of Dengue In Tamil Nadu, India 2017 – 2019

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## ABSTRACT

**Background:** Dengue, a viral infectious disease, is constantly reemerging and is spread by mosquitoes. It is most common in tropical and subtropical areas of the world, particularly in the Asia-Pacific region. A Surveillance study was carried out in the state of Tamil Nadu-India, from 2017 to 2019 to better understand the epidemiology and geographic spread of dengue.

**Materials & Methods**: Geographical information system (GIS) software was used to map the district-wise endemicity. To pinpoint dengue hotspots and coldspots, spatial statistical analysis techniques like Getis-Ord Gi* were used. To comprehend the endemicity and clustering patterns in the state, self-organising maps (SOM)was also used.

**Results**: Dengue hotspots are Chennai, Thiruvallur, Kancheepuram and cold spots are Cuddalore and Ariyalur for across three years. The SOM divides 30 districts into six clusters. The 10 districts are identified as extremely high endemic cluster and 9 districts as very high endemic cluster. These SOM clusters were projected geographically, and the districts were divided based on the intensity of the cases.

**Conclusion**: SOM-GIS, a visualization technique, identifies hot spots and endemic clusters which helps in prompt decision-making for disease management by public health personnel.

**Key words**: Dengue, GIS, Spatial Distribution, SOM, Tamil Nadu

## ARTICLE INFO

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# Introduction

Dengue is a break bone fever spread by Ades mosquitoes. It occurs more frequently in tropical and subtropical regions. People who are bitten by mosquitoes carrying the dengue virus (DENV) acquire the disease. About 50% of the world's population is currently at risk of dengue, and 100–400 million cases are thought to occur each year.[1] Problem of dengue can be brought on by any of the four closely related dengue viruses (DENV), 1, 2, 3, and 4. A person can get dengue multiple times in their lifetime.[2] There are dengue epidemics in numerous nations throughout the America, Africa, the Middle East, Asia, and the Pacific Islands.[3] Dengue fever is spread by Aedes mosquitoes, which is a day biter and its size is between 3 -5 mm, black with white stripes. The virus develops in mosquitoes within 7 to 8 days and spreads the disease. Predominantly feeds on people in domestic and peri-domestic settings. Bite frequently and bites multiple people per blood meal.[4] According to the World Health Organization's 2010 First Report on Neglected Tropical Diseases, dengue is one among them. Each year, there are hundreds of thousands of severe cases manifest and 20000 of which result in death.[5] Ten of the SEAR's eleven member nations, including India, have dengue as an endemic disease. SEAR countries reported around 0.29 million cases in 2012, with Thailand accounting for nearly 30% of those, Indonesia for 29%, and India for 20%.[5] The dengue virus was originally discovered in India in 1945, and the country's first case of dengue fever was documented in the Vellore district of Tamil Nadu, in 1956. In West Bengal, Calcutta had the first dengue hemorrhagic fever outbreak in 1963. In the last 20 years, dengue cases have been documented in 35 of the 36 states and UTs. Multiple states and the UTs (Andhra Pradesh, Chandigarh, Delhi, Goa, Haryana, Gujarat, Karnataka, Kerala, Maharashtra, Rajasthan, Uttar Pradesh, Punjab, Tamil Nadu, and West Bengal) have reported recurrent dengue fever and dengue hemorrhagic fever epidemics. There has been an increase in dengue/DHF cases every year from July to November. The prevalence of this disease fluctuates throughout the year, peaking following the monsoon season. Southern and western states of India, has perennial transmission. The majority of cases were previously seen in urban areas, but this pattern is now shifting due to invasion of Aedes aegypti mosquitoes into rural regions, as a result of socioeconomic and man-made ecological changes.[5] Tamil Nadu rainfall statistics shows that, the state has four rainfall spells Pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–December), and winter (January–February). Tamil Nadu gets low rainfall in southwest monsoon which occurs from June to September & high rainfall in northeast monsoon lasts from October to December.[6] Multiple DF/DHF epidemics in Tamil Nadu weren't discovered till 1990. In Tamil Nadu over the past ten years, there is comprehensive documentation of the geographic expansion, increase in cases, reporting system, laboratory diagnosis, monitoring of vector density, and investigation of outbreaks.[7] Complex interactions between hosts, vectors and viruses, impacted by environmental, climatic, demographic, and socioeconomic factors, are the causes for increase in dengue incidence. Along with this, other factors that influence the spread of dengue fever include human population expansion, migration, rapid urbanization, more international travels, inadequate public health infrastructure, and insufficient vector control and disease surveillance systems. Dengue's complicated epidemiology is still poorly understood. Numerous field observations have cast doubt on dengue's epidemiological characteristics, which have long been accepted. Determining the effectiveness of prevention and control programs thus depends on having a thorough understanding of dengue's changing pattern and trend.[8]

The current study aims are to investigate the spatial distribution of dengue cases and to pinpoint dengue hotspots in Tamil Nadu by employing spatial cluster analysis methods like Getis-Ord Gi* and self-organizing maps (SOM) with Geographical Information System (GIS) tools.

# Methodology

**Study Area:** Tamil Nadu (Fig 1 & 2) population as per 2011 census is 72,147,030 of which male and female are 36,137,975 and 36,009,055 respectively.[9] Tamil Nadu covers an area of 130,058 sq km [10] and it is situated in Latitude and longitude 11.059821, 78.387451.[11] Tamil Nadu receives less rain fall from South West monsoon from the month July to September and receives more rain fall from North East monsoon from the month October to December.[12]

**Epidemiological Data:** The Directorate of Public Health and Preventive Medicine (DPH&PM), Tamil Nadu provided the epidemiological data on dengue cases from 2017 to 2019, which includes details on dengue patients from 30 districts in Tamil Nadu.

**Ethical Approval:** The DPH&PM, Tamil Nadu granted scientific committee permission and an ethics committee waiver for the study, and the Karpaga Vinayaga Institute of Medical Sciences and Research Centre in Maduranthakam granted ethical approval. No specific patient name was used in the analysis of the data, which was conducted anonymously.

**Geographical Information System (GIS) Mapping Dengue:** A GIS technique was used to map the district wise distribution of dengue cases using the ArcGIS software.

**Data Analysis**

**Hot Spot Analysis:** Getis-OrdGi* statistics detects various spatial clustering patterns across the state, including hot spots, cold spots and high-risk areas.[13]


Figure 1: Layout map of India

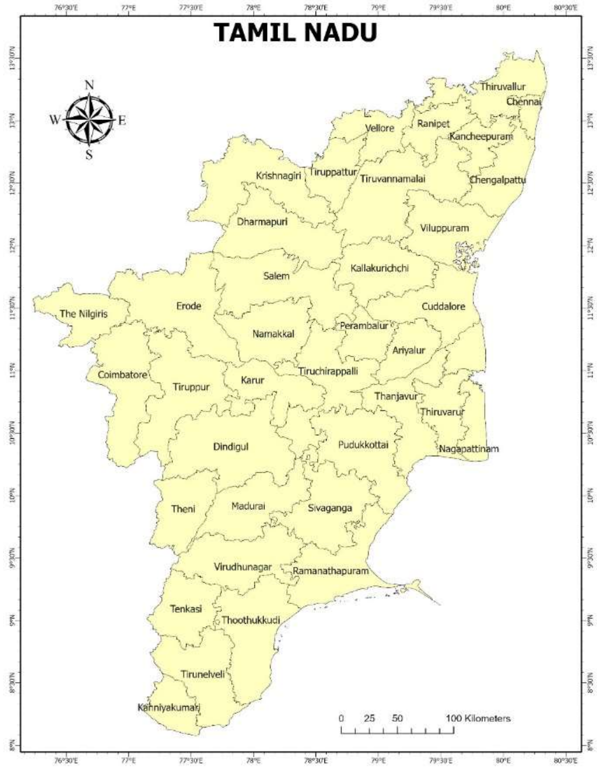


Figure 2: Layout map of Tamil Nadu

The result is reported as the Z-score and p-value of the estimated Gi*, when compared to the normal distribution of the statistics acquired from simulation.[14] When considering the notion of spatial links and the scale of analysis (distance parameter), these values show the statistical importance of the geographical clustering of values. According to the results of Gi * statistics, hot spots are defined as spatial clusters (Districts) with a high number of cases that are surrounded by other districts with high numbers of cases, while cold spots are defined as spatial clusters (Districts) with a low number of cases that are surrounded by other districts with low numbers of cases. In order to provide evidence to support the policy decisions, this hot spot study accurately identifies dengue hot and cold spots that have spatial association with various districts in Tamil Nadu. Cutoff for statistical significance was chosen as $P < 0.01$.

**Cluster Analysis using (SOM) Self Organizing Map:** A straight forward, planar self-organizing map that uses techniques akin to Scikit Learn's clustering techniques. Sklearn-som is a Kohonen self-organizing map with a planar (rectangular) topology. It is a modest, straightforward implementation. It is employed for data clustering and dimensionality reduction for an overview of self-organizing maps in brevity.[15]

In order to offer a novel method for the study from various perspectives, SOM and spatial applications have been combined into GIS. The SOM results (i.e., clusters) of the disease endemic regions were coupled with the GIS in the current study, which is the first of its type study on dengue in Tamil Nadu and it reveals the pattern of the disease in various endemic regions. This SOM GIS approach aids in both vector control operations and disease transmission.

**Table1: District wise distribution of Dengue cases for three years**

| Sr. No | Districts | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| 1 | Kancheepuram | 1883 | 568 | 1760 |
| 2 | Thiruvallur | 3634 | 1321 | 4192 |
| 3 | Vellore | 1427 | 369 | 1641 |
| 4 | Tiruvannamalai | 2698 | 317 | 778 |
| 5 | Cuddalore | 1598 | 583 | 1256 |
| 6 | Villupuram | 1992 | 408 | 861 |
| 7 | Thanjavur | 3254 | 346 | 667 |
| 8 | Thiruvarur | 725 | 99 | 305 |
| 9 | Nagapattinam | 980 | 171 | 375 |
| 10 | Tiruchchirappalli | 2546 | 288 | 831 |
| 11 | Karur | 562 | 106 | 337 |
| 12 | Ariyalur | 799 | 125 | 309 |
| 13 | Perambalur | 621 | 44 | 249 |
| 14 | Pudukkottai | 3376 | 591 | 758 |
| 15 | Madurai | 4120 | 192 | 768 |
| 16 | Theni | 1706 | 405 | 370 |
| 17 | Dindigul | 2101 | 146 | 348 |
| 18 | Ramanathapuram | 2388 | 406 | 582 |
| 19 | Sivaganga | 1650 | 134 | 575 |
| 20 | Virudhunagar | 2429 | 414 | 594 |
| 21 | Tirunelveli Kattabo | 6357 | 837 | 442 |
| 22 | Thoothukudi | 5105 | 612 | 405 |
| 23 | Kanniyakumari | 4429 | 328 | 397 |
| 24 | Salem | 3403 | 141 | 1057 |
| 25 | Namakkal | 1994 | 121 | 694 |
| 26 | Dharmapuri | 1591 | 232 | 1125 |
| 27 | Coimbatore | 5225 | 641 | 1944 |
| 28 | Erode | 2015 | 166 | 636 |
| 29 | Nilgiris | 314 | 28 | 48 |
| 30 | Chennai | 9502 | 4837 | 5095 |

## RESULTS

The epidemiological data shows the descriptive statistics of Tamil Nadu (districts = 30) during the period 2017 to 2019. The number of positive dengue cases in 2017 (80424 cases) which was comparatively higher than dengue cases in 2018 (15056 cases) and dengue cases in 2019 (29410 cases).

**District Level Distribution Pattern of Dengue Cases**: Distribution pattern is based on number of dengue cases in all districts (n=30) of Tamil Nadu shown in Table 1 and descriptive statistics of dengue cases for three years shown in Table 2.

The figures indicate the choropleth maps showing dengue cases distribution in the years 2017, 2018 & 2019. The distribution was divided into five quantiles and it is shown in the legend. Darker color indicates more number of cases and lighter color indicates less number of cases. In 2017, high number of cases were in Chennai, Madurai, Tirunelveli, Thoothukudi, Coimbatore and Salem. (Fig 3) In 2018, high number of cases were in Chennai, Thiruvallur, Cuddalore, Thirinelveli, Theni & Coimbatore. (Fig 4) In 2019, high number of cases were in Chennai, Thiruvallore, Kancheepuram, Dharmapuri, Salem & Coimbatore. (Fig 5)

**Table 2: Descriptive statistics of Dengue cases for three years**

| Details | 2017 | 2018 | 2019 | 2017-2019 |
|---|---|---|---|---|
| **Mean** | 2708.31 | 496.83 | 953.07 | 4158.21 |
| **Standard Error** | 371.67 | 163.22 | 206.00 | 671.51 |
| **Median** | 2101.00 | 317.00 | 636.00 | 3437.00 |
| **Standard Deviation** | 2001.53 | 878.98 | 1109.36 | 3616.21 |
| **Sample Variance** | 4006124.51 | 772598.50 | 1230686.07 | 13076977.46 |
| **Range** | 9188.00 | 4809.00 | 5047.00 | 19044.00 |
| **Minimum** | 314.00 | 28.00 | 48.00 | 390.00 |
| **Maximum** | 9502.00 | 4837.00 | 5095.00 | 19434.00 |

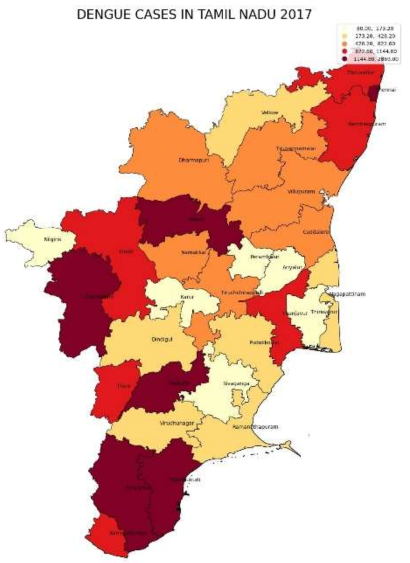


**Figure 3: Distribution of Dengue cases in Tamil Nadu 2017**

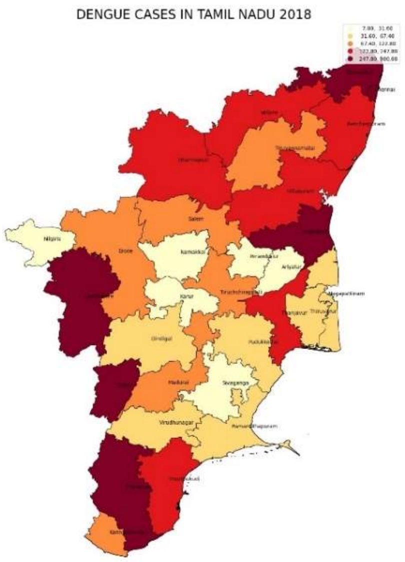


**Figure 4: Distribution of Dengue cases in Tamil Nadu 2018**

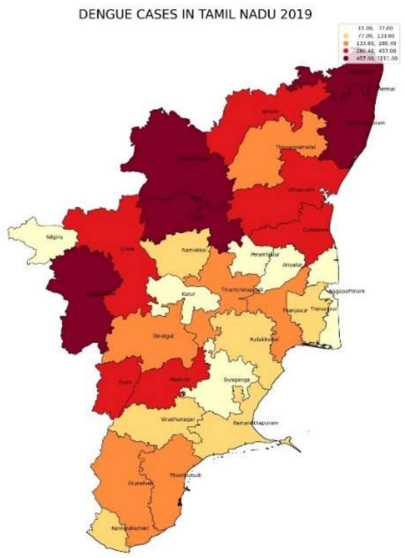


**Figure 5: Distribution of Dengue cases in Tamil Nadu 2018**

**Hot spot Analysis**: With the help of Getis-OrdGi* and its Z-score, the locations with high and low dengue case abundance clusters were identified. In 2017, Chennai, Thiruvallore, Thirunelveli, Kancheepuram & Kanniyakumari were hot spots with 95% confidence and Cuddalore & Ariyalur were cold spots with 90% confidence. (Fig 6) In 2018 & 2019, Chennai, Thiruvallore & Kancheepuram were hot spots with 99% confidence. (Fig 7&8) Hot spot analysis for across three years shows Chennai, Thiruvallore & Kancheepuram were hot spots with 99% confidence. (Fig 9)

**SOM Cluster Analysis**: For the year 2017, 2018 & 2019, dengue data were analyzed using SOM. According to number of cases in each districts the SOM classified into six endemicity clusters. The extremely high prevalence clusters were Chennai, Thiruvallore, Coimbatore, Salem, Tanjavur, Pudukottai, Madurai, Thoothukudi, Thirunelveli and Kanniyakumari. The very high prevalence clusters were Kancheepuram, Thiruvannamalai, Villupuram, Erode, Namakkal, Trichy, Dindugal, Virudhunagar and Ramnad. The high prevalence clusters were Dharmapuri, Vellore, Cuddalore, Sivagangai, Theni. The low prevalence clusters were Ariyalur, Nagapatinam & Thiruvarur. The very low prevalence cluster was Nilgiris. The extremely low prevalence cluster were Karur and Perambalur. The dengue endemic area was divided into six quantiles based on SOM cluster analysis, and these were physically plotted using GIS (Fig 10).

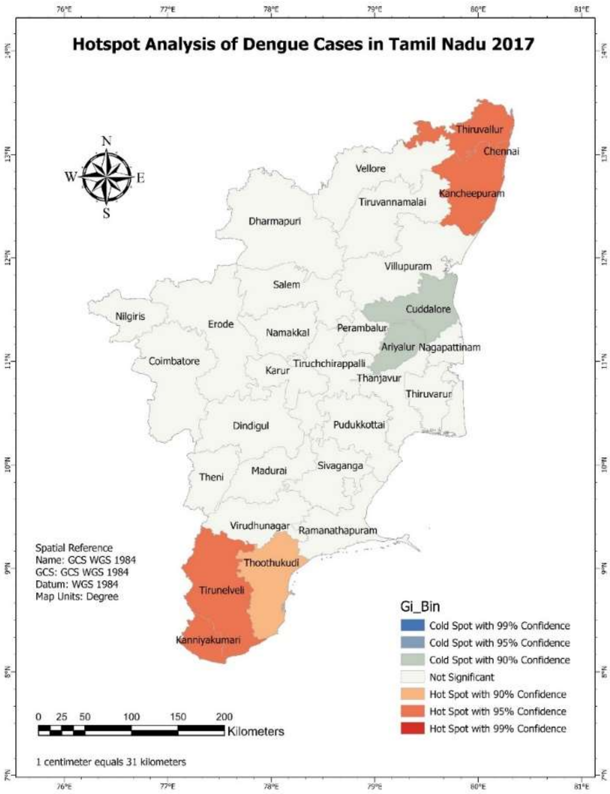


**Figure 6: Hotspot Analysis of Dengue cases in Tamil Nadu in 2017**

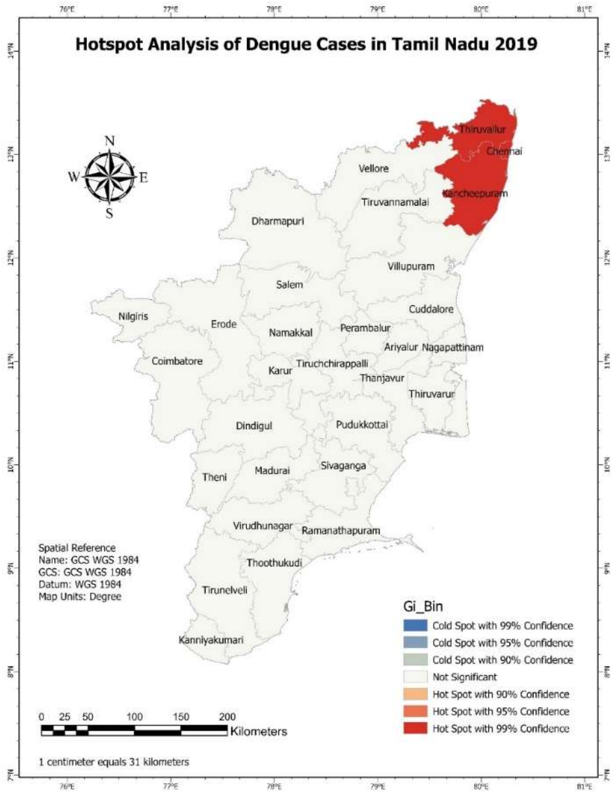


**Figure 8: Hotspot Analysis of Dengue cases in Tamil Nadu in 2019**

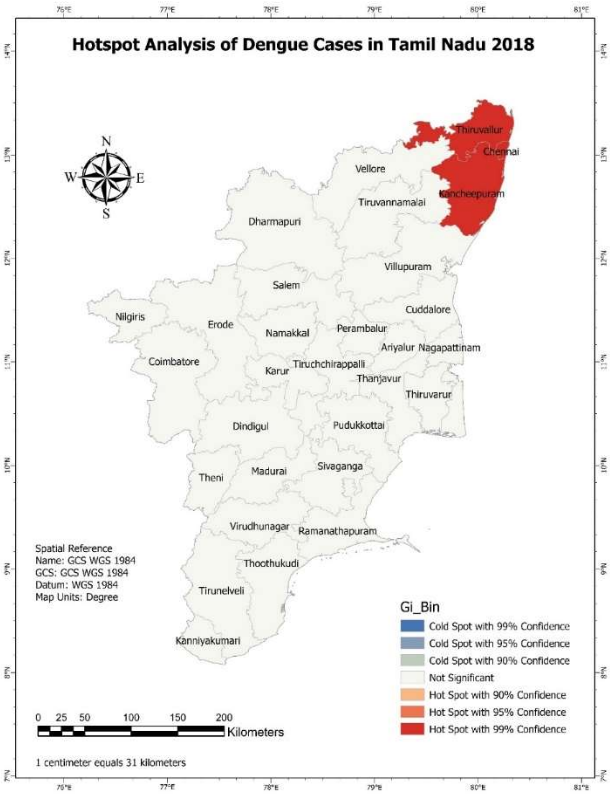


**Figure 8: Hotspot Analysis of Dengue cases in Tamil Nadu in 2018**

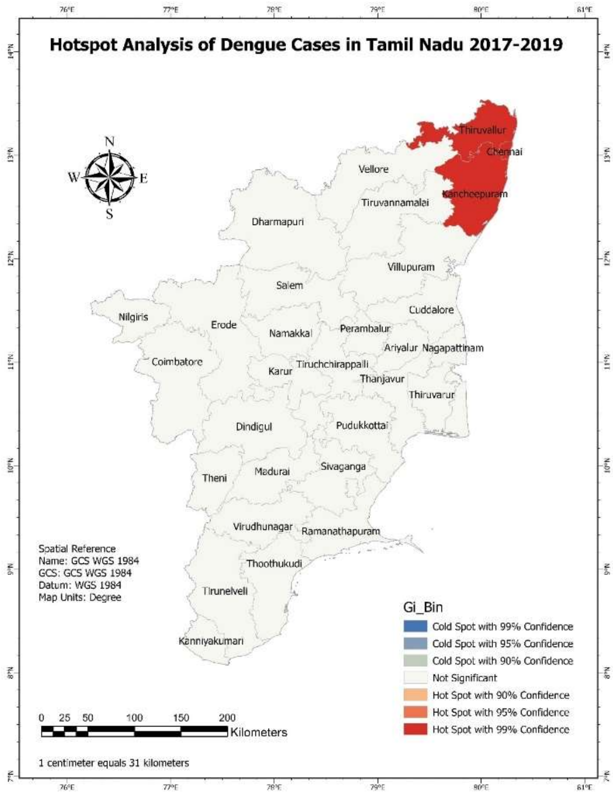


**Figure 9: Hotspot Analysis of Dengue cases in Tamil Nadu in 2017 – 2019**

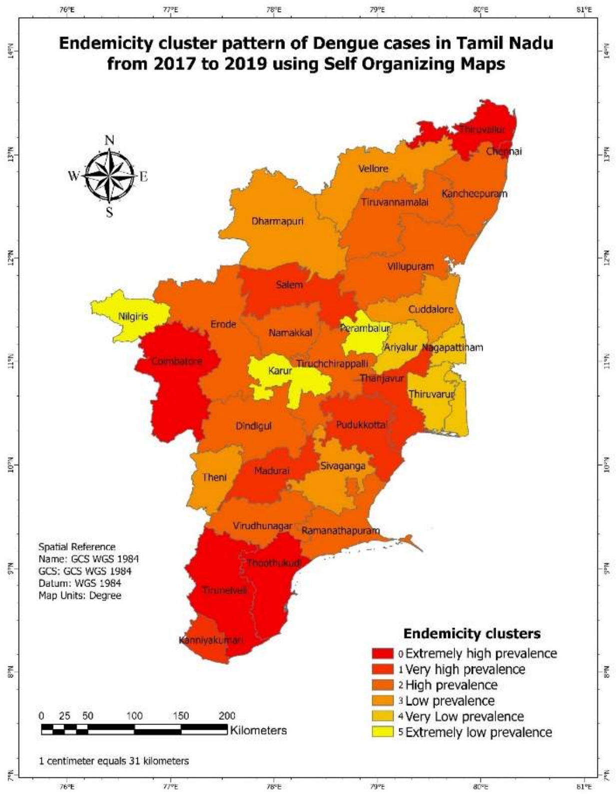


**Figure 10: Endemicity of cluster pattern of Dengue cases in Tamil Nadu from 2017 – 2019 using Self Organizing Maps**

# DISCUSSION

India is one of the countries, with the highest dengue endemicity in the world, and dengue incidence is steadily rising over years. Despite improved case management and drop in CFR, number of dengue cases has continually increased over time.[16] It is crucial to conduct appropriate surveillance studies, epidemiological data analysis, outbreak prediction, and hot spot analysis in order to comprehend dengue epidemiology. This study shows the changing and trend pattern of Dengue all over the state. Few of the districts were high endemic for consecutive years and will have chances of secondary dengue, which is a risk factor for Dengue hemorrhagic fever (DHF) and Dengue shock syndrome (DSS).[17] In this study, we used cluster analysis to know the epidemiological distribution and the spatial pattern of dengue in Tamil Nadu, India, from 2017 to 2019. During the year 2017, there was a significant dengue outbreak in Tamil Nadu.[18] Regarding distribution of dengue cases all over Tamil Nadu, high number of cases were found in Chennai and Coimbatore Districts for all the three years from 2017 – 2019. In districts, like Salem, Tirunelveli and Thiruvallur high number of cases were reported for two years. The findings of this study showed that distribution of dengue fever is not similar in all districts of Tamil Nadu. The variation in geographic distribution may be due to mosquito densities, transmission intensities and mosquito biting rates.[19] Districts with more rainfall usually have more number of cases. Districts with low rainfall, can also have more dengue cases due to improper water storage practices among public, may act as source of dengue.[20]

The SOM projections classified high endemic and low endemic clusters based on the neighboring relations which is important for disease clustering. Out of 30 districts, 10 districts were extremely high endemic cluster, 9 district were very high endemic cluster (See Fig:10). Low case severity locations may be crucial for the development of extremely virulent dengue strains. Understanding the history of shifting patterns of infection, is essential for anticipating sources of virulent dengue strains as the dengue virus's distribution changes globally.[19] These endemic clusters areas shown in the study were done by SOM analysis. The successful integration of SOM and GIS has produced dynamic visualization, which in turn aids public health authorities in making quick decisions for disease management and control.

In 2017, Chennai, Thiruvallur, Kancheepuram districts in north eastern part and Kanniyakumari & Tirunelveli in southern part of Tamil Nadu were identified as hot spot, by spatial distribution. Ariyalur and Cuddalore were cold spots in the same year. In 2018 & 2019, Chennai, Thiruvallur, Kancheepuram districts were identified as hot spots. It was observed that the population of these regions keep close connections, frequently migrate and rapidly urbanize for development activities of Tamil Nadu and have emerged as hot spots. Gubler et al study shows that future dengue outbreaks are expected to increase in intensity, frequency, geographic spread and magnitude due to worldwide patterns of extraordinary population expansion, ongoing globalization, and increasing urbanization.[21] Fan J et al study shows that precise information on the geographical pattern of DF transmission is necessary for the effective allocation of health resources in DF control and prevention activities. IVM, environmental improvements, climate pattern and vector surveillance-based early warning system, planned population expansion, and managed urbanization should all be included in an effective long-term sustainable control program that combines a top-down and bottom-up approach.[22] Given that Tamil Nadu is the seventh most populous state in India by population, all of the aforementioned factors could lead to an elevated dengue risk in the state's districts.[9] Prevention of dengue cases in the Tamil Nadu depends on holistic vector control measures, behavior change of public in water storage practices, rainfall statistics and proper disposal of plastic wastes. Spatial analysis with geographic distribution will help public health persons in dengue control activities.

**Strengths of the Study:** Our study's advantages include using three years' worth of dengue data from the DPH&PM in Tamil Nadu, including data from every district in the state, and using tools like the Geographic Information System (GIS) and Self-Organizing Maps (SOM). The results of this study will help public health officials and health officers to pinpoint the hot spot regions (a novel presentation), allocate additional funding and effective resources, for all-encompassing integrated vector control strategies there.

## Limitations

Our study's limitations include the fact that we lack information on the local mosquito population, climatic change, population expansion, and socioeconomic conditions, all of which will affect the incidence of dengue in Tamil Nadu.

## Conclusion

Using GIS tools, we identified dengue clusters in the state of Tamil Nadu that were spatially and temporally clustered, as hot and cold spots. Geographically variable distribution of dengue in Tamil Nadu will benefit from these spatial and temporal clusters, as well as from highly supportive locally tailored interventions. Additionally, our research implies that geographical and temporal studies of population-based disease monitoring data could be useful in managing vector-borne disease like dengue by indicating when and where scarce public health resources should be focused.

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