A SPATIAL ANALYSIS ON INCIDENCE OF TUBERCULOSIS INFECTION USING INTERPOLATION TECHNIQUE

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Abstract: Tuberculosis (TB) remains an eminent health burden in many developing countries. The prevalence of TB is much larger than earlier thought, particularly in India. The secondary data of reported cases from 2011-16 were collected from the Revised National Tuberculosis Control Program (RNTCP). TB incidence was found highest in Uttar Pradesh state during 2011(1165379), 2014(1296575), 2015 (116630) & 2016 (297746), West Bengal in 2012(7875158) and Maharashtra in 2013 (22766). The international incidence of TB is around 82,09,000; 69,74,000; 73,21,000; 79,92,000; 86,79,000 from 2011-15 respectively. The spatial distribution of TB incidence worldwide is expected to be in patches. The variation of TB incidence is identified and estimated using GIS software tool viz., Spatial autocorrelation of ArcGis 10.2.2 demo version and Moron's Index. The national and international distribution of TB incidence was mapped with the population density from 2011-15. The study emphasized on finding the re-emergence, hotspots location, local cluster in the TB incidence and dissemination in recent years. According to the report, India has significant increase and stands highest. The comparative analysis of the TB incidence (2011-16) is found to be re-emerging according to the recent TB data and international report detected significant increase in TB cases in recent years.

Index Terms— Tuberculosis Cases, Arc-Gis (Geographic Information System) software (Demo Version), Spatial Interpolation, IDW (Inverse Distance Weighted) method, Spatial Scan Statistics, SPSS Software for Statistical details.

1 INTRODUCTION

Tuberculosis (TB) is a re-emerging contagious disease caused by the bacillus *Mycobacterium tuberculosis* which is major lung infection rated among other infections [1]. According to 2015 report, it has an account of wide ranging prevalence around 22 countries including India, therefore it has been considered as high burden countries (HBCs) [2].Additionally, in April 1993, TB is declared as a global emergency stated by the World Health Organization (WHO) [3]. Globally 1.4 million cases were reported in 2015. In India, RNTCP covered a population of 1.28 billion in 2015. A total of 91, 32,306 TB suspects were examined by sputum smear microscopy and 14, 23,181cases were registered for treatment. The National Disease Surveillance System grouped TB among the top ten leading diseases in the year 2013[4].

The Government of India and its partners like RNTCP have taken significant steps to prevent, diagnose, and treat TB. Several studies have been regulated at the national, regional, provincial, district, and sub-district levels to investigate the epidemiology of this disease in India. Although RNTCP is helpful in estimating the incidence of TB and control programs, spatial context such as disease spread and clustering patterns of TB cases. Currently, Statistical Process Control (SPC) with spatial statistics including spatial filtering and cluster analysis has been applied to analyze and visualize the spatial patterns of TB.

SPC and spatial scan statistics is used to detect the geo- spatial hotspots of TB at national and international level and found significantly high-rate of TB incidence. In Japan, the incidence of TB in Fukuoka was identified by space-time scan statistics [5]. Whereas, in South Africa GIS and spatial analysis were used to estimate high incidence area of TB transmission [6]. Significantly, High-rate clusters were detected in the reported incidence of TB cases. To describe the TB patterns in the selective area the geographical information systems (GIS) and spatial autocorrelation analysis were used to find the TB density. The significant hotspot of TB in India were determined by the inverse distance weighted (IDW) interpolation technique. It measures the values of surrounding predicted location. SPC and spatial analysis by interpolation method were utilized to study transmission patterns of the disease from 2011-16 in a high-incidence areas in India.

The identification of the TB spread and severity in an area determines the necessary management approach towards disease spread. The incidence and intensity of TB can be located using Geographical Information System (GIS) and statistics [7]. The spatial distribution of TB is identified in an area with the GIS and statistics which support the clear identification of the disease. It aimed to characterize the epidemiology of TB in the province, evaluate geographic variations of TB incidence randomization or statistically significant identification of location of such phenomenon. This determines whether statistically excess or deficits were temporary or time persistent. This report would provide the possible insight to formulate the incidence and hotspots that would target strategies for TB management.

2 MATERIALS AND METHODS

2.1 Study design

This was an illustrative study of the TB incidence data, assessing incidence cases reported by RNTCP annually from 2011-16. It's a retrospective analysis of the incidence of TB at the global level.

2.2 Data collection

The Annual TB Report provides an update on services provided throughout the year under RNTCP and progress status of initiatives implemented. Among the private sectors, the data from sub-national and local province survey from RNTCP the TB incidence were estimated. The relevant data of TB in local and global used in this study was on the records of TB cases from 2011-16[7]. WHO reported Global scenario of the year 2015 where India estimates to be at the risk of disease. In order to know the risk of TB in each country and state, a hotspot map was created using ArcGis 10.2.2 software. This is the comparative study of TB incidence from 2011-16, which shows gradual increase in the cases.

2.3 GIS mapping

To determine the variations in the most populated area at local and national level, the annualized average incidence of TB and population density were calculated [8]. To determine the disease prospects at Global and local level, an intemperate map may be focused. The map represents the proportion of the reported incidence at highly reported area over the average incidence [9].

To estimate disease possibility, the average incidence of all area with the ratio of the observed incidence was calculated.

2.4 Spatial autocorrelation analysis

Spatial autocorrelation analyses were performed in ArcGis 10.2.2 software and using Global Moran's I statistics to detect the spatial distribution pattern of TB in India and worldwide. The spatial aggregation of the TB incidence was calculated by the Moran's I index statistics along with inverse distance weighted (IDW) method. It measures the values which are similar to one another in the surrounding. Predicted location accordingly, the TB incidence distributed in an area and hotspots can be estimated by random underlying process.

Statistical Process Control (SPC) is an industry- standard methodology for measuring and controlling quality. The data is mapped with the spatial Statistics toolbox that contains statistical tools for analyzing spatial distributions, patterns, processes, and relationships.

2.5 TB hot spots

The TB cases in India are spotted by Getis-Ords with computer tomography (CT) which detects the hotspots and cold spots. The collected data was surveyed and mapped using ArcGis (10.2.2 version). The statistics used is the correlation of values of local TB cases in a locality of distance covered by the spread of disease. The values of local sum (detected cases) are different than the actual values these difference results in random providence which is identified by Z-score. The Z-score analysis was scaled by spatial autocorrelation [10, 11].

2.6 SPATIAL PATTERN DETECTION

The detection of TB spatial patterns was divided into two parts: local and global detection of spatial autocorrelation technique.

2.6.1 LOCAL DETECTION

The spatial pattern detection of the disease in the local area is collected through cluster analyses. These methods provide evident data of aggregated disease cases around state population.

2.6.2 Global Detection

The TB incidence around the globe is designed by Global detection technique. To differentiate certain locations and its neighboring units, the degree of correspondence is evaluated by spatial autocorrelation. Moran's I coefficient was used to signify the incidence by collected data from 2011-2016[12].

2.6.3 Cluster detection and hotspot mapping

In order to identify maximum TB affected area with respect to the population, cluster detection is implied [13]. It is identified that areas with more cases has been considered with more clustered with no value of prevalence in terms of population [1]. To detect the cluster of TB in selective area, three lead implications of spatial autocorrelation were included (Moran's I, Z- Score and G statistics). The negative and positive values of Moran's I which has impact on spatial autocorrelation *viz.*, values range -1 signifies perfect dispersion and +1 signifies perfect correlation. The Z score is the intense cluster dataset in G* statistics (Geo statistical) for hot spots (high values) detection. The clusters for cold spots are determined by the negative Z score value which signifies the smaller Z score.

To understand the exact spread of the TB these models would provide better knowledge. Thus, it consists of three interpolation methods viz., kernel, local polynomial and inverse distance weighting (IDW) are the most accurate methods [14]. The features of collected data among the populated global and local area were determined using interpolation technique [15] in the present study.

3 RESULT AND DISCUSSION

3.1The reported TB incidence 2011-15 globally

The TB pattern is found to be varying from 2011-15. Globally there were 3,917,500,000 cases reported in respective years. In 2015, the estimated TB burden worldwide was 10.4 million & India stands in one fourth position. In 2015, around 28 lakhs cases occurred and 4.8 lakhs death was due to TB. The TB incidence reported in 2011 was 820,900,000. The cases elevated at 799,200,000 in 2014. The least cases were reported during 2012-13 with 697,400,000; 732,100,000 respectively. In 2015, the number of TB cases extended to 867,900,000 which have shown rapid increase in disease spread and hotspot analysis is done by a ArcGis map. The reported cases over the globe and maximum cases in India were recorded [Fig: 1].

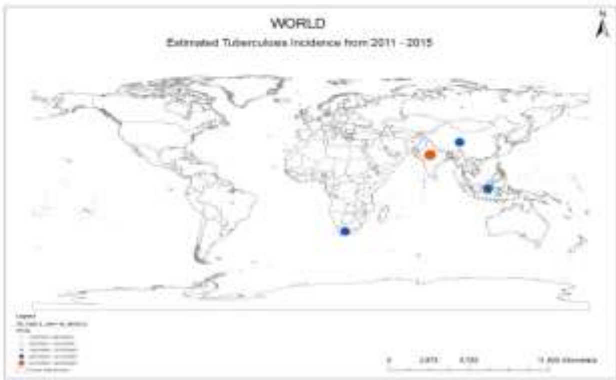

Fig: 1 The Reported cases of TB worldwide (2011-15)

In terms of spatial autocorrelation detection of TB incidence using ArcGIS 10.2.2 software with maximum spatial detection less than total population, the spatial autocorrelation detection was identified by cluster of significantly high and low rates of TB in 2011-16 [1].

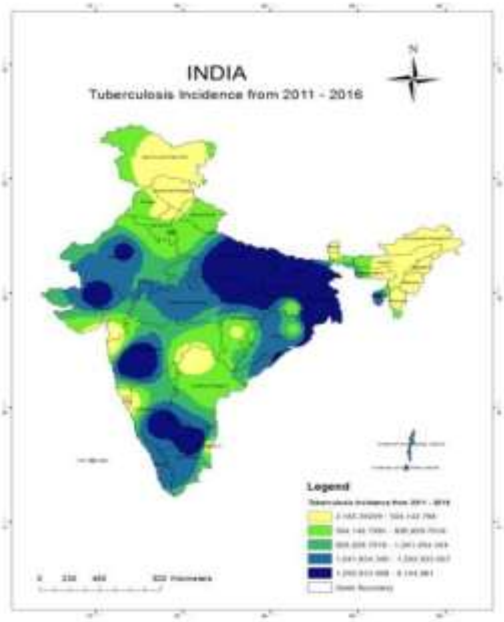

Fig 2: The incidence of TB in India during (2011-16).

3.2 TB incidence in India 2011-16

There were 15,750,313 cases were found in 2012. India accounts for one-quarter of the global burden in TB [1–3]. During 2011-16 estimated cases of TB in India are 34,187,899. In India TB incidence was found to be 2011 (7235516); 2012(15,750,313); 2013(59,058); 2014(8,783,551); 2015(604,774) & 2016(1,754,687) respectively.

3.3 TB incidence in Local spatial patterns

Hotspots of TB during 2011-16 were found random, while the cold spots were in Himachal Pradesh, Jammu and Kashmir, Andhra Pradesh and Arunachal Pradesh[Fig:3].

In 2011, 1,165,379; 694931 and 681,042 cases were recorded in Uttar Pradesh, Maharashtra and Tamil Nadu respectively and 395; 2182 & 2532 cases were observed in Lakshadweep, Dadra & Nagar Haveli and Daman & Due respectively and 7,875,158; 1268669; 710985 cases were notified in West Bengal, Tripura & Maharashtra and 951; 2654 & 3043 cases in Lakshadweep, Dadra & Nagar Haveli and Daman & Due respectively in 2012. In 2013, 22766; 6555; 5077 cases were recorded in Maharashtra, Karnataka and Kerala respectively. In 2014, 1,296,575; 959,184; 701,297 cases were notified in Uttar Pradesh, Maharashtra and Tamil Nadu respectively. In 2015, 116,630; 49,108; 43,242 cases were recorded in Uttar Pradesh, Maharashtra and West Bengal respectively. In 2016, the TB cases were noticed, 297,746; 15,139 and 129,915 in Uttar Pradesh, Maharashtra and Madhya Pradesh respectively.

During 2011-16, the reported cases of TB showed random variation at different time intervals. In particular areas the hotspots detected the increase in disease spread and the map targeted the severity of infection. The region with least reported cases due to the medical progress in public health awareness by various division and control programs were also acknowledged.

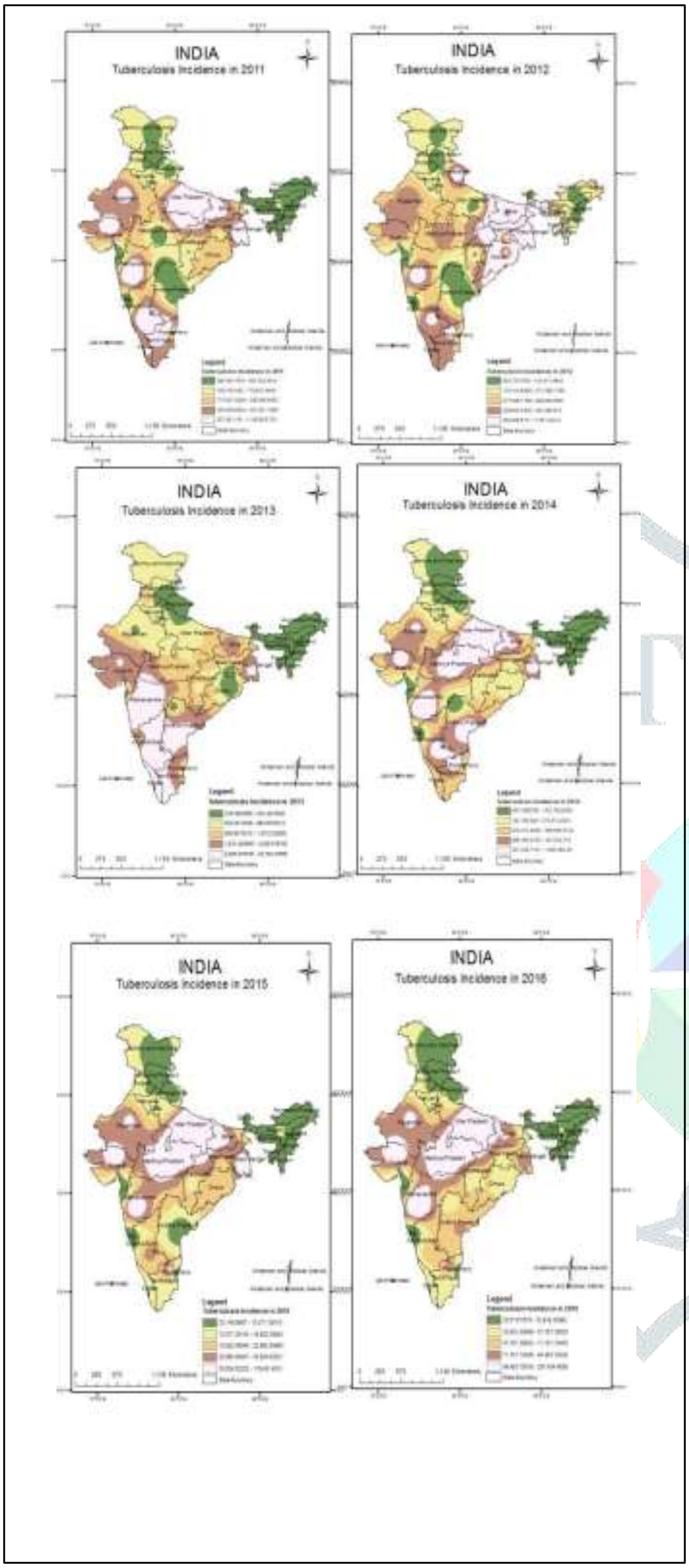

Fig. 3: TB Incidences are studied in India. With the help of the IDW (Inverse distance weight) technique distribution of TB cases. The disease has random distribution from 2011-16 depict a somewhat a regular pattern. The TB incidence is equally disturbed from 2015-2016.

3.4 Global measures of autocorrelation of Predicted TB incidence:

The TB incidence in a clustered area is measured by Moran's Index and Gestid-Ord with the disaggregated data derived from the interpolation of TB prevalence. Annual report revealed constant high TB cases in

2015 -16. The comparative study reveals that the incidence of TB cases is re-emerging from past two years. It can be interpreted that over population is also reliable aspect for the re-emergence of incidence. In all cases, the Moran's I index depicted values (0.0.026839) which indicate spatial autocorrelation of the TB incidence. The year 2011 has recorded -0.445 and 0.656 for the z and P-value respectively. This suggests that low clustering of the TB incidence.

Table: 1 local measure of Gestid-Ord during 2011-16 of TB in India

G.(d	2(	2(	2(	2(	2(	
Obse	0.(5	0.(9	0. 2	0.(1	0.(3	(
Ex G	0.(5	0.(5	0. 5	0.(5	0.(5	(
Var nc	0.(0	0.(0	0. 0	0.(0	0.(0	(
Sig , (z	0.8 1	0.5 9	1. 3	1.8 2	0.8 4	2
P- val	0.3 5	0.5 7	0. 1	0.(4	0.3 5	(

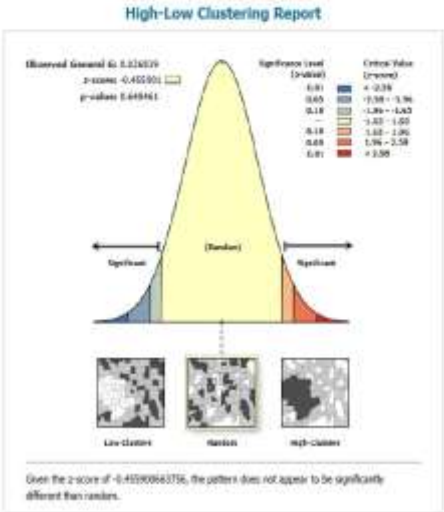

Fig: 4. Global measure of spatial autocorrelation of Tuberculosis prevalence (2011-15)

In all cases, the Moran's index determines negative values which indicate negative TB spatial autocorrelation. The P value (0.648461) being lowest recorded features for cluster. Observed general G (0.026839) and Z score (0.455901) are statistically significant that are not uniform in order to the reported TB cases.

This determines that spatial low random clustering of TB incidence. This pattern of reported TB cases from 2011-15 is due to very low Z score and high P value. This aspects reveals that TB incidence is random with respect to reported cases from 2011-15.

3.5 Local measures of autocorrelation of TB incidence from 2011-16:

The local Moran's I test for TB cases across different periods is depicted in [Table 2]. The values of Moran's I index, Z score and P value is around -0.036820: - 0.445297 and 0.656105 respectively [2011]; - 0.036820: -0.445297and 0.656105[2012]; 0.006073: 1.264998 & 0.205872[2013]; -0.001992:

0.541063 & 0.588464[2014]; -0.064811: -0.824520 & 0.409644[2015]; 0.003739: 0.689615 & 0.490436 [2016] respectively. This suggests that spatial random clustering of TB incidence.

Table: 2 local measure of Moron's Index during 2011-16 of TB in India.

Moron's I	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Moron's I	-0.036820	-.036820	0.006073	-0.001992	-0.064811	0.003739
Expected Index	-0.028571	-0.028571	-0.028571	-0.028571	-0.028571	-0.028571
Variance	0.000343	0.000343	0.000750	0.002413	0.001932	0.002195
Z- score	-0.445297	-0.445297	1.264998	0.541063	-0.824520	0.689615
p- value	0.656105	0.656105	0.205872	0.588464	0.409644	0.490436

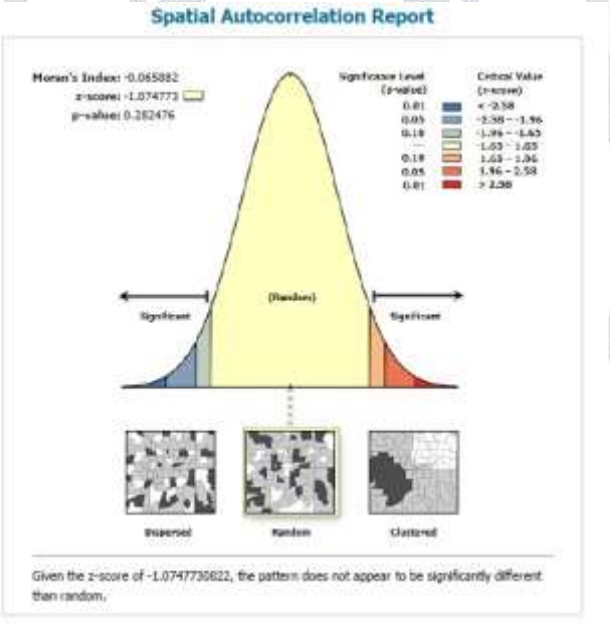

Fig: 5 Local Measure of Spatial Autocorrelation Of Tuberculosis Prevalence 2011-16

In all reported cases, the Moran's index determines negative values in 2011, 2012, 2014 & 2015 respectively that indicate negative TB spatial autocorrelation. The P value is 0.6 lowest recorded features for all the clusters. Observed General G is 0.025578;0.024997;0.040223;0.034168;0.031317;0.035930 &0.026839 in 2011, 12, 13,14,15,16 respectively and Z score range is 0.4-1.2. These are statistical significant is not uniform in order to reported TB case. This determines the spatial low random clustering of TB incidence. These patterns of reported TB cases from 2011-16 since Z score & P value recorded low values. This aspect reveals that TB incidence is random with respect to reported cases.

4. Discussion:

The distribution of TB in Global scenario is found to be re-emerging in recent years. The TB incidence in populated area reported with maximum cases. The studies conducted in Thailand shows influence of cases on population group, age standardization commonly applied [3]. In this study population density is opted and compared with reported TB cases globally from 2011-15. According to secondary data, TB incidence could be designated as remaining with the evidence of reported cases in India (2.2 million) & global (9.6 million) in 2015 respectively.

The global TB patterns were found to be deviated from 2011-15 shown rapid increase in disease spread. These findings suggested that application of spatial autocorrelation technique is a preferred approach in detection and disease spread in selective area. Numerous studies proposed that the exact adaptation of data processing in standardized methods to evaluate disease incidence [16-18]. Hence to determine the consistency in reported cases compare with population density being studied as direct method. Various studies have also adopted indirect method of data standardization [19-22].

In this study the comparative analysis of disease spread in population density witnessed the severity of TB incidence. These aspects supports the minimal fluctuation of TB incidence from 2011-15, thus, it provides effective data for the TB prevalence and treatment. This is in accordance to the studies conducted in Thailand, South Africa, Nepal, England, and in India [3, 23-26].

4.1Reported incidence in India 2011-15

The prevalence of TB in India is determined by the comparative study across population density. Many reports suggested that the TB incidence in spatial patterns and highlighted geographical areas would reveal the significant TB incidence in selective area [23, 27-29]. Each method has its own method of cluster analysis in a selective geographical area [3].

The spread of the TB in the highly clustered area is due to the low altitude which favors the high oxygen tension that results in high growth of *Mycobacterium tuberculosis* which explains the biotic factors that influence the spread of disease [30]. The study in Linyi city, China, reveals the statistical cluster of TB in the region improves the factors that identify the spread of TB [31]. In this study incidence in India studied by ArcGis tool that shows the random increase which is highlighted as hotspots. This would progress in medical support that creates the public health and control programmers. The tool like Inverse distance weighted tool of ArcGis has acknowledged in health Sciences. This tool is extrapolated to measure the global incidence of TB and its spatial autocorrelation from 2011-16.

4.2 Measures of autocorrelation of TB incidence: The cluster analysis used successfully in various studies, to determine the rate of TB incidence in selective geographical areas [3]. These analyses has found that cluster of disease incidence is evaluated in spatial statistics that had occurred in the reported region [4]. In this study, the applicability of spatial statistics (Moran's I and Gestid-Ord) and hotspot analysis has resulted in disaggregated data that reveal the result and in comparison to estimated data.

In all cases the Moran's index determines negative values which indicate negative TB spatial autocorrelation. The study in Thailand reveals the values of Moran's indices were positive [0.05] [3] whereas in the present study the P value is negatively random in respective years. All the cases show the random spread of TB in the selected area due to the recorded Z and P value. This aspect reveals that TB incidence is random in distribution.

5. CONCLUSION:

This study focused on the applicability of Geographic information system [GIS], Moran's Index method and spatial analyses in detecting the spatial spread of TB disease in the selective area. This technique is highly effective to study the TB patterns at global and local areas. The results of this study reveal the diversity of TB patterns in some geographical area showed random spread of TB with respective years.

The spatial methods like IDW interpolation technique are advantageous since it assumes substantially the correlations and similarities between points & proportional distance between them. The map clearly indicates the incidence of TB analyses hotspot locations given out high and low hotspots and cold spot areas. It is interesting for further studies to examine factors responsible for high density of TB prevalence in hotspot locations. GPS could be used to plot the locations of health providers or incidence of TB patients in a particular community, to understand the spread of the TB. It could help calculate the spread of disease. These data could be analyzed to study the incidence of TB with respect to population. The most important implication of this review is that risk of TB continues to be high in India. Exposure is approximately correlated with number of TB incidence. Risk can be reduced, although never completely eliminated, by the implementation of administrative and effective controls measures.

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