Epidemiological Study of Dengue Cases in India : A Perspective on Biomedical Statistics

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***Abstract*— Dengue is a serious disease and has been proven fatal to society for over a decade. The only benefit of this illness is that it is not contagious. Its origin is due to Aedes species mosquitoes. Dengue prevails in waterlogged regions across the world. It is also associated with particular weather and climatic conditions mostly prevalent in tropic regions or zones. The treatment cost associated with dengue is substantially high because of the fall in blood platelets level that could probably lead to sudden causality or death. Even though the dengue eradication programme has been in place since 1999, we have not yet eliminated all dengue cases. The worst part of this disease is the likelihood of dengue cases is more for marginal workers and low-income people. They are relatively economically poor and are not able to cope with the high cost. The relevance of the present work is that it gives the roadmap for our policymakers for needful evolution and designing a concrete strategy ranging from awareness programs to treatment and post-treatment, optimization of resources and available health infrastructure, developing a surveillance system, monitoring and control.**

The objective of the present work is firstly to identify the most likely cluster of dengue cases in India through hotspot analysis and descriptive analysis and identify the consistency of the clusters throughout the years.

Keywords*— *Dengue, Hotspot, StaTScan, Z-score, Scanner Statistics.

Introduction

Dengue is a vector-borne illness highly prevalent in tropical and subtropical areas. Dengue is transmitted to people through the bite of an infected Aedes species mosquito (Ae. aegypti or Ae. albopictus). Dengue shock syndrome and dengue hemorrhagic fever are severe forms of illness that can be lethal, even though the majority of infections are moderate. Without rapid diagnosis and in the absence of appropriate antiviral medications or vaccinations, the case fatality rate can reach 20%, especially in places with limited resources. The flood of severe dengue cases during an outbreak might overwhelm the healthcare system and limit the delivery of the best care. Many of the tropical nations where dengue is endemic also bear a heavy societal and financial price. An accurate prediction of the size of the outbreak and trends in disease incidence early enough can limit further transmission and is likely to facilitate planning the allocation of healthcare resources to meet the demand during an outbreak.

I. Literature Review

The incidence of dengue has been rapidly increasing not only in India but in many countries all over the world like Bangladesh, Singapore etc and studies have been done on this to analyze the cause and effects of the spread of the disease [2][3].In a study, it has been found that in Singapore, 86% of the increase was attributable to population growth, and the remaining 14% was explained by temperature rise[2].

It is time for both scientists and policymakers to pay more attention to the adverse impacts of urbanization and the urban environment on diseases like dengue[2]. Another study carried out in Bangladesh has indicated that dengue transmission is still widespread. The lack of proactive interventions, unplanned urbanization, environmental degradation, rising population mobility, and economic considerations will all increase the risk of dengue in the future[3]. Rainfall and temperature increases could make this situation worse[3].Even though dengue primarily affects countries with minimal resources, it does not inevitably target the underprivileged and marginalized in those countries. Public health concerns about dengue are growing, and in some affected nations, it is now a prominent disease[5].

In India, the first outbreak of a clinical dengue-like sickness was documented in Madras (now Chennai) in 1780, and the first epidemic of dengue fever (DF) with virological proof occurred in Calcutta (currently Kolkata) and the Eastern Coast of India in 1963–1964. In India over the past 50 years, many doctors have treated and characterized dengue sickness, but only a small number of facilities have conducted scientific research on the disease's numerous complications. Indian scientists have made several advances, but much more work needs to be done before they can significantly influence[9].

II. METHODOLOGY

A. Descriptive Analysis

The characteristics/features of a dataset are analyzed using descriptive statistics which can represent the entire population or a sample of the population. There are two measures in Descriptive Statistics such as Measures of Central Tendency (mean, median, mode) and Measures of Dispersion (variance, standard deviation, kurtosis, etc).

The Coefficient of Variation is one of the statistical measures of dispersion, which helps in comparing the variation from one data to another. Hence, we have computed the Coefficient of Variation to analyze the variation between different years which is causing the dengue and the deaths.

$$\text{Coefficient of Variation (CV)} = (\sigma / \bar{x})*100 \qquad (1)$$

We have calculated the mean and standard deviation during the period 2015 to 2022 and computed the coefficient of variation for every state and ranked them accordingly.

B. Hotspot Analysis:

A Hotspot is characterized as a region with a higher concentration of events than would be anticipated from a randomly distributed set of events. From the study of point distributions or spatial configurations of points in space, hotspot detection developed. A complete spatial randomness model—also known as a homogeneous spatial Poisson process—describes a process in which point events happen entirely at random and is used to compare the density of points within a specific area while analysing point patterns[8].

The major three files needed for hotspot analysis are. They are as follows:
1. Case file, which contains information on the number of incidents in the area.
2. The population file contains information about the population in the area.
3. The Location file consists of the details of the longitude and latitude of the geographical area.

With the use of these three files, hotspot analysis will enable us to pinpoint the primary cluster, secondary cluster, tertiary cluster, etc. that is most likely to have the most events. And doing so assists in determining the severity and consistency of the clusters over time, which helps create plans of attack for the epidemics in those identified clusters.

III. DATA COLLECTION

The data for the analysis has been collected from the National Center for vector borne Diseases control, Ministry of Health and family welfare, Government of India (https://ncvbdc.mohfw.gov.in/) for the years 2015 – 2022 containing the number of both the cases and deaths for all the states and union territories.

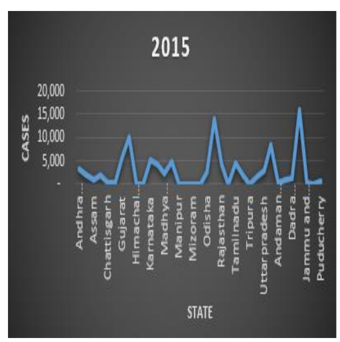
In the analysis the states with very smaller number of cases or deaths over the years have been excluded as they might affect the ranking based on coefficient of variation and the clusters resulted from spatial analysis.

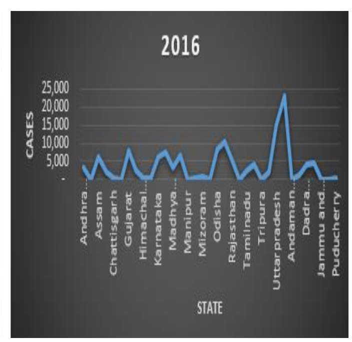
IV. RESULTS & DISCUSSION

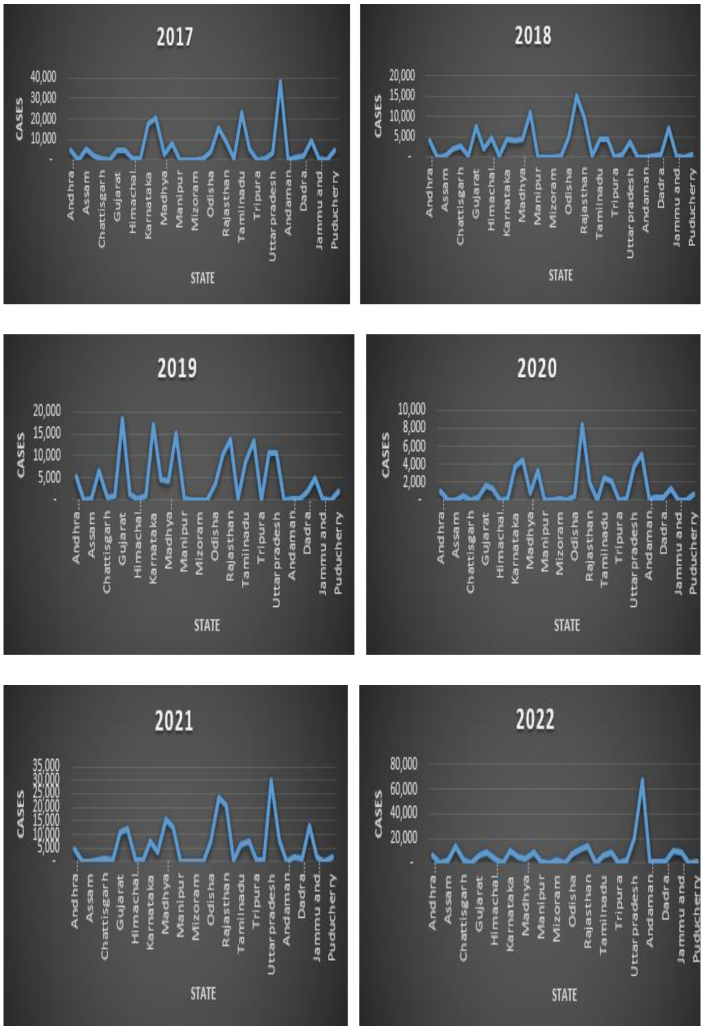
A. Visualization using Line Graph:

Cases:

The following are the line graphs visually shows the rise and fall of the dengue cases over the period of years 2015-2022

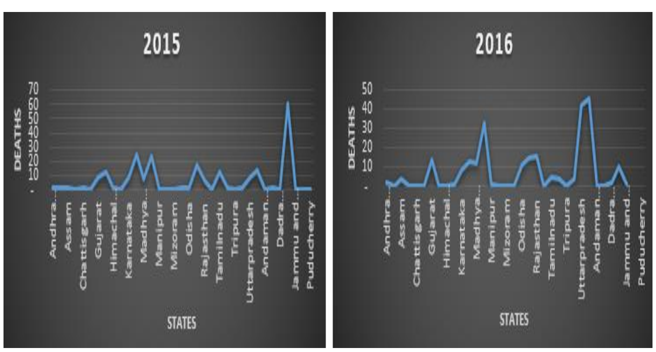


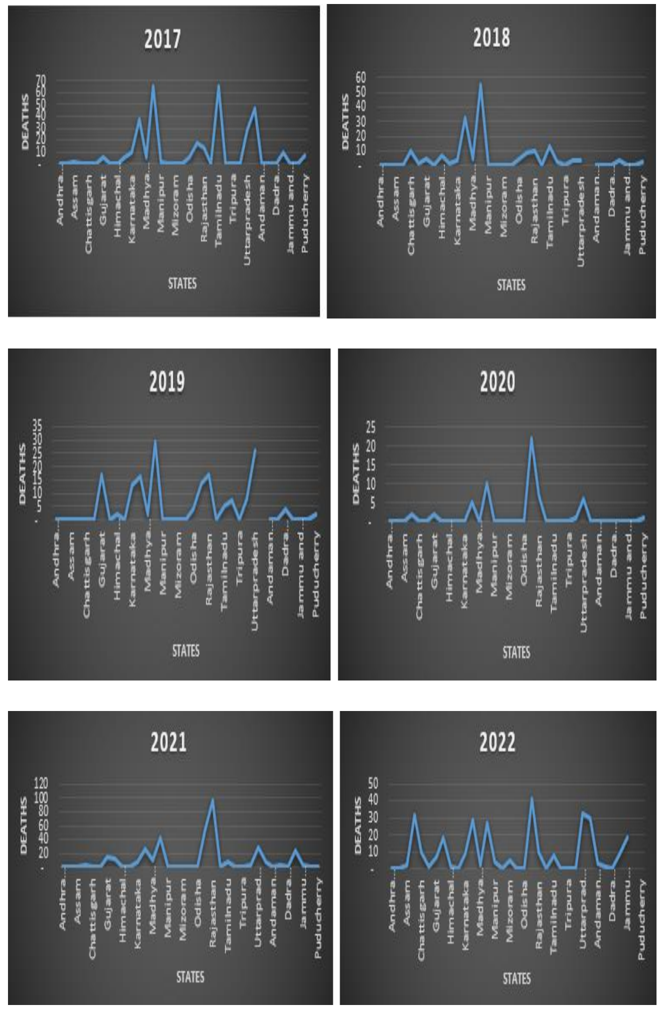




Deaths:

The folloeing visualizes the dengue fatalities over the year 2015 to 2022.





B. Z score Normalization (Outlier Detection):

A data point's deviation from the mean can be calculated using the Z-Score. It keeps track of the standard deviations that are either positive or negative to the mean. It falls within the -3 to +3 point standard deviation range. Each year's cases and deaths are normalised, and anomalies are noted. An observation that differs abnormally from other values in a population-based random sample is known as an outlier. An outlier state is one whose z-score does not fall within the range of -3 to +3.

$$Z \text{ score} = (x - \mu) / \sigma$$

where X is the original value,
μ is the mean.
σ is the standard deviation

TABLE 1: Outliers

Year	Cases	Deaths
2015	Delhi	Delhi
2016	West Bengal	Uttar Pradesh West Bengal
2017	West Bengal	Maharashtra Tamil Nadu
2018	Punjab	Maharashtra
2019	-	Maharashtra
2020	Punjab	Punjab
2021	Uttar Pradesh	Rajasthan
2022	West Bengal	-

Table 1 presents three columns and 8 rows where column one represents years, column 2 indicates the number of cases for each year and column three represents the number of deaths. The rows represent the number of cases and death for each year from 2015 to 2022. From Table 1 it can be inferred that the outliers vary yearwise or have no fixed pattern. The absence of outliers in the year 2019 for dengue cases and in the year 2022 for dengue fatalities were noted.

C.. Ranking of States: Coefficient of Variance

By computing the coefficient of variation for each state from 2015 to 2022 (using equation 1), the ranking of each state is determined. The state with the lowest coefficient of variation indicates the consistency of dengue cases or fatalities.

TABLE 2: Top Five States/UTs with Consistent Dengue Cases.

Rank	State
1	Punjab
2	Andhra Pradesh
3	Maharashtra
4	Odisha
5	Delhi

Table 2 has consists of two columns where the first one is the rank of the state with high risk of dengue cases determined through coefficient of variation and the second column is the name of the states

TABLE 3: Top Five States/UTs with a consistency of Death due to Dengue

Rank	State
1	Kerala
2	Maharashtra
	Karnataka
4	Gujarat
5	Uttar Pradesh

Table 3 has consists of two columns where the first one is the rank of the state with high risk of dengue cases determined through coefficient of variation and the second column is the name of the states

Another observation was made that the consistency of dengue cases and the consistency of dengue deaths are mutually exclusive.

The states with higher coefficent of variation are considered as the volatile states. Arunachal Pradesh, Jammu and Kashmir, Mizoram, Himachal Pradesh and Anadaman and Nicobar are the most volatile staes for dengue incidences. Bihar, Jammu and Kashmir , Dadra Nagarhaveli and Daman Diu and Andhra Pradesh are the most volatile states for dengue mortality

D.Hotspot Analysis (SaTScan):

A discrete scan statistic is utilised since the data on dengue cases and fatalities are discrete in nature. It employs a Poisson-based model, where the distribution of occurrences in a given location is Poisson. The study focuses on the states that are most geographically affected, hence a purely spatial analysis is performed.

A pure spatial analysis for scanning for clusters with high rates has been done on the dengue cases and deaths over the years 2015 to 2022.

TABLE 4: Hotspot analysis for Dengue Cases for the year 2015.

CASES 2015				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Delhi, Uttarkhand, Chandigarh, Haryana, Punjab	9.64	48386.04821	1E-17
Secondary cluster	Arunachal Pradesh	16.43	3578.423	1E-17
Tertiary cluster	Dadra nagarhaveli and daman diu	21.66	2790.622	1E-17

TABLE 5: Hotspot analysis for Dengue Deaths for the year 2015.

DEATHS 2015				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Delhi	24.3	124.73	1E-17
Secondary cluster	Arunachal Pradesh	4.37	16.67	0.00000063.
Tertiary cluster	Dadra nagarhaveli and daman diu	3.42	15.47	0.0000021

- In the year 2015 Delhi, Uttarkhand, Chandigarh, Haryana, and Punjab were found to be the primary hotspots for dengue cases, with a relative risk of 9.64, a log likelihood ratio of 48386.048210, and a P value < .00000000000000001. For deaths due to dengue it has been found that Delhi as the primary cluster with a highest relative risk of 24.3, Log Likelihood ratio of 124.728326 and P value < 0.00000000000000001.

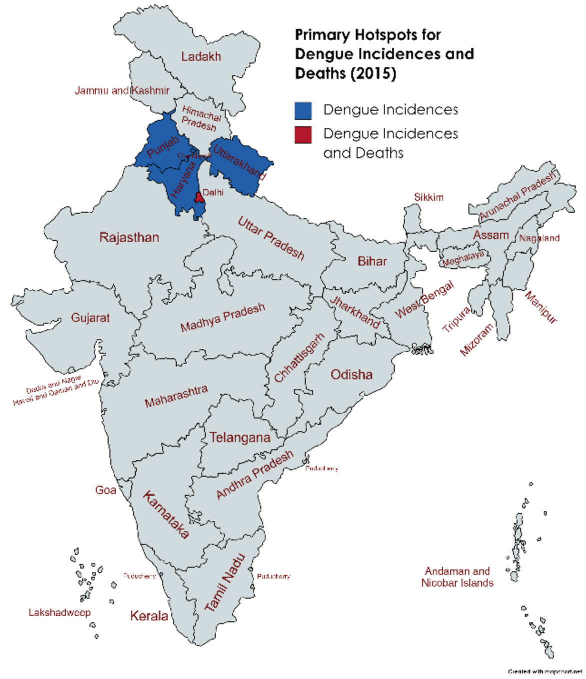


Figure 1 Most Likely Cluster (2015)

TABLE 6: Hotspot analysis for Dengue Cases for the year 2016.

CASES 2016				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Dadra nagarhaveli and daman diu	56.15	12875.938	1E-17
Secondary cluster	Andaman and Nicobar, Odisha, West Bengal, Mizoram	2.68	9742.6	1E-17
Tertiary cluster	Delhi, Uttarakhand, Chandigarh, Haryana, Punjab	2.64	6571.67	1E-17

TABLE 7: Hotspot analysis for Dengue Deaths for the year 2016.

DEATHS 2016				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	West Bengal	2.83	15.80	0.0000014
Secondary cluster	Delhi, Uttarakhand	2.6	4.5912	0.086.
Tertiary cluster	Kerala, Puducherry	2.27	3.76	0.197

- In 2016, West Bengal is the main hotspot for dengue deaths, with a relative risk of 2.83, log likelihood ratio 15.80, and P value of 0.0000014. The primary hotspot for dengue incidence is Dadra Nagarhaveli and Daman Diu, with a highest relative risk of 56.15, log likelihood of 12875.937848, and P value <0.00000000000000001.

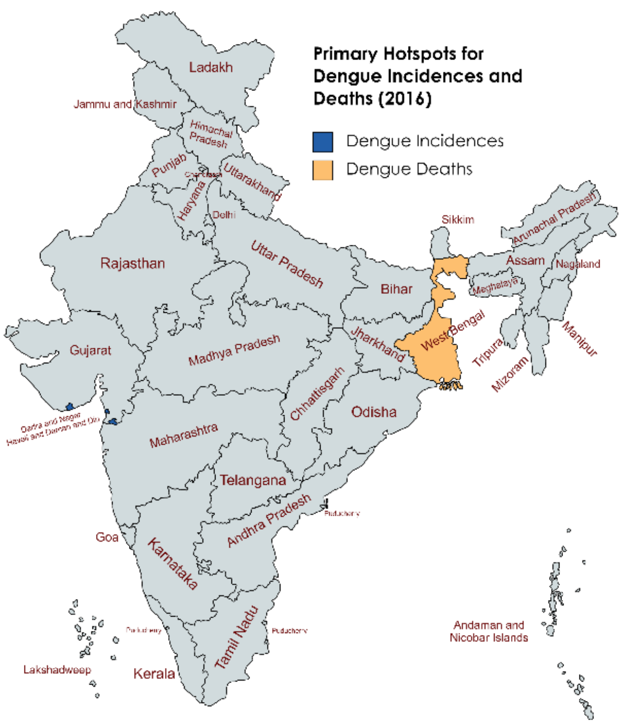


Figure 2 Most Likely Cluster (2016)

TABLE 8: Hotspot analysis for Dengue Cases for the year 2017.

CASES 2017				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Puducherry, Tamilnadu, Karnataka, Kerala	3.43	27559.2678	1E-17
Secondary cluster	West Bengal	3.16	15713.1301	1E-17
Tertiary cluster	Delhi, Uttarakhand, Chandigarh, Haryana, Punjab	2.73	10451.3741	1E-17

TABLE 9: Hotspot analysis for Dengue Deaths for the year 2017.

DEATHS 2017				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Kerala, Karnataka, Puducherry, Tamilnadu, Maharashtra	4.42	86.068	1E-17
Secondary cluster	Puducherry, Tamilnadu	4.57	47.66	1E-17
Tertiary cluster	Kerala	4.68	26.635	2.3E-11

- According to records for 2017, the majority of states that are coastal, namely Kerala, Goa, Karnataka, Puducherry, and Tamilnadu, are the primary hotspots for dengue incidents and fatalities. Warm, humid environments which are often found along coastlines are the most conducive to mosquito breeding and the transmission of dengue. The population and risk of dengue transmission both rise as a result. Due to urbanisation and tourism, coastal areas are also typically densely populated, which creates an environment that is conducive to breeding, such as stagnant water in gutters and other places.

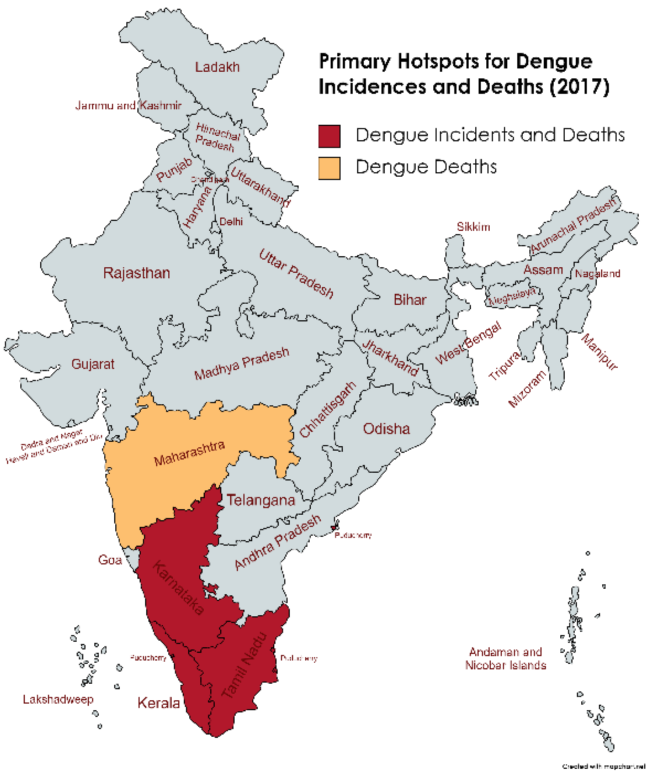


Figure 3 Most Likely Cluster (2017)

TABLE 10: Hotspot analysis for Dengue Cases for the year 2018.

CASES 2018				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Chandigarh, Haryana, Punjab, Himachal Pradesh, Uttarakhand, Delhi	4.88	20192.5062	1E-17
Secondary cluster	Dadra Nagarhaveli and Daman Diu, Maharashtra, Gujarat, Goa, Madhya Pradesh	1.38	911.410	1E-17
Tertiary cluster	Maharashtra, Dadra Nagarhaveli and Daman Diu, Goa, Gujarat, Telangana	1.37	872.65	1E-17

TABLE 11: Hotspot analysis for Dengue Deaths for the year 2018.

DEATHS 2018				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Kerala, Karnataka, Puducherry, Tamilnadu, Maharashtra	5.07	54.66	1E-17
Secondary cluster	Kerala, Puducherry	8.02	38.121	5.6E-16
Tertiary cluster	Maharashtra	4.33	32.521	1.3E-13

- The most likely dengue clusters for the year 2018 were found to be in Chandigarh, Punjab, Harayana, Himachal Pradesh, Dellhi, and Uttarakhand, with a relative risk of 4.88, a log likelihood ratio of 20192.506218, and a P value of 0.00000000000000001. While the Indian coastal states of Kerala, Karnataka, Puducherry, Tamil Nadu, and Maharashtra are the primary hotspots for dengue deaths.

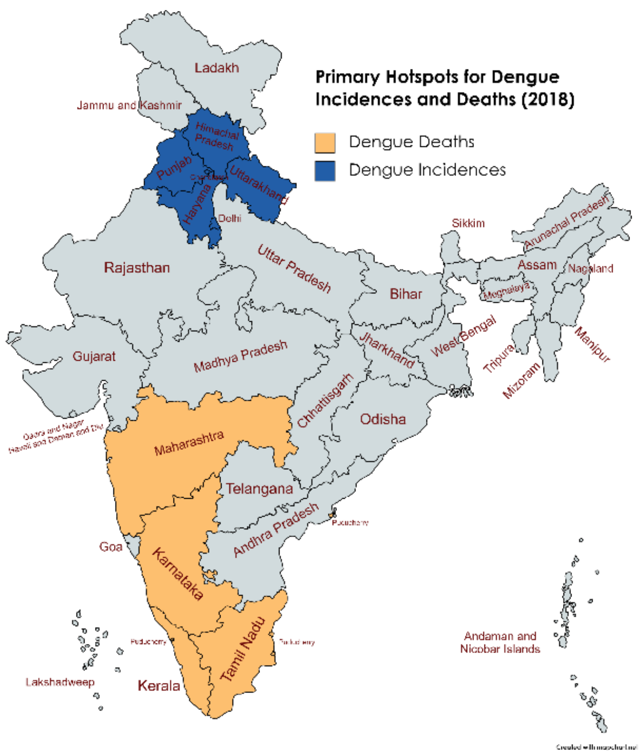


Figure 4 Most Likely Cluster (2018)

TABLE 12: Hotspot analysis for Dengue Cases for the year 2019.

CASES 2019				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Uttarakhand	7.96	12462.54	1E-17
Secondary cluster	Goa, Maharashtra, Karnataka, Telangana, Dadra Nagarhaveli and Daman Diu,, Andhra pradesh, Tamilnadu, Puducherry, Kerala, Gujarat	2.09	10578.43	1E-17
Tertiary cluster	Gujarat, Dadra Nagarhaveli and Daman Diu	2.51	6000.95	1E-17

TABLE 13 : Hotspot analysis for Dengue Deaths for the year 2019.

DEATHS 2019				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Maharashtra, Karnataka, Telangana, Dadra Nagarhaveli and Daman Diu, Andhra pradesh, Tamilnadu, Puducherry, Kerala, Gujarat	2.15	12.02	0.000061
Secondary cluster	Maharashtra, Dadra Nagarhaveli and Daman Diu, Gujarat, Telangana	2.29	11.5393	0.000099
Tertiary cluster	Kerala, Puducherry	3.98	10.814	0.0002

- In the year 2019, showed a peak in the mortality rate as many states were categorized as the primary hotspot such as Maharashtra, Karnataka, Telangana, Dadra Nagarhaveli and Daman Diu, Andhra Pradesh, Tamilnadu, Puducherry, Kerala, Gujarat. With a relative risk of 7.96, a log likelihood ratio of 12462.539282, and a P value of 0.00000000000000001, Uttarkhand is the most likely cluster for dengue episodes.

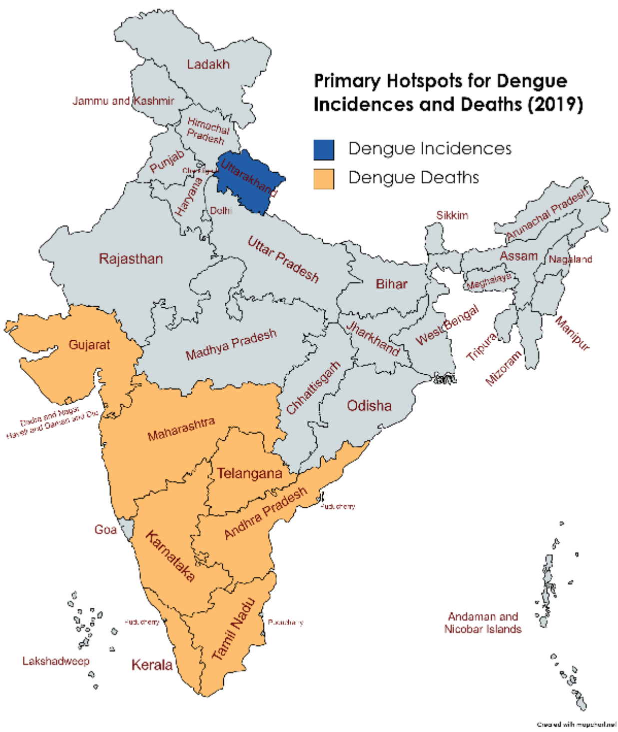


Figure 5 Most Likely Cluster (2019)

TABLE 14 : Hotspot analysis for Dengue Cases for the year 2020.

CASES 2020				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Chandigarh, Haryana Punjab	6.22	9043.14	1E-17
Secondary cluster	Kerala, Goa, Karnataka, Puducherry	3.11	3719.3	1E-17
Tertiary cluster	West Bengal	1.69	546.65	1E-17

TABLE 15: Hotspot analysis for Dengue Deaths for the year 2020.

DEATHS 2020				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Chandigarh, Haryana, Punjab	13.79	32.3453	1.2E-13
Secondary cluster	Maharashtra, Dadra Nagarhaveli and Daman Diu, Gujarat, Telangana	4.29	3.9340	0.146
Tertiary cluster	Kerala, Puducherry	2.16	2.057	0.597

- Punjab, Chandigarh, and Haryana were the primary hotspots for dengue and death and incidents in 2020. The hot, humid weather in this region, especially during monsoon season, encourages a proliferation of mosquito breeding grounds. Rapid urbanisation in these states has resulted in a lack of infrastructure for waste management, including the collection and removal of solid waste and standing water. People in these states frequently struggle with a lack of water, and they frequently store water in open containers. Due to the Aedes mosquito's preference for breeding in clean, stagnant water, this leads to an increase in dengue transmission.

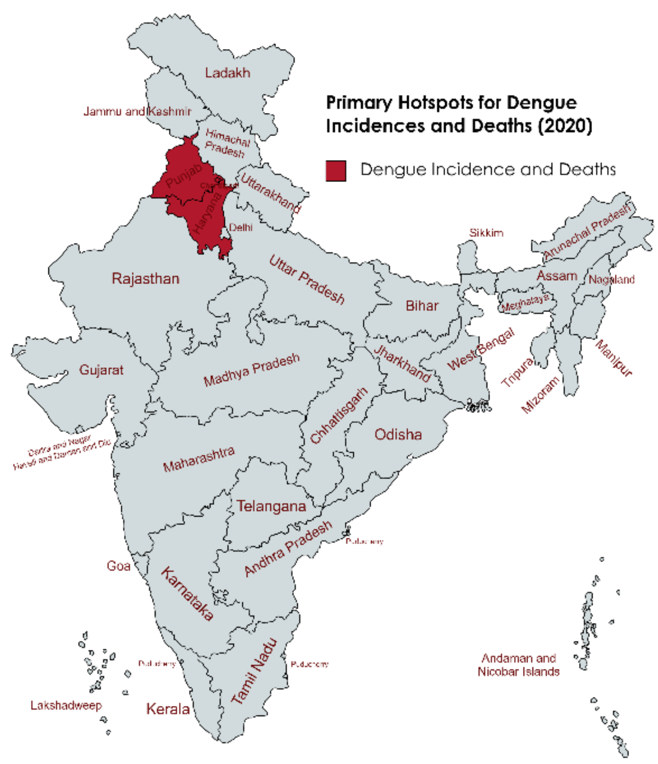


Figure 6 Most Likely Cluster (2020)

TABLE 16: Hotspot analysis for Dengue Cases for the year 2021.

CASES 2021				
Cluster	States	Relativ e risk	Log likeliho od ratio	P valu e
Most likely cluster	Rajasthan,Delhi, Chandigarh,Punj ab, Haryana	4.3	39426.4 2	1E- 17
Seconda ry cluster	Puducherry	7.34	1830.43	1E- 17
Tertiary cluster	Dadar Nagarhaveli and Daman Diu	5.42	721.44	1E- 17

TABLE 17: Hotspot analysis for Dengue Deaths for the year 22021.

DEATHS 2021				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Rajasthan, Delhi, Chandigarh, Haryana, Punjab	9.09	187.21	1E-17
Secondary cluster	Rajasthan	6.21	83.62	1E-17
Tertiary cluster	Chandigarh, Haryana, Punjab	5.5	57.45	1E-17

- In the year 2021, from the summary report it is observed that Rajasthan, Delhi, Chandigarh, Punjab and Haryana are the primary hotspot for both dengue incidence and fatalities.

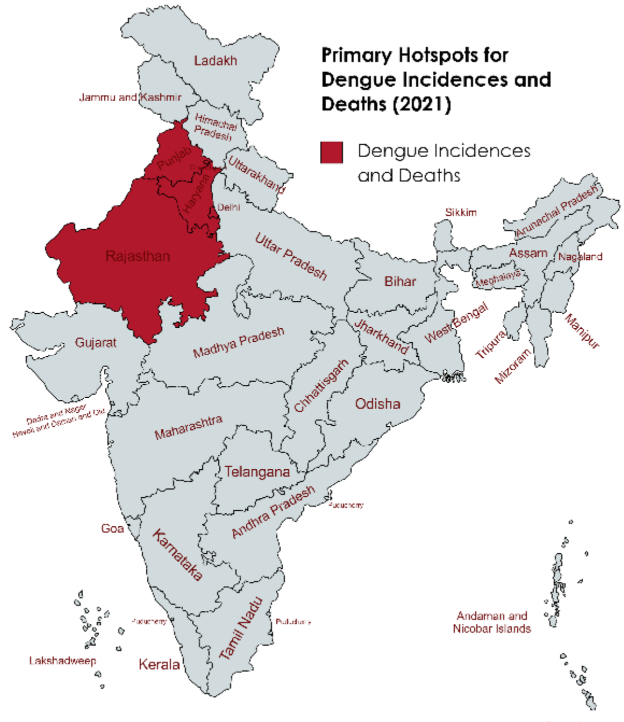


Figure 7 Most Likely Cluster (2021)

TABLE 18: Hotspot analysis for Dengue Cases for the year 2022.

CASES 2022				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	West Bengal	22	49488.1196	1E- 17
Secondary cluster	Chandigarh, Haryana, Punjab, Himachal Pradesh, Uttarakhand, Delhi, Jammu and Kashmir	2.65	13987.67	1E- 17
Tertiary cluster	Jammu and Kashmir, Himachal Pradesh, Chandigarh, Haryana, Punjab	2.57	9938.77	1E- 17

TABLE 19: Hotspot analysis for Dengue Deaths for the year 2022.

DEATHS 2022				
Cluster	States	Relative risk	Log likelihood ratio	P value
Most likely cluster	Jammu and Kashmir, Himachal Pradesh, Chandigarh, Haryana, Punjab	5.59	62.98	1E-17
Secondary cluster	Chandigarh, Haryana, Punjab	5.26	46.66	1E-17
Tertiary cluster	Kerala, Puducherry	4.24	20.727	2.5E-09

- In terms of dengue cases for the year 2022, West Bengal is the main hotspot, while Jammu and Kashmir, Himachal Pradesh, Chandigarh, Haryana, and Punjab are the main clusters for dengue fatalities.

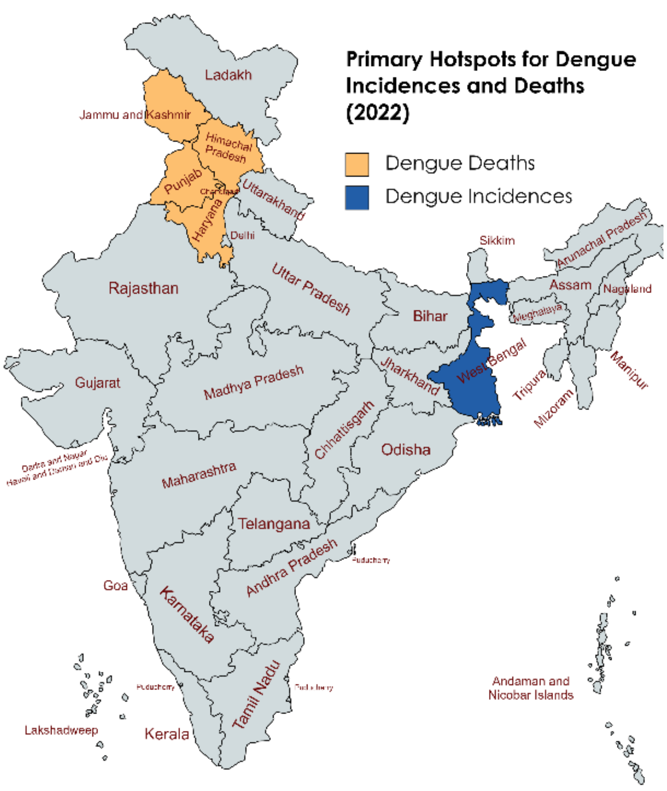


Figure 6 Most Likely Cluster (2022)

IV.CONCLUSION

The descriptive analysis revealed that the dengue cases are consistent in Punjab, Andhra Pradesh, Maharashtra, Odisha, and Delhi while the dengue related deaths are consistent in Kerala, Maharashtra, Karnataka, Gujarat and Uttar Pradesh. The hotspots of dengue incidence and fatalities are a combination of both static and dynamic in nature. It might be due to the accumulation of water bodies in various places and the variation in the South-West Monsoon since the Aedes mosquito breeds in freshwater.

It has been noted that Maharashtra consistently has higher dengue prevalence and mortality, which may be related to a serious lack of government action or a lack of accessible health facilities for citizens. Similarly over the period of 2015–2022, Chandigarh, Haryana, and Punjab are the areas with the highest dengue incidence (four years) and deaths from dengue (three years).

It has been identified that the tropical climate, highly populated areas that facilitate the spread of disease, and inadequate water management and storage are major causes of the increase in dengue infections. Implementing appropriate waste management practises, public awareness campaigns, and thorough mosquito control programmes is imperative. In order to completely eradicate dengue, it is crucial for the government to create stronger healthcare facilities for the citizens.

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