

SPATIO-TEMPORAL RISK MAPPING OF JAPANESE ENCEPHALITIS/ACUTE ENCEPHALITIS SYNDROME IN THE GAYA AND NAWADA DISTRICTS OF BIHAR

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ABSTRACT

This study investigates the spatio-temporal trends and endemicity of JE and AES in the Gaya and Nawada districts of Bihar between 2016 and 2020. JE/AES have become a great menace to public health in India, especially in the tropical and subtropical environs. This study uses spatial statistical techniques such as Global and Local Moran's I, cluster and outlier analysis, and Getis-Ord Gi* hot spot analysis to identify high-risk blocks and the emerging spatial patterns. The epidemiological data were collected from the State Malaria Office and analysed through GIS-based methodology. The results highlight clustering of JE/AES cases in the Gaya district, with Manpur, Imamganj, and Atri emerging as the persistent high-risk blocks. Despite a general drop in reported incidences over the years, the spatial clusters and hot spots continue to exist, thus depicting localized endemicity. The Nawada district consistently records lesser incidences and emerges mostly as a cold spot zone. The study, therefore, highlights the importance of spatial epidemiology to ensure focused surveillance and control of diseases. In identifying the persistent high-risk areas, it imparts support for rationalizing resources and public health interventions. The study further exemplifies how spatial statistical tools can be of great use in decision-making for the mitigation of vector-borne diseases at a local level.

Keywords: Acute Encephalitis Syndrome; Disease mapping; Gaya and Nawada; Spatial Analysis; Vector borne diseases.

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INTRODUCTION

Vector-borne diseases are illnesses transferred to humans by communicators such

as mosquitoes, sandflies, and evil vectors. These are imposed by parasites, viruses, and

bacteria, and these diseases form major groups of infectious diseases worldwide, with serious threats to public health. According to the Global Vector Control Response of WHO in 2017, vector-borne diseases covered 17 percent of the total global burden of communicable diseases with more than 700,000 deaths yearly.¹ The shocking truth is that vector-borne diseases risk has been imposed on nearly 80% of the world's population, while almost half of the world's population is at risk from two or more vector-borne diseases.

In India, the National Vector Borne Disease Control Programme has considered Malaria, Dengue, Kala-azar (Leishmaniasis), Lymphatic Filariasis, Chikungunya, and Japanese Encephalitis as some of the most important vector-borne diseases.² Furthermore, there have also been reports of localized outbreaks of diseases such as Kyasanur Forest Disease (KFD) and Crimean-Congo Hemorrhagic Fever (CCHF) in some specific regions. These diseases have a myriad effect on the general health of people, with approximately millions at risk and several thousand falling ill every year. In the year 2016 alone, India recorded approximately one million malaria cases, over 1 lakh cases of dengue, more than 60,000 cases of Chikungunya, 6,000 cases of Kala-azar, and over 1,500 cases of Japanese Encephalitis.

The resurgence of these diseases in a matter of decades, with their rapid fast spreading over new regions, and increased transmission taking place in endemic areas, makes vector-borne diseases a growing threat. This increase in incidence is not only a challenge to India's public health infrastructure but also a cause for concern at an international level.² These developments call for stronger health systems and coordinated administrative responses to effectively manage and mitigate their impact.

These vector-borne diseases seem to pose

the greatest risks in tropical and subtropical regions. Other prevalent vector-borne diseases worldwide include Malaria, Dengue, Lymphatic Filariasis, and Schistosomiasis. Other important vector-borne-type diseases include Chikungunya, Onchocerciasis, Chagas disease, Leishmaniasis, Zika virus, Yellow Fever, and Japanese Encephalitis.¹ A viral illness, Japanese encephalitis is the primary factor causing viral encephalitis in Asia. According to the WHO's 2017 Key Facts, it is a flavivirus transmitted through the bites of female mosquitoes from the *Culex* mosquito group, specifically *Culex tritaeniorhynchus*, *Culex vishnui*, and *Culex pseudovishnui*. According to the NVBDCP of 2011, the JE virus is largely zoonotic in nature, with humans serving as unintentional hosts.³

As a result of the development of an efficient vaccination, JE now only accounts for 15 per cent of all cases of Acute Encephalitis Syndrome (AES) in the nation. The Government of India has adopted a multi-sectoral collaborative strategy to control AES as the patterns of AES vary among states. According to reports, there are roughly 1,000 cases of Japanese encephalitis per year in the Southern, Northern, and North Eastern states, with death tolls varying from 100 to 34,200. In India, JE has been widely spread throughout time. The first case of Japanese encephalitis recorded was in 1955. There have reportedly been outbreaks around the nation. Between 1998 and 2004, JE cases were reported in more than 15 states and UTs. The states with the highest prevalence of the disease are Assam, Uttar Pradesh, Bihar, Odisha and Tamil Nadu. In addition to these states, low JE incidence has also been reported from other parts of India. Uttar Pradesh and Assam account for more than 80 per cent of all JE cases in India.

The epidemiological situational analysis of AES/JE prevalence in Bihar shows that the cases were reported from 31 districts of Bihar.

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The intensity of cases differs year basis. The High reporting cases are from Gaya, Patna, Muzaffarpur almost 50 per cent of all the cases of AES/JE in Bihar. The AES/JE cases show a decline in recent years from 324 cases in 2016 to only 58 cases in 2020. But the re-emergence nature of this disease in any particular year poses a serious threat to the state.

JE and AES have emerged as major public health concerns in Bihar with districts such as Gaya and Nawada recording outbreaks every now and then. Spatio-temporal analysis of these diseases is very much essential for identifying high-risk areas and adhering to timely intervention measures. Climatic variables have been suggested by many workers to influence JE incidence patterns across Bihar, thus hinting at a seasonal and geographical pattern of outbreaks.^{4,5} Spatio-temporal studies in neighbouring areas such as eastern UP and Nepal have identified disease clusters and environmental correlates.^{6,7} The studies also bring into focus the role of the pig population as amplifying hosts and the susceptibility of children in endemic areas.^{8,9} The present study combines GIS mapping and epidemiological data for a more efficient regional surveillance-intervention strategy. Aside from climate and environmental factors, the social and demographic vulnerabilities have been taking a bigger part in the occurrence of JE/AES. It is recognized that the diseases are being retained in certain areas mainly due to poverty, illiteracy, no food, bad hygiene and unawareness about health care facilities. The problems are more complicated in Bihar, as a great part of the rural population there is not provided with healthcare and education of good quality. This opens the door for vector-borne diseases to take their toll heavily. On top of that, the agricultural workers who come into contact with the vectors and also the communities living next to the pig farms are

at higher risk. Thus, it becomes indispensable to consider social determinants of health in order to get the complete picture of the endemicity and to control it through more integrative disease intervention approaches. The spatial-temporal analysis of the vector-borne disease clearly shows that even though all the six major vector-borne diseases are prevalent in India as well as in Bihar. The detailed analysis of all the vector-borne diseases at the state level could not be feasible within the limited point of time therefore, the selection of the disease is to be made for our study to have a deeper understanding of the pattern of these disease occurrences. Thus, for this purpose two major diseases have been selected for the present research, Kala-azar and Japanese Encephalitis.

MATERIALS AND METHODS

Vector-borne diseases are generally endemic to a region, putting populations residing in those regions at risk of contracting the disease. The major aim of risk mapping is to measure the degree of risk of a specific disease in a specific population at a specific period. Disease mapping is a crucial investigative tool in epidemiology, as it helps monitor preventative efforts, identify high-risk locations, and offer fresh insights into the genesis of disease. Even while disease mapping is a crucial tool for visualising disease spatial pattern data, without any statistical approach it becomes a visualisation aid only, making it impossible to perform any actual scientific research.¹⁰

Spatial analysis is an important methodology for disease mapping and identifying risk areas. It has the intrinsic ability to reveal patterns in data that have not been previously observed. The recent advancement in spatial analysis by incorporating GIS with spatial statistics tools enables the epidemiologist to look at the occurrence of the disease's spatial

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by Incidence rate (IR).

pattern and the possibility of an outbreak in a region more accurately.^{11,12} Spatial statistics uses statistical methods to examine spatial data to assess spatial processes, discover patterns, and model them in a geographic context. It is based on inferential statistics and hypothesis testing. There are several methods, approaches, and techniques through which spatial analysis can be conducted. These methods tend to answer three important questions: what, where, and why/how. The question of what is generally answered by descriptive statistics, while the question of where gives an understanding of exploration. The question of 'where' is one of the important aspects of spatial analysis, which is applied to explore and map data and identify trends and associations with space. The third and most important aspect of spatial analysis is to explain not only the trend and association of data concerning space but also the cause of these events and the drivers behind these occurrences. Therefore, in addition to straightforward visual analysis, spatial statistics give the user the ability to reliably respond to inquiries and make significant decisions. One way to gain a deeper knowledge of geographic phenomena, identify the reasons behind certain geographic patterns, summarise the distribution of a single number, and make judgements with more certainty is to utilise spatial statistics.¹³ Thus, spatial analysis methods enrich research by revealing hidden information through the analysis of spatial data.

The present research incorporates spatial analysis along with disease mapping by building its base on exploratory spatial data analysis methodology for understanding the spatial distribution of the vector-borne disease, their endemicity to the region and their spatial pattern. For this purpose, the methodology undertook the epidemiological data from the State Malaria office and these raw data are converted into disease incidence

$$IR = \frac{\text{Number of cases}}{\text{Population at risk}} * 1000$$

The population at risk was determined by

$$P_t = \frac{P_o + (P_o * r * y)}{100}$$

Where,

P_t = Estimated population of a particular year

P_o = Population of 2011 census

r = Annual Growth rate of population

y = Number of differences in a year

The calculated disease incidence is smoothed to reduce noise prevalent in the data with the help of Bayesian methodology which is freely available in Geoda application and these smoothed data are used for the spatial association, especially the Global Moran I, Local Moran I (Cluster and Outlier analysis) and Getis Orb G_i^* Hot Spot analysis. The cluster-outlier analysis is performed for the vector-borne disease in our research with the help of ArcGIS. The spatial continuity or neighbourhood feature also known as Queen contiguity was utilized for conducting the cluster outlier analysis and Hot Spot analysis.^{14,15,16}

RESULTS AND DISCUSSION

When we look at how JE/AES cases were distributed in Gaya and Nawada districts in 2016, it is clear that there is an unequal distribution. Six blocks in the area had no JE/AES cases reported, the majority of these blocks are in the Nawada district, while the Gaya district only has one block with no JE/AES cases reported. The Gaya district's Wazirganj Block had the highest cases reported of any block in 2016, at ten. The two other high-case reporting blocks are Manpur Block (8 cases) and Gaya Town CD Block (9 cases). Low cases (below 3 cases) are reported in 16 out of the 38 blocks in the region (Table 1).

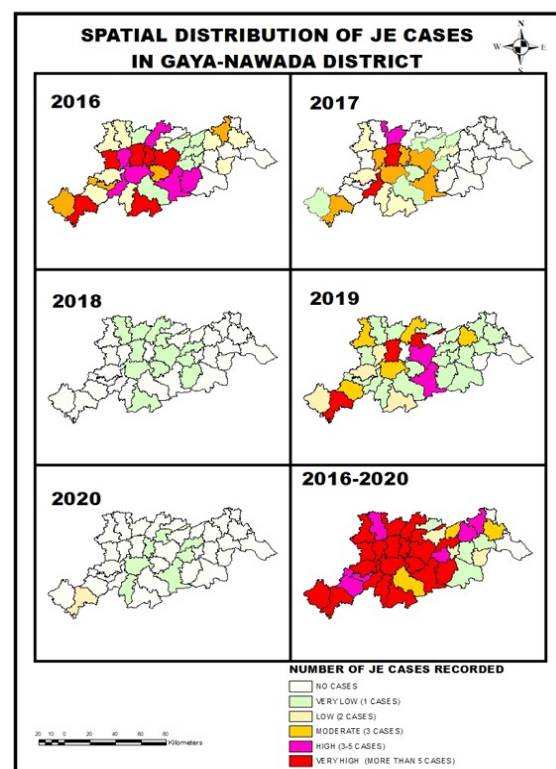
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The spatial distribution of JE/AES cases in 2017 exhibits a clear pattern, with the highest number of cases coming from Gaya CD Block itself, where 11 cases of JE/AES were documented. Another significant number of JE/AES cases (7 cases) were reported in 2017 from the Sherghati block in the southern-eastern area of the Gaya district. In 2017, the number of Blocks reporting no cases of JE/AES increased from 6 to 17 Blocks in the Gaya-Nawada district. In 2018, there were much fewer JE/AES cases reported in the Gaya area, including the Nawada district. There are currently 26 blocks that have not reported any JE/AES incidents in 2018. The number of JE/AES cases reported by the remaining 12 blocks has also shrunk to only one. As a result, the trend of declining JE/AES incidences persisted in 2018, which was encouraging for the area. However, the downward trend of JE/AES cases from 2016 to the lowest level in 2018 has been reversed in 2019. 2019 has seen a reduction in the number of blocks reporting no incidences of JE/AES, from 38 to only 5. 18 cases, which is the highest number of cases documented, are from the Gaya block. Each of the other two blocks, Imamganj and Atri, reported six incidents in 2019. In 2019, the 19 blocks report single JE/ AES cases. In contrast, in 2019 there were 5 block reports 3 cases of JE/AES and 4 block reports 2 cases. According to the 2020 data, there have been much less JE/AES reports in the districts of Gaya and Nawada. 30 Blocks out of 38 Blocks reported no cases of JE/AES. Only seven blocks, predominantly in the Gaya District, report a single case of JE/AES in 2020. The only block in the Gaya District to record two occurrences is Imamganj (Figure 1).

Table-1: JE/AES reported Blocks in Gaya-Nawada District.

Category of Blocks	2016	2017	2018	2019	2020
NO CASES	6	17	26	5	30
VERY LOW	7	7	12	19	7
LOW	9	5	0	4	1
MODERATE	4	6	0	5	0
HIGH	6	1	0	2	0
VERY HIGH	6	2	0	3	0

Source: Computed by the Author



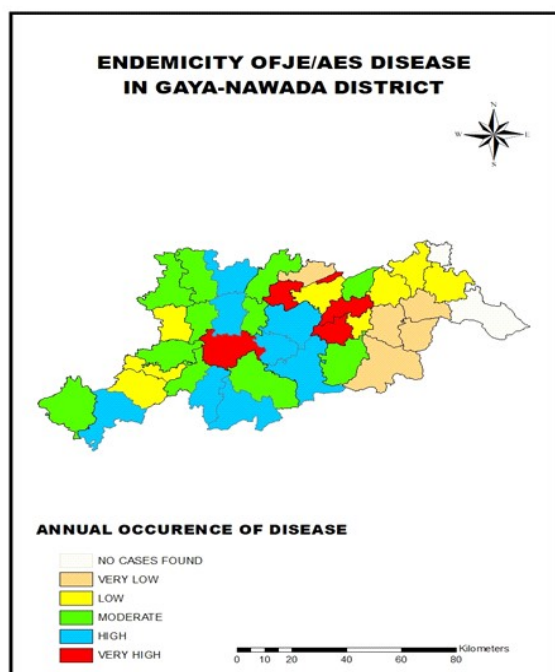
Source: Prepared by the Author

Figure 1: Spatial Distribution of JE/AES Cases in Gaya-Nawada District.

Endemicity of JE/AES in Gaya-Nawada District
When we look at the endemicity of JE/AEs in Gaya- Nawada District we can see that only 2 blocks out of 38 blocks have not recorded any instances of JE/AES in the research period. These two blocks are both located in the Nawada District. While Hisua and Meskaur blocks in the Nawada district are classified as highly endemic to the JE/AES epidemic, Bodh Gaya and Atri blocks in the Gaya district have continually recorded cases of JE/AES during the research period between 2016 and 2020. There are eight blocks in the Gaya-Nawada district that record cases for consecutively four years out of five year study period and hence considered as high endemic.

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The greatest number of blocks (11 blocks) are moderately endemic (Figure 2).



Source: Prepared by the Author

Figure-2: Endemicity of JE/AES Cases in Gaya-Nawada District between 2016-2020.

Disease Pattern Analysis

Observing the pattern of a disease's incidence through time and space is one of the main objectives of determining the risk of the disease. According to the first law of geography (Tobler, 1970), objects close to one another interact and have more similarities than those farther apart and are referred to as "spatial dependency."

The analysis of spatial autocorrelation in geographic studies is crucial. The relationship between attribute values at nearby locations and whether these values form patterns in space are investigated using spatial autocorrelation. Geographical analysis would not be very interesting if there were no spatial autocorrelation (O'Sullivan & Unwin, 2010). Spatial autocorrelation can be detected using a variety of diagnostic techniques. The most important and prevalent method is through

Global Moran I (Spatial auto-correlation). Global spatial autocorrelation measures are those that estimate spatial auto-correlation by a single value for the entire study area. The most common Global Spatial auto-correlation measures are Moran I Index.

Global Moran I for JE/ AES in Gaya-Nawada District

Global Moran I was used to analyse the spatial autocorrelation for Japanese Encephalitis/ Acute Encephalitis Syndrome in the Gaya-Nawada region. The outcome demonstrates that the disease was discovered to be concentrated in the district over the entire study period. The table shows that 2017 and 2019 have the highest z scores, which are all significant at 99 per cent, 2017 saw the highest Moran I values recorded. The variance has not changed over the course of our study. We discovered that, on average, during the 2016–2020 study period, the z score was 7.678 with a high Moran I index of 0.839 and a 99 per cent significant level of significance (Table 2).

Table-2: Spatial Auto-correlation estimation Moran's I index of JE/AES in Gaya Region.

YEAR	Moran's Index	Expected Index	Variance	z-score	P-value	Pattern
2016	0.717	-0.027	0.012	6.597	<0.01	clustered
2017	0.807	-0.02703	0.012	7.373	<0.01	clustered
2018	0.752	-0.02703	0.012	6.889	<0.01	clustered
2019	0.764	-0.02703	0.012	7.028	<0.01	clustered
2020	0.669	-0.02703	0.011	6.367	<0.01	clustered
TOTAL	0.839	-0.02703	0.012	7.678	<0.01	clustered

Source: Calculated by the author

Cluster and Outlier Analysis

A cluster is defined as an overabundance of cases in either area known as a geographical cluster, time a temporal cluster, or both space and time (Boulos, 2004). The cluster and outlier analysis through Local Moran I provides us with a better understanding in terms of the distribution of features in a more localised manner and provides a clear picture of the distributional pattern of diseases. The

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cluster and outlier analysis provides results into four major categories of high-high cluster and low-low cluster and outlier in terms of high – low outliers and low-high outliers.

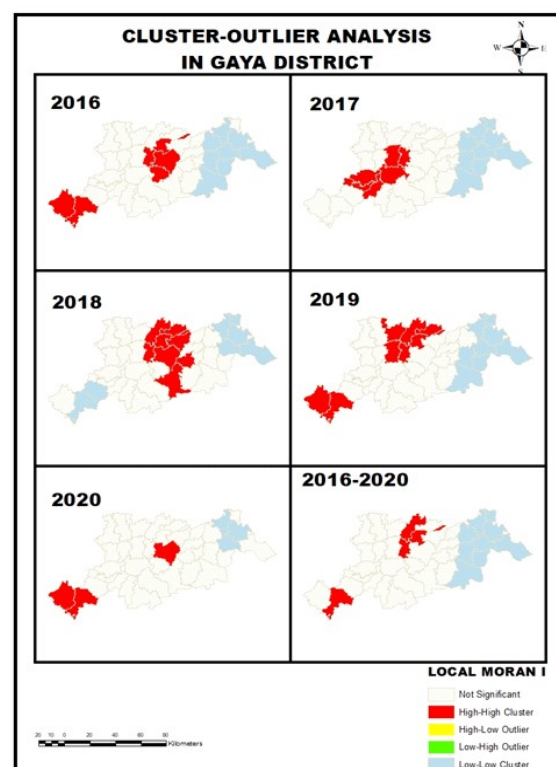
Table-3: Cluster analysis of JE/AES in Gaya-Nawada District.

Type of cluster	HIGH HIGH CLUSTER				LOW LOW CLUSTER			
	Year	Number	Z score	P value	Index	Number	Z score	P value
	2016	6	2.392	0.021	1.236	8	3.576	0.006
	2017	6	2.860	0.010	1.121	9	3.831	0.002
	2018	8	3.427	0.003	1.402	7	2.532	0.019
	2019	8	3.169	0.011	1.778	8	2.574	0.017
	2020	3	5.163	0.002	3.733	3	2.364	0.020
	2016-2020	4	2.594	0.018	1.192	9	4.139	0.001

Source: Computed by the author

The Cluster and Outlier analysis of JE/AES disease was conducted at the block level to map the localisation of these clusters in the Gaya-Nawada District. A distinct pattern is observed in our analysis as the cluster, both high and low cluster, was observed in the region but there was no outlier, both high low and low high outlier, observed during our study period. The cluster of high-incidence reporting blocks also saw an uneven trend as we can observe from Figure 3. The number of high clusters observed in 2016 and 2017 was 6 which increased to 8 clusters of Blocks in 2018 and 2019, but suddenly decreased to 3 blocks in 2020. The Manpur block distinctly forms part of the high cluster in the year between 2016 to 2019. The mean Local Moran z score obtained through local Moran I analysis shows that the highest value was observed in 2020 despite having a low number of clusters of blocks in 2020. The z value obtained through our analysis shows that the z score was significant at 95 per cent in 2016, whereas in the rest of the year, from 2017 to 2020 was highly significant at 0.01. The low cluster obtained from our analysis is mainly located in the western part of the Nawada district. The number of the low cluster also shows an irregular trend in our research period where the lowest number was observed in 2020 in comparison to the highest

number observed in 2019. The low cluster block mainly consists of the Kasi Chak, Warisaliganj, Pakribarawan, Roh and Kawakol blocks of the Nawada district. The one interesting feature noticed in our analysis of low cluster results is the Imamganj block of Gaya District which was part of the High Cluster block in 2016, 2019 and 2020 and was categorized into a low cluster block in 2018. The Local Moran z score obtained through our analysis also that all of these low clusters are formed of high significant p value at 0.01. There was a complete absence of any outliers during our research period from 2016 to 2020 (Table 3).



Source: Prepared by the Author

Figure-3: Cluster and Outlier Analysis in Gaya-Nawada District.

Hot Spot Analysis of JE/AES in Gaya-Nawada District

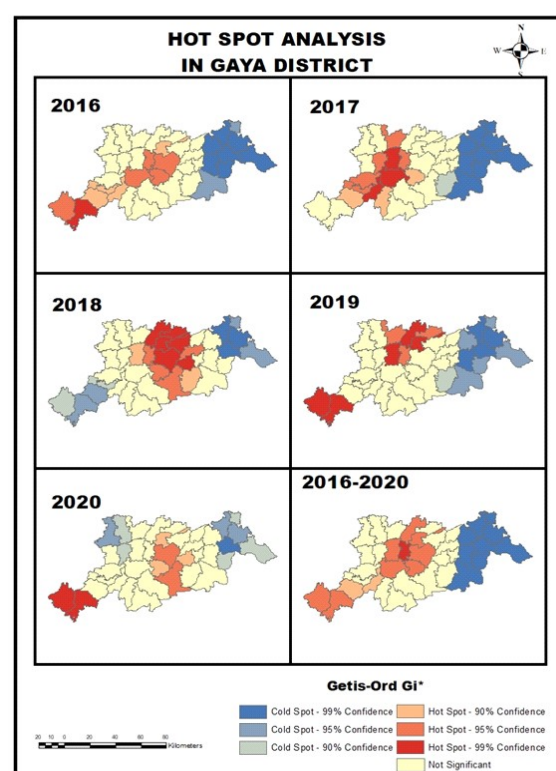
According to a 2016 hot spot research, there was 99 per cent confidence that the Imamganj block in the Gaya district was a hot site. Wazirganj, Manpur, Tankuppa, and Bodh Gaya

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in the region's heart, where confidence was 95 per cent, and the Dumaria block in the south, where confidence was 95 per cent, served as the other hub of the block, which in 2016 created the JE /AES hot spot cluster. Although they were also hotspots in 2016, Banke Bazar, Sherghati, Amas, and Atri blocks had lesser confidence (90 per cent) than those. There are no cold spots; all the hot spots are in the Gaya district. On the other hand, Nawada is, with 99 per cent to 95 per cent confidence, the epicentre of cold patches in the northeast of the region. With a 98 per cent confidence level, the 2017 hot spot research identifies three blocks in the districts of Sherghati, Bodhgaya, and Gaya CD as hot spot centres. With 95 per cent probability, the adjacent blocks have also evolved into the hot spot's centre. The fact that a new block has become a hot area now rather than in 2016 is an intriguing change that can be noticed in 2017. Belaganj, Paraya, Gurua, and Dobhi are the new structures that have recently emerged as hotspots. As was stated in 2017, all hot spot blocks are still located in the Gaya district. The Nawada district contains the location of every cold spot centre.

The hot spot centre is now firmly positioned in the northern half of the region, according to the analysis of the hot spots in 2018. Compared to the preceding two years, there are more hotspots where blocks can form. The hot spot's 12-block radius has expanded to include these blocks. The Gaya District's Kizirsarai, Neem Chak Bathani, Atri, Muhra, and Wazirganj block is now a hot zone with 99 per cent control. An essential component of 2018 demonstrates that the Mesakur district of Nawada also consistently showed as the district's centre with 99 per cent certainty. In 2018, the Nawada district's Hiroshi, Surala, and Fatapur districts also became hot spots. Blocks including Paraiya, Sherghati, and Gurua from the beginning of 2017 have vanished in 2018. The fact that the

hot places in 2016 and 2017 were located in the blocks Dumaria, Imamganj, and Amas in 2018 instead became the cold locations is an additional intriguing feature of the year. In 2018, there were less cold patches in Nawada, which is still in the northeast of the region. The Dumaria and Imamganj blocks in southern Gaya district are currently becoming hot zones with 99 per cent probability, according to 2019 study. The Gaya CD block, Atri, and Khizisarai are the other blocks that make up the 99 per cent confidence interval. With 95 per cent, Belaganj, Nhim Chak Sarai, and Manpur are in first place. As a result, there are fewer hotspots now in 2019. No specific block has developed as a hotspot in the Nawada district. The north of Nawada District has consistently been noted to have cold patches (Figure 4).



Source: Prepared by the author

Figure-4: Hot-Spot analysis of JE/AES Cases in Gaya-Nawada District.

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Table-4: Hot-Spot Analysis of JE/AES Disease in Gaya-Nawada District.

Year	Description	Hot Spot 90 %	Hot Spot 95 %	Hot Spot 99 %
2016	Number of villages	4	5	1
	GiZ Score	1.827	2.300	2.632
2017	Number of villages	3	5	3
	GiZ Score	1.831	2.423	3.161
2018	Number of villages	2	4	6
	GiZ Score	1.720	2.331	3.074
2019	Number of villages	0	3	5
	GiZ Score	0.000	2.378	3.056
2020	Number of villages	3	2	2
	GiZ Score	1.736	2.104	3.744
016-2020	Number of villages	2	8	1
	GiZ Score	1.712	2.205	2.812

Source: Computed by the author

Table-5: Cold-Spot Analysis of JE/AES Disease in Gaya-Nawada District.

Year	Description	Cold Spot 99 %	Cold Spot 95 %	Cold Spot 90 %
2016	Number of villages	7	2	0
	GiZ Score	-3.151	-2.200	0.000
2017	Number of villages	9	0	1
	GiZ Score	-3.134	0.000	-1.936
2018	Number of villages	3	4	2
	GiZ Score	-2.807	-2.189	-1.794
2019	Number of villages	4	5	1
	GiZ Score	-2.906	-2.229	-1.725
2020	Number of villages	1	3	5
	GiZ Score	-2.614	-2.249	-1.898
2016-2020	Number of villages	9	0	0
	GiZ Score	-3.258	0.000	0.000

Source: Computed by the author

The examination of 2020's hot spots reveals a sharp decline in hot spot block. The Dumaria and Imamganj block, which had 99 per cent confidence in 2019, had continued in 2020. With 95 per cent and 90 per cent confidence in 2020, the Nawada district's Fatehpur and Mesakur block has already emerged as a hot spot centre. The other block in the Gaya district that has emerged as a hot zone for 2020 is Atri, followed by Tankuppa block with 90 per cent certainty and Wazirganj with 95 per cent confidence (Table 4). In the cold spot, where two centres can be seen emerging in 2020, the significant difference can be noticed. Nawada district's north-eastern block and Gaya district's north-western block (Table 5).

The analysis by space and time tells a different story with respect to JE/AES in the Gaya and Nawada districts, with Gaya regarded as the

high-risk location while Nawada has rather sporadic incidences. Spatial clustering at blocks like Manpur and Imamganj exhibits a perennial endemicity, with some ecological and social factors at play. Other studies had highlighted environmental factors such as rainfall and temperature in vector abundance and JE outbreaks.^{17,18} Agricultural activities and existence of piggeries near human habitation add to this risk.^{19,20} GIS-based spatial statistics such as Moran's I and Getis-Ord Gi* have greatly aided in defining these high-risk pockets as targets for evidence-based public health interventions.²¹ The patterns share resemblance with those recorded from similar endemic zones in Assam and Tamil Nadu.^{22,23} The continued existence of the hotspots in Manpur, Imamganj and Atri blocks might be connected to the social ecology of these areas. The disease burden is a result of several factors including high rural populations, lack of awareness regarding mosquito control, limited vaccination coverage and poor health-seeking behavior. In addition, seasonal migration among agricultural laborers, which is a common practice in these areas and the setting up of pig farms close to human habitations are community-based environmental factors that might further spread JE. It has been found in eastern Uttar Pradesh and Nepal that the social factors operating at the level of the community are as significant as the climatic or environmental variables in determining the JE risk clusters. Combining these social aspects with spatial epidemiology will not only improve surveillance but also enable the implementation of equity-based public health interventions. Outbreaks being cyclic in nature and resurgence coming in regular seasons further call for aggressive surveillance coupled with the early-warning systems.²⁴ Known cases of vaccination and community awareness administration have proved effective in reducing the burden of JE,

especially among children.^{25,26}

CONCLUSION

The study of Japanese Encephalitis/ Acute Encephalitis in Gaya Nawada region also provides us interesting result through our spatial analysis. Even though when we look at the cases reporting from the block the uneven yearly trend of Japanese Encephalitis can be easily noticed but in between our study period we can see that 2016 and 2020 itself the disease has outbreak in the region. The spatial analysis conducted in our study reveals that the block in Gaya district are more at risk of the outbreak of JE/AES than Nawada district. The Mapur Block in the Gaya district emerges as the high cluster and Hot Spot in our study period 2016 to 2020. The other block that emerges as the new centre of the outbreak of the disease is Imamganj block as the disease outbreak has taken place in 2016 and 2019. The other important risk blocks that need to be in constant surveillance are Gaya C.D. block, Bodh Gaya block and Atri block. As these blocks have also constantly reported the cases of Japanese Encephalitis.

The research could pursue further integration of real-time geospatial surveillance systems with climate modeling into socio-demographic analytical tools to provide for better early warning mechanisms in JE/AES. Upgrading local healthcare systems, expanding vaccinations, and maintaining constant supervisory watch over high-risk locations for immediate responses will be imperative for long-term mitigation of disease transmission and vector control.

Future studies should incorporate block-wise social indicators literacy, access to sanitation and available healthcare into the GIS framework so as to disclose compounded vulnerability. Public health measures in the high-risk blocks such as Manpur and Imamganj should not only focus on vector control but also consider community

awareness, vaccination drives and education outreach. The social aspect is essential for shifting from reactive containment to proactive prevention in the endemic areas of Bihar.

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