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Spatio-temporal distribution and identification of Encephalitis disease hotspots: A case study of Gorakhpur Tehsil, Uttar Pradesh, India

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Abstract: Encephalitis is a complex disease with a high mortality, morbidity and disability ratio. In India, it is a major pediatric problem, which has spread over many different areas ever since reporting of the first clinical case in 1955 in Vellore. Gorakhpur district is located in the eastern part of Uttar Pradesh and in low-lying region with tropical climate. It is mainly paddy growing area, with clay soil and high ground water table. Gorakhpur and its surrounding region have very conducive conditions for the breeding habitat of Encephalitis vector and this area has been experiencing the outbreak of Encephalitis since 1978. Every year from July to November, the outbreak of Encephalitis, causes many deaths and long term disability to children and young adults. The study aims to provide a database and thematic maps using geospatial tool for Gorakhpur tehsil. The database created on GIS platform has compiled and track information on the incidence, prevalence and spread of the encephalitis disease in Gorakhpur tehsil. The disease distribution pattern shows the clustering of the disease in the tehsil. Hotspots maps have been created for different years and for the whole period also. Most of these hotspots (very high risk areas) are located in the middle part starting from the northern part of the region and stretching from north to south. The geospatial database created through the study on Encephalitis will provide an effective platform, which can be utilized by the health care providers, public health managers and policy makers to generate policies that will best meet the need for prevention, control and management of Encephalitis in Gorakhpur tehsil.

Key words: Encephalitis Hotspots, Spatial Statistics, Statistically Significant, Spatial Autocorrelation.

1. Introduction

Encephalitis is a complex disease with a high mortality, morbidity and disability ratio. It is a seasonal epidemic disease with a 40-year recorded history in Gorakhpur region. Gorakhpur and its surrounding region have very conducive conditions for breeding habitat of encephalitis vector. This area has been experiencing almost every year the outbreak of Encephalitis. Gorakhpur and its surrounding region have been a known focus of encephalitis since 1978, when the first case was reported here. It is mainly a paddy growing area, with clay soil and high ground water table. Every year, particularly from July to November the outbreak of encephalitis causes many deaths and long-term disability to children and young adults. People at highest risk for encephalitis and its complications, include the very young, the very old and people with weakened immune systems. Since 1988, the disease manifestations have changed and apart from Japanese Encephalitis cases, unidentified categories of cases are also reported. These cases are now classified under the category of EVE (Entero-Viral Encephalitis). both types of cases occurring in Gorakhpur region are termed as AES (Acute Encephalitis Syndrome) cases since 2005. This paper is an attempt to identify high risk area of the disease. In medical geography geospatial analysis tool is an effective means of finding spatial distribution, areas of concentration, assessing trends, and decision making related to health and epidemiology. Spatial statistics empowers the user to answer questions confidently and make important decisions than the simple visual analysis, spatial statistics is one method for better understanding of geographical phenomena, pin pointing the causes of specific geographical patterns, summaries the distribution of single number and make decisions with a higher level of confidence (Chakraborty, 2013).

Spatial statistics is most powerful tool for describing and analyzing how various geographic objects or events occur and change across the study area. Spatial analysis tools such as GIS and spatial statistics, enable epidemiologists to address the spatial distribution and predict the outbreaks of disease more accurately (Chaput et al., 2002).

Identifying clusters is the process that follows basic series of steps. It can be done manually and by using tools. The aim is to investigate disease clusters and disease incidence near point source (Lawson and Denison, 2002). Automated tools which can do cluster analysis are Spatial Autocorrelation (Moran's I), Hotspots analysis, Cluster Outlier Detection, Interpolation IDW, Kernel Density Mapping, Anselin's LISA (local Indication of spatial Association) etc., are many methods which can provide the information whether there is clustering or statistical autocorrelation occurring (Anselin and Getis, 1992; Anselin, 1993; 1995; 1996).

2. Objectives

1 Spatial distribution of encephalitis at CD block, village and ward level in Gorakhpur tehsil during the period of 2006-2016.

2 Creation of occurrence map of the disease through this database.

3 To understand the statistically significant and spatial pattern of the encephalitis occurrence region using hotspots analysis to identify the priority areas, in order to formulate strategies that might help in reducing the burden of disease.

3. Methodology

Present paper intends to investigate the spatio-temporal pattern of Encephalitis and uses spatial statistical techniques and analysis to study the characteristics of spatial patterns of the distribution of encephalitis in Gorakhpur tehsil at village and ward level. Mapping of the disease for every year from 2006-2016, in GIS domain has been carried out using Arc GIS 10.1. A database has thus been generated with the help of line list data collected from the District Hospital of Gorakhpur and analyzed by tabulation, diagrams and mapping. Spatial auto-correlation analysis using Hotspots Analysis has been carried out with the Spatial Analyst extension (version 10) of Arc GIS 10.1 tool, which uses Getis-OrdGi* or G statistics (Getis and Ord, 1992) to identify the spatial pattern.

4. Study Area

Gorakhpur tehsil occupies the north eastern portion of the district of the same name. The study area lies between latitude $26^0$36'4' N to $26^0$57'3" N (40 km) and Longitude $83^0$13' 58" E to $83^0$37'26"E (41 km) and is spread over an area of 841 km.^{2}, which is about 25.32% of the district area (Figure 1). According to 2011 census, the tehsil has 16,30,731 population and contributes 36.72 per cent of the total population of Gorakhpur District (44,40,895). The district headquarters Gorakhpur city having the population 673,446 (2011census) is also located within the study area. Administratively Gorakhpur Tehsil, incorporates whole of Chargawan, Bhathat CD block and partial areas of Jungle Kaudiya, Pipraich, Piprauli and Khorabar CD blocks. Two villages of Sardarnagar CD block are also included in this Tehsil. It has 511 villages out of which 444 villages are inhabited and 67 villages are uninhabited.

Besides Gorakhpur City (Municipal Corporation) one Nagar Panchayat Pipraich and five census towns are also located within the limits of study area. Gorakhpur city is divided into 70 wards, while Nagar Panchayat Pipraich has been divided into 12 wards. Bansgaon tehsil forms the southern boundary of the study area, on the west and north-west the boundary marches along Sahjanwa tehsil and Campierganj tehsil respectively, on the north east study area adjoins Mahrajganj and Kushinagar districts and further south Chuari Chaura tehsil forms the dividing line. NH-28 running almost east-west passes through the southern portion of tehsil and NH 29 runs almost north-south in the western part and south of Gorakhpur city and connects the region with Varanasi. NH-24 connects the region to Saunauli (near Nepal border).

5. Encephalitis in Gorakhpur and its surrounding region

Acute Encephalitis is a clinical condition caused by the Japanese Encephalitis Virus (JEV) or other infectious causes (Kakkar et al., 2013). Encephalitis is a seasonal epidemic disease with a 40-year recorded history in Gorakhpur Region. The increasing number of encephalitis cases in the study region has become a priority health issue. Recent outbreak shows two trends- incidence of disease is reported not only in peak period but throughout the year and increasing outbreaks outside the endemic rural areas, particularly in urban area also.

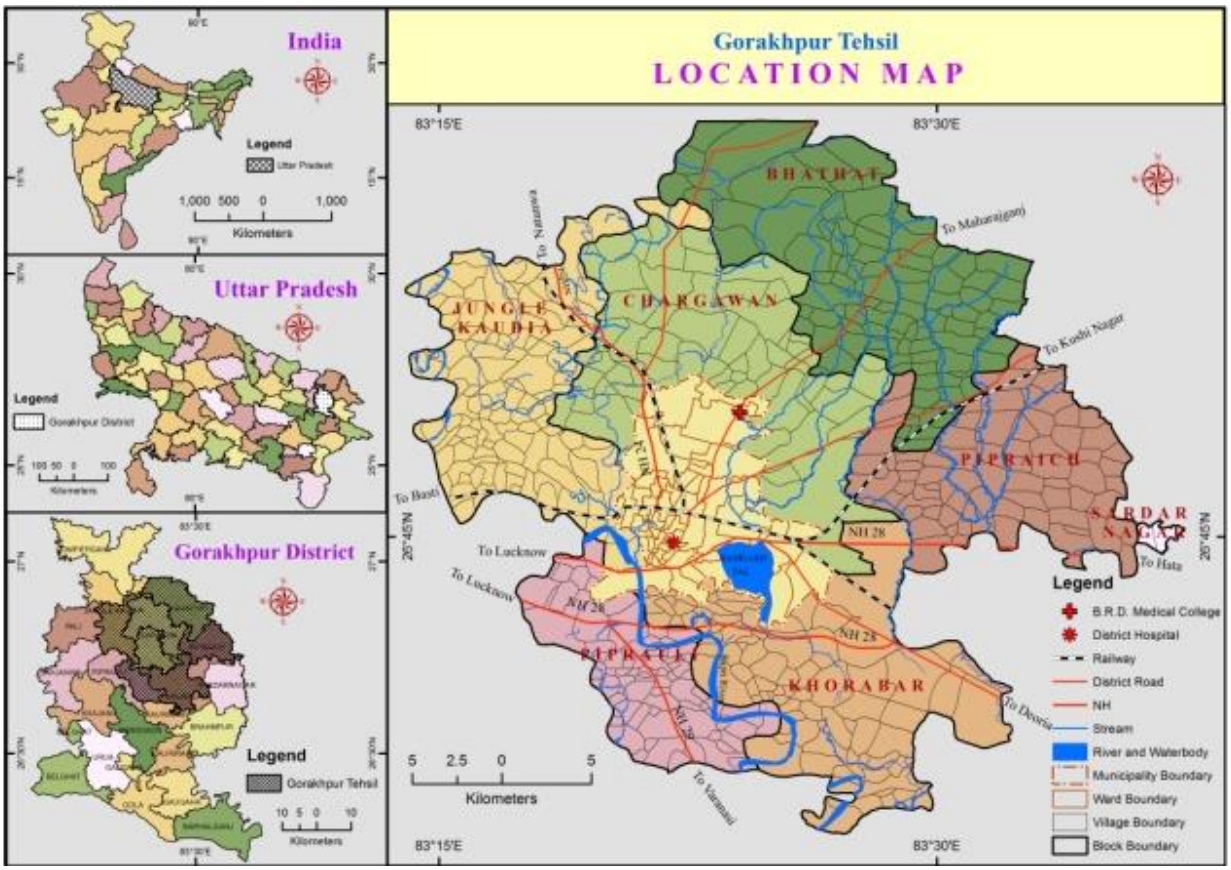

Figure 1: Location of study area

Gorakhpur and its surrounding region have very conducive conditions for breeding habitat of encephalitis vector. This area has been experiencing almost every year the outbreak of Encephalitis. The disease has been a public health burden in this region since 1978, when the first case was reported here. Overall 15 districts of surrounding region of Gorakhpur district are affected by encephalitis. Gorakhpur district remained the most affected district in the region.

Gorakhpur tehsil situated in the north eastern part of the district has highest concentration of the reported cases of encephalitis. During 2006-2016, nearly half (51.54 per cent) of the cases of the district are reported from here. During the span of study time, overall 3256 encephalitis cases are reported in Gorakhpur tehsil. It is very surprising fact that highest number (856 cases) of encephalitis cases are registered from the urban area, i.e., Gorakhpur city. The study area also includes the two most affected CD blocks (Chargawan and Khorabar) of the Gorakhpur tehsil and district. It is quite remarkable that at village level, all the villages are not affected by the outbreak this disease. It is concentrated in some villages, while others are absolutely free from the disease till now.

6. Spatial Pattern of Encephalitis in Gorakhpur Tehsil

6.1. Geographic Distribution of Encephalitis Cases, 2006- 2016

Distribution pattern of encephalitis cases reveals that distribution of the cases is concentrated in some parts of the tehsil. To analyse the spatial distribution pattern of encephalitis annual incidence of the disease, between 2006-2016 (eleven-year span) has been used and villages are grouped into seven classes (Table 1) according the reported cases and endemism (Figure 2). There is no definite trend in the incidence because cases appear in fluctuating manner.

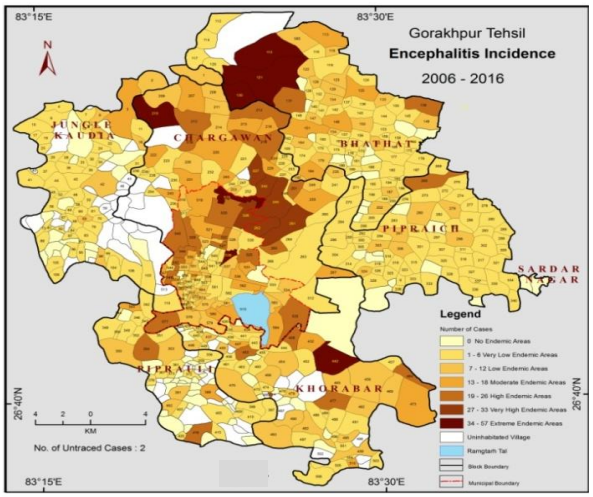

Figure 2: Encephalitis incidence

6.1.1 Non Endemic Areas

In this category villages which do not have reported cases during the study period are included. About 148 villages (28.63 per cent of the total) have never experienced the outbreak of encephalitis. Most of these villages are concentrated and distributed in the western and south western part of tehsil. Many of them are uninhabited ones. These villages are also scattered in north east and eastern areas of the region in Bhathat and Pipraich CD block. In the middle part non-endemic areas are found in patches. Three wards of Gorakhpur city have no reported cases of encephalitis, viz., Lohia Nagar, Jungle Tulsiram East and Kalyanpur.

6.1.2 Extremely High Endemic Areas (>34 Encephalitis Cases)

In these areas highest number of encephalitis cases (287 cases) have been reported, which ranges between 34-57 cases. Five villages (J. Janul Abden Urf Jainpur, Jungle Dumari No 2, Jungle Ramgarh Urf Chauri, Rampur Gopalpur and Jungle Dumari No1) and two wards (Manbela and Shahpur) fall under this category. Manbela ward of Gorakhpur city ranks first (with 57 cases) as far as the incidence of cases is concerned. Jungle Dumri No -1, situated in the north-western part of tehsil has 48 reported cases. These areas account for 8.82 per cent of the total incidence of disease. The combined population of these areas is 70,376 people, which is 4.32 per cent of the tehsil population.

6.1.3 Very High Endemic Area-(27-33 Encephalitis Cases)

This category area includes five villages, viz., Jungle Dhusar, Jungle Chatradhari, Harsewakpur No.2 (Census town), Bangai, Gulariha (Chargawan block) and are located in north middle area of the region. Semra ward of Gorakhpur city with total 29 cases is also in this class and out of total cases 5.41 per cent cases of the tehsil are reported from these areas. The combined population of these areas represents 3.21 per cent (52,306 people) of the tehsil population. Total 176 cases have been reported from these villages and wards.

6.1.4 High Endemic Areas (19-26 Encephalitis Cases)

High Endemic area includes the areas where 19-26 encephalitis cases have been reported during last eleven years and total 600 cases are reported from the areas included in this category. Ten wards of Gorakhpur city (Surya Kund, Engineering College, Chargawan, Shivpur Sahbaganj, Basharatpur, Lachhipur, Rajendra Nagar West, Nausarh, Rasoolpur, Rapti Nagar and Tiwaripur), 15 villages and Pipraich Nagar Panchayat are high endemic areas and located mostly in the adjoining areas of high endemic areas. 18.43 per cent of the total reported cases appear here. Fifteen villages, viz., Jungle Belwar, Dangipar, Sahookol Urf Mirzapur, Khorabar Urf Soobabazar, Motiram Adda (Khorabar CD block), Parmeshwarpur, Ekla No.2, Jungle Tinkonia No1, Bisunpur, Jungle Tinkonia No1, Jungle Pakri, Khuthan Khas, Karmaha Buzurg (Chargawan CD block), Jungle Ranee Suhas Kunwar urf Mahaveer Chappra, Bagha Gara (Piprauli CD block), Karmaha Buzurg and Bailo (Bhathat CD block) are under this category.

Table 1: Gorakhpur Tehsil: Distribution of Encephalitis cases 2006 – 2016

Sl. No.	Endemic Areas	No. of Cases	Percentage	No. of Villages	No. of City Wards
1	No Endemic Areas (0)	0	0	148 (28.63%)	3 (4.29%)
2	Very Low, <6 cases	855	26.25	256 (49.52%)	19 (27.14%)
3	Low, 7-12 cases	764	23.47	63 (12.19%)	20 (28.57%)
4	Moderate, 13-18 cases	574	17.63	24 (4.64%)	14 (20%)
5	High, 19-26 cases	600	18.43	15 (2. 90%)	11 (15.71%)
6	Very High, 27-33 cases	176	5.41	5(0.97%)	1 (1.43%)
7	Extremely High >34	287	8.82	5 (0.97%)	2 (2.86%)
	Total	3256	100	517 (100)	70 (100)

6.1.5 Moderately Endemic Areas (13-18 Encephalitis Cases)

Fourteen wards of Gorakhpur city and 24 villages are included in these areas, Total 574 cases (17.63% cases) are reported from these areas. Fourteen wards of the city are under this category and the distribution of the wards included in this category are scattered all over the city, while villages are distributed and concentrated in the middle part stretching from north to south.

6.1.6 Low Endemic Areas (7-12 Encephalitis Cases)

Low endemic areas are distributed in the eastern, western and southern fringe areas of the region. Encephalitis cases appear in 20 (28.57 per cent) wards and 63 (12.19 per cent) villages. Overall 764 (23.47 per cent) encephalitis cases are reported from the areas under this category.

6.1.7 Very Low Endemic Areas (<6 Encephalitis Cases)

Very low endemic areas are scattered all over the study area. 19 wards of the Gorakhpur city and 256 villages are included under this category and covers 26.25% of the total incidences (855 cases).

Distribution of these villages is more on eastern and western sides of the tehsil. From the analysis of annual incidence of encephalitis cases in Gorakhpur tehsil, it is clear that high endemic areas are located in north and mid part of the tehsil and also include the northern wards of the city. Rest of the high endemic areas are distributed in patches, while low endemic areas are scattered all over the tehsil.

7. Occurrence of Encephalitis cases (2006-2016)

According to the analysis of annual incidence of encephalitis data it is revealed that in some areas encephalitis is appearing almost every year, and some villages have reported cases sporadically (Figure 3; Table 2), while some villages do not have any incidence of the disease. During the study period about 148 villages of the tehsil were found to be unaffected by the annual outbreak of encephalitis. In 69 villages (18.65 per cent), the disease occurred only once and in 58 villages (15.68 per cent) twice. 70 villages (18.92 per cent) experienced the outbreak thrice and four and five times outbreak was recorded in 46 (12.43 per cent) and 28 villages (7.57 per cent) respectively. As the occurrence of the disease increases the number of villages in that category got reduced. Six, seven and eight times disease incidence occurred in 36 (9.73 per cent), 20 (5.41 per cent) and 17 (4.59 per cent) villages respectively. Disease incidence of nine times in eleven years appeared in 14 villages (3.78 per cent), out of which 4 villages are located in Chargawan CD block.

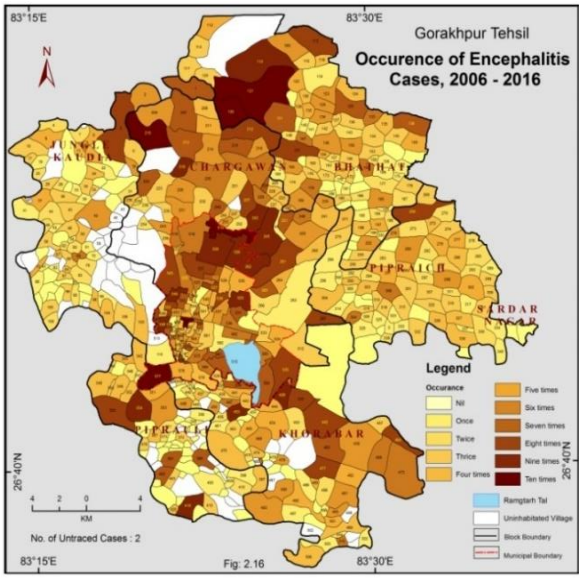

Figure 3: Occurrence of Encephalitis cases

Jungle Janual Abden urf Jainpur, Jungle Dumari No.-1 (Bhathat CD block) and Rampur Gopalpur (Chargawan CD block) have the incidence of disease every year. That is why these villages have highest number of encephalitis cases during the study period. Nagar Nigam Gorakhpur area shows a different trend. Lohia Nagar, Jungle Tulsiram and Kalyanpur are the three wards of the city which are not affected by encephalitis and no incidence of the disease was recorded here during the study period.

In Civil Lines II ward, only once in 2007, encephalitis cases were reported and after that it is free from the disease. 3 wards, viz., Janpriya Vihar, Narsinghpur and Raiganj have reported cases twice. Average of three times occurrence of encephalitis is reported from Jharna Tola, Jatepur Railway Colony, Civil Lines and Hansupur wards. Nine wards (Vikas Nagar, Chaksa Hussain, Netaji Subhash Chandra Bose Nagar, Jafara Bazaar, Dilezakpur,

Table 2: Gorakhpur Tehsil: Occurrence of Encephalitis cases at village and city level (2006-2016)

Occurrence	Bhathat	Chargawan	Jungle Kaudia	Pipr auli	Pipr aich	Khor abar	Sardar Nagar	Total Villages	Per cent	Gorakhpur City	Per cent
Once	14	2	19	7	14	13	-	69	18.65	1	1.49
Twice	11	6	14	4	15	8	-	58	15.68	3	4.48
Thrice	21	6	16	6	16	5	-	70	18.92	4	5.97
Four times	7	8	7	7	10	7	-	46	12.43	9	13.43
Five times	7	2	5	2	4	8	-	28	7.57	8	11.94
Six times	10	9	4	1	3	9	-	36	9.73	6	8.96
Seven times	4	4	1	4	2	5	-	20	5.41	11	16.42
Eight times	3	8	1	3	-	2	-	17	4.59	9	13.43
Nine times	2	4	1	1	1	5	-	14	3.78	8	11.94
Ten Times	1	4	-	2	-	2	-	9	2.43	5	7.46
Eleven Times	2	1	-	-	-	-	-	3	0.81	3	4.48
Total Cases	82	54	67	37	65	64	0	369	71.57	67	95.71
No cases	15	7	43	47	9	24	2	148	28.43	3	4.29

Purdilpur, Diwan Bazaar, Sheshpur and Mahui Sugharpur, of the city have the occurrence of the disease four times, while five times disease cases are reported from eight wards (Shaktinagar, Jungle Salikram, Mahadev Jharkhandi-2, Bhediagarh, Krishna Nagar, Humayunpur North, Alhadadpur and Mahewa). Six and seven times the disease appeared in 6 and 11 wards respectively. 9 wards recorded the incidence eight times and 8 wards nine times. 10 times incidence is recorded in 5 wards, viz., Chargawan, Shivpur Shabajgang, Semra, Tiwaripur and Rasoolpur, while cases are recorded every year in three wards, viz., Manbela, Alinagar and Nausarh wards and are also worst affected areas of the city

8. Hotspot delineation

Basically, "hotspot" refers to area with unusually high occurrence of point incidents. Hotspot analysis aims to assist identification of locations with unusually high concentration of occurrence in the form of hotspots and cold spots within a limit of geographical area that appear overtime. This method has the advantage of detecting the presence of hotspots and cold spot for each feature in a data set over the entire area. This tool works by looking at each feature with context to neighbouring features. It identifies spatial clusters of High values (Hotspots) and spatial clustered low values (Cold spot). These hotspots and cold spots can be thought of as spatial concentrations.

Hotspot analysis can identify that whether spatial variation in distribution is statistically significant and help to target those areas for further study. Delineation of these hotspots and cold spots helps in optimizing the use of resources for timely interventions (Handique, et al., 2011). Spatial autocorrelation is a statistical tool that can be used in epidemic study. Global Moran's I is used to establish the autocorrelation and Getis-ord. General G. (global) Hotspots Delineation (Moran, 1950). Density mapping can locate clusters in the dataset but cannot specify its significance.

9. Results

Getis-OrdGi* or G statistics method has the advantage of detecting the presence of hotspots and cold spot for each feature in a data set over the entire area. Gi* statistics returned for each feature in dataset is a Z score. For statistically significant positive Z score, the larger the Z score, more intense is the clustering of high value (hotspots). For statistically significant negative Z score, smaller the Z score more intense is the clustering of low values (cold spot). The resultant Z score tells the user where features with either high or low value cluster are spatially distributed. The resultant Z score values for Gorakhpur tehsil is between 5.97 to 11.51, which is significant at 99% confidence level indicating clustering pattern for each year during 2006 to 2016 (Table 3).

Table 3: Gorakhpur Tehsil: Spatial Autocorrelation

Year	Z-score	Moran's I	Pattern
2006	8.49	0.12	Clustering
2007	5.97	0.08	Clustering
2008	6.99	0.09	Clustering
2009	9.50	0.13	Clustering
2010	6.92	0.10	Clustering
2011	11.52	0.16	Clustering
2012	6.67	0.09	Clustering
2013	8.82	0.12	Clustering
2014	7.22	0.10	Clustering
2015	6.99	0.09	Clustering
2016	3.76	0.07	Clustering
2006-2016	12.13	0.22	Clustering

The value of Moran's I index range from -1 to +1. The value '1' means perfect positive spatial autocorrelation (This means values are clustered together), while close to -1 value suggests perfect negative autocorrelation. Moran's I is a spatial autocorrelation analysis tool which is used to measure the presence of clustering in similar value (Tsai et al, 2009).

Table 3 shows the calculated Z score and Global Moran's I for Gorakhpur tehsil from 2006-2016. The Moran's I index of 2006 shows that on the basis of encephalitis cases distribution this year Moran's I value calculated as 0.11. In 2009, 2011 and 2013 Moran's I index were found to be 0.13 (highest), .015 and 0.11 respectively and rest of the year, it remained below 0.1 ranging from 0.08 to .09. The average value for 2006-2016 period comes 0.22. The values of Moran's I suggest that the disease pattern could be a result of random chance. Z score values being between 5.97 to 11.51, which is significant at 99% confidence level indicate clustering pattern for each year.

Apart from the annual spatial distribution pattern of the disease, hotspots maps for each year and for whole study period (Figure 4 and 5) have been created. The analysis of this result shows that some areas of the tehsil have emerged as hotspots of encephalitis. The disease distribution is highly clustered and most of the region of tehsil is in no significant category.

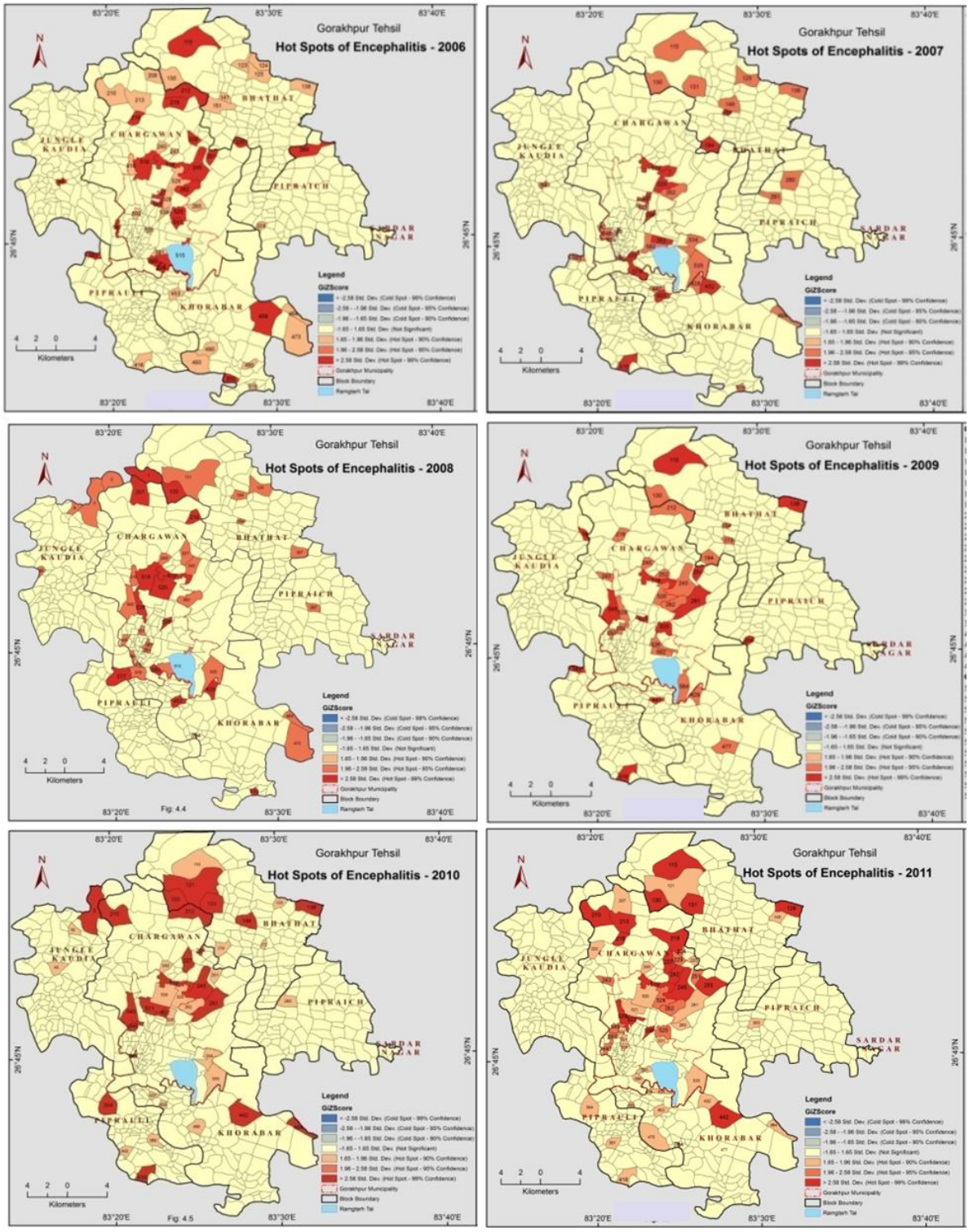

Figure 4: Hotspots of Encephalitis, 2006-2011

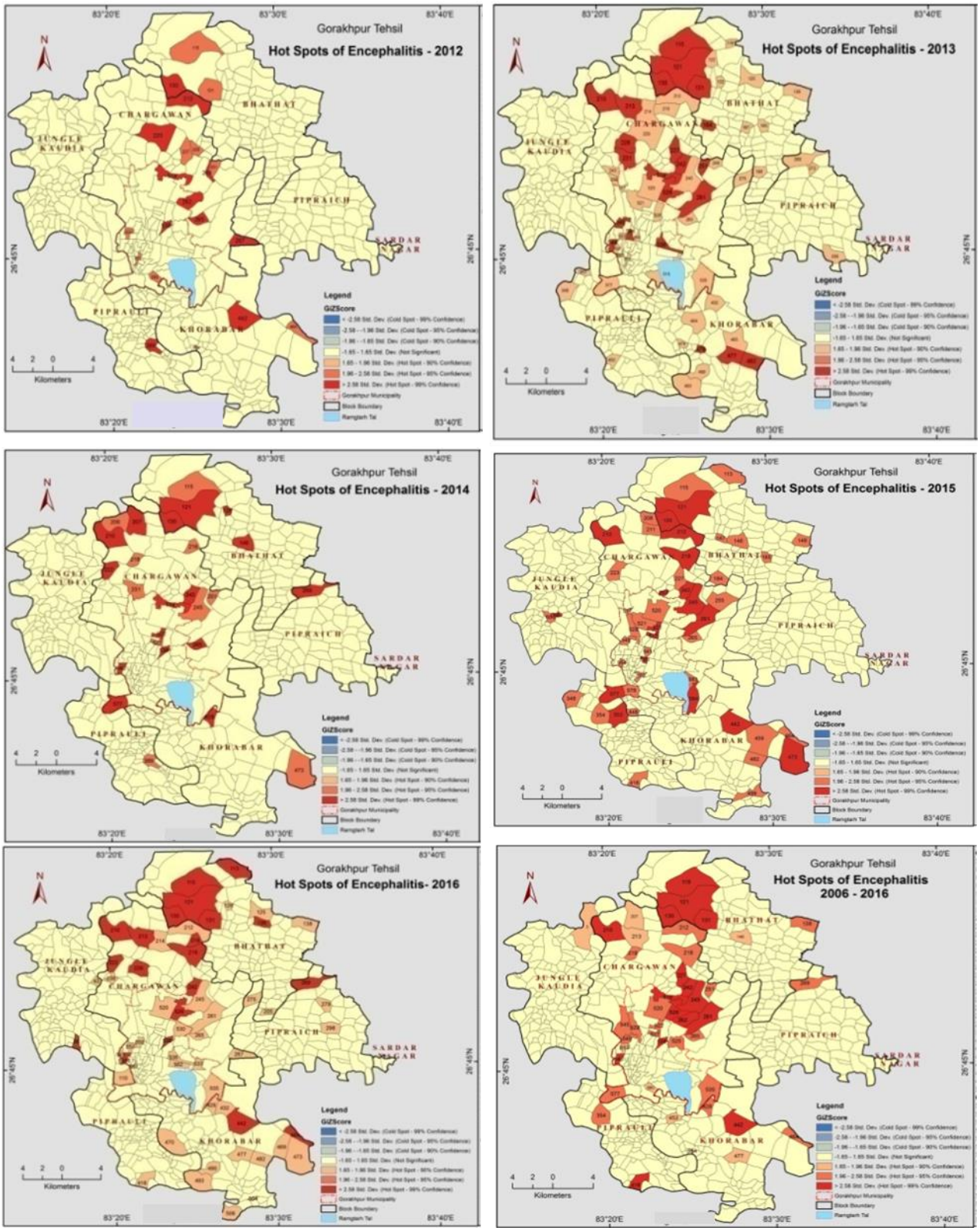

Figure 5: Hotspots of Encephalitis, 2012-2016 and 2006-2016

Z score which is > 2.58 has been considered to be significant at 99% confidence level ($p<0.01$) and put into Hotspots category. Areas. Areas having Z score between 1.65-1.96 (Significant at 90% confidence level) and P value<0.10 areas are categorized Low Risk Areas. Z score from 1.96-2.58 is considered significant at 95% confidence level ($p <0.05$) are High Risk and Z value <1.65 are under no significant category.

Most of these hotspots (very high risk areas) are located in the middle part starting from the northern part of the region and stretching from north to south. Two prominent clusters have been categorized as encephalitis hotspots. The biggest hotspots spreads in the central part of the region, covers 5 villages, viz., Bangai, Gulariha, Jungle Chatra Dhari and Jungle Dhoosar and two wards-Shahpur and Tiwaripur of Gorakhpur city. The second hotspots covering four big villages, viz., Jungle Dumari 1, Jungle

Dumari 2, Jungle Janaul Abden urf Jainpur and Kamraha Bujurg is located in the northern part of Gorakhpur Tehsil. This makes clear that these two regions in Chargawan and Bhathat CD blocks are highly sensitive region of the study area. Other four spots are scattered in north western, central, south east and south west part of the region, covering single village or ward and over all three villages and two wards. Overall 12 villages and 4 wards fall in the category of hotspots of encephalitis.

In High Risk Areas, 9 wards of the city are included. These wards are located in northern, south western and south eastern part of the city and also includes11 villages. All of these areas are mostly located adjacent to hotspots. 6 villages and two wards (Suryakund and Rustampur) are in Low Risk category.

It is revealed from the analysis that Jungle Kaudia and Pipraich CD block are not much affected by the outbreak of encephalitis. All remedial Areas. 55 wards (78.57 per cent) and 488 villages (94.39 per cent) are in no significant measures should be given priority for hotspots and high risk areas. As far as the cold spots are concerned, there are no cold spots as such in the study region.

The study shows that Encephalitis is concentrated in some areas tehsil and even in the wards of the city as well. This analysis helps to visualize the disease distribution pattern. The study can pin point the high risk areas and provide guidelines to administrators, planners, health department to prioritise their planning, monitoring and surveillance for the high risk areas. This kind of efforts will definitely helpful in the mitigation of Encephalitis occurring in this region. Thus, the result of the study is fulfilling the main objective of reducing the burden of the disease.

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