

APPLICATION OF GIS MODELING FOR DENGUE FEVER PRONE AREA BASED ON SOCIO-CULTURAL AND ENVIRONMENTAL FACTORS –A CASE STUDY OF DELHI CITY ZONE

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ABSTRACT:

Affected area of Dengue risk based on socio-cultural, environmental factors and its possible spatial relationship was investigated in dengue prone area i.e. city zone of Delhi. Data were collected from all total no of 37 Dengue Confirm Samples (DCS) through interview out of 127 no. probable/suspected dengue incidence cases. Results indicate that out of thirty socio-economic and socio-cultural variables, six variables such as housing pattern/densities, frequency of cleaning of water storage containers, frequency of cleaning drainage/garbage, no of flower pot /home garden, mosquito protection measure/awareness and storage of water are significantly contributing for dengue incidences. These variables are highly correlated with incidence of Dengue Fever (DF)/Dengue Hemorrhagic Fever (DHF)/Dengue Shock Syndrome (DSS) and value of R^2 equal to 0.996 when carried out the multiple regression analysis. Correlation and regression are appropriate technique to find significant social risk indicators contributing to dengue disease. Geographical Information System (GIS) modeling was done to generate risk map of dengue incidences, with four risk levels i.e. very high, high, medium and low social risks. Out of 127 suspected, probable and confirm cases, 112 no. of cases (88.2 %) of dengue cases found in very high risk zone with area coverage of 11.18 Km² (39.4%). This risk zone map helps in implementing precautionary and preventive strategies and control incidences of dengue effectively.

1. INTRODUCTION

Dengue virus infection is one of the most important among human arboviral infections. The global incidence of dengue fever (DF) and dengue hemorrhagic fever (DHF) has increased dramatically in recent decades. Dengue is a mosquito-borne infection which in recent years has become a major international public health concern. Dengue is found in tropical and sub-tropical regions around the world, predominantly in urban and semi-urban areas. DHF, a potentially lethal complication, was first recognized in the 1950s during the dengue epidemics in the Philippines and Thailand, but today DHF affects most Asian countries and has become a leading cause of hospitalization and death, majority of them were children. The global prevalence of dengue has grown dramatically in recent decades. The disease is now endemic in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, South-east Asia and the Western Pacific. South-east Asia and the Western Pacific are most seriously affected. Before 1970 only nine countries had experienced DHF epidemics, a number that had increased more than four-fold by 1995. Some 2500 million people, i.e. two fifths of the world's population are now at risk from dengue. WHO currently estimates there may be 50 million cases of dengue infection worldwide every year. This is greater than double the number of dengue cases which were recorded in the same region in 1995. Not only is the number of cases increasing as the disease is spreading to new areas, but explosive outbreaks are occurring (WHO). The outbreak of dengue in Delhi city zone occurred in September, October and November. Until now all research had focus on biological, entomological and clinical aspects of DF/DHF/DSS separately. Location specific, integrated with socio-cultural practices and environmental factors were lacking

in previous research studies. In depth study of the interrelationship of socio-cultural practices, environmental factors and identification of the most significant risk indicators under local condition using statistical modeling as an analytical tool were considered to evaluate and model the relationship between socio-cultural practices, environmental factors and the incidences of DF/DHF/DSS in the present study. Insights gained in this study are how the socio-cultural practices and environmental factors reflect the occurrence of DF/DHF/DSS.

2. METHODS

2.1. Description of Study Area

Delhi, the capital of India, is situated on the bank of river Yamuna at the longitude between 76°50'11"E and 77°02'54"E and latitude between 28°02'57" N and 28°05'35" N. It occupies a 1,485 Km² area of which 900 Km² is classified as urban. It lies 233m high from the Mean Sea Level. In Delhi three agencies, namely the Municipal Corporation of Delhi (MCD), New Delhi Municipal Committee (NDMC) and Defense are responsible for dengue control activities inside their own areas. The MCD with its 12 zones, cover the largest part. The study area is spread at the 28.4 km² and has population 644,005. The Indian capital city of New Delhi remains hot in summer, humid in monsoon season and is cold during the winters. The average temperature of New Delhi ranges from 25°C to 46°C during summer and 2°C to 25°C during winter. The cold wave from the Himalayan region makes the winters in New Delhi very chilly. In summers, the heat wave in New Delhi is immense and adequate precaution has to be taken before going out in the afternoons.

Rainfall season in Delhi is between July and September. The average rainfall recorded in Delhi University is 887.6 mm, which is the nearest centre from the study area, i.e. city zone.

2.2. Collection of Data for dengue incidence cases

Dengue Incidence data were collected from the Lok Nayak Jayaprakash (LNJP) Hospital of the Delhi and from Municipal corporation of Delhi. This data include information about all the suspected and confirmed DH/ DHF/DSS cases reported during the year 2006 in the city zone of Delhi municipality. These patients were mainly diagnosed on the clinical symptoms at the Delhi government hospital as well as public and private hospitals. Data was available with traceable address for 127 dengue suspected cases. Using the available address we categorized them into ward wise that is the lowest administrative level of Delhi municipality by using traceable address dataset. Major factors considered for analysis of the occurrence of DF/ DHF /DSS cases were population & house densities, rainfall, temperature, land use types and socio-cultural practice. Climatic, land use, and demographic data were collected from the relevant state agencies.

2.3. Socioeconomic Features and Dengue -Control Data

Socio-economic data were obtained from a report published by the Department of Census and Statistics in 2001 and from a questionnaire survey carried out from the Dengue incidence patient. The report of the census of India 2001 and Statistics contained data for the whole study area of the city zone, including the number of houses, the number of families, the income of families, the number of slum families. Questionnaire survey was conducted to evaluate the impact of dengue incidences, correlate factors governing the incidences and for GIS modeling among 37 households in 10 different wards located within the study area. Questionnaire was taken in all Dengue confirm cases.

The data collected based on household interviews using questionnaire to investigate for the socio-economic and cultural practices. The primary information derived from the questionnaire survey used for this study consisted of the use of protective measures against mosquitoes and social cultural practices. GPS points of the solid waste collection points were collected from the field. The collected points are projected in land use /Land cover map. These solid waste collection points were buffered by 0.5 km for the prediction of dengue risk area on the basis of breeding place on these points.

Data on average rainfall, humidity and temperature were collected from the relevant state agencies and meteorological department of India. These climatic data were compared with monthly dengue incidence data to evaluate dengue fever favorable environmental condition.

2.4. Dengue incidence assessment using feedback

Primary data were collected through a field survey. A structured questionnaire compose of thirty variables, all potentially influencing the occurrence of DF/DHF/DSS, were designed to obtain information through personal interviews and discussions with both Dengue Confirmed Samples (DCS). The questionnaire collected data about family details, human dwellings, occupational patterns, awareness and knowledge about dengue and mosquito protection practices, sanitation and waste disposal management, cultural practices regarding storage of water containers and health care. Each individual household in the study area was defined as a sampling unit. All available confirmed dengue patients were taken as sample in the study

area were interviewed. Suspected and probable cases were only considered for the reference of Dengue confirms cases.

Secondary data included demographic information about the city zone of Delhi such as climate, temperature; relative humidity, rainfall, and a list of DF/DHF/DSS patients are analyzed for dengue incidence causes. The dengue incidence cases along with their addresses as registered in Government Hospital, city zone of Delhi, during the 2006 outbreak, Physical environment (land use, land cover) from Google earth, and topographical and administrative map were also used to analyze dengue incidence cases. These data were acquired with the help of the census book, government/nongovernmental agencies and from published reports

3. RESULTS AND DISCUSSION

3.1. Statistical Analysis for dengue risk assessment

Correlation and regression analysis were the major statistical tools used in this study for investing and testing the statistical significance in the relationship between socio-cultural parameters and dengue incidences. Social cultural variables were studied and were screened based on the significance test of the Pearson's correlation coefficient regression predictive model for study of these variables.

3.2. Correlation of socio-cultural practices with dengue incidences

Pearson's correlation coefficient was computed for the thirty variables divided into six groups with the incidence of DF/DHF/DSS. This statistical technique could identify and isolate six variables that had the strongest positive or negative correlations, tested at 1% and 5% of significance levels. STATISTICA 7.1 software was used to find the correlation and regression analysis.

3.3. Regressive predictive modeling on the basis of regression analysis

From the six groups, the six variables that were significantly correlated to the dengue incidence were submitted to multiple regression analysis. The different characteristics of the socio-cultural variables interact together to contribute a combined effect on the dengue incidence. In the multivariate case, when there is more than one independent variable, the regression line cannot be visualized in the two-dimensional space, but can be computed. It is possible to construct a linear equation containing all variables. In general multiple regression procedures will estimate a linear equation of the form

The six variables were used to derive the following regression equation:

$$Y = 0.186 + .0587x_1 + 0.105x_2 + 0.119x_3 + 0.118x_4 - 0.14x_5 + 0.257x_6$$

Y = Incidence of dengue (dependent variable)

x_1 = Housing pattern/densities

x_2 = Frequency of cleaning of water storage containers

x_3 = Frequency of cleaning drainage

x_4 = Use of flower pot/home garden

x_5 = Mosquito protection and awareness

x_6 = Uncovered water storage containers

The regression coefficients represent the independent contribution of each independent variable for the prediction of the dependent variable. In present study social cultural practices independent variables such as Housing pattern, frequency of cleaning of water storage containers, frequency of cleaning drainage, use of flower pot/home garden, protection dengue awareness, Uncovered water storage containers are related to the dengue incidence cases in city zone of Delhi.

The results of multiple regression analysis indicated that the multiple R and R² for the final model were 0.99944601 and 0.99889233 respectively. Adjusted R² was 0.99667698 explaining 99.6% of the total variation in the dengue incidence.

3.4. Buffering of Land use/Land cover map

Land use land cover map is buffered to predict the risk level map of the dengue incidence on the basis of life span, flying distance, solid waste collection points and highly populated area as breeding place of the dengue incidence.

3.5. Spatial modeling for Dengue risk map generation

A data base was created in Geographical Information System (GIS) for dengue risk categories and linked with spatial point data of each house. Accordingly spatial surfaces were created from point samples. The inverse distance weighing (IDW) interpolation (nearest neighbor technique) was employed to produce the desired results. The IDW interpolator assumes that each input point has a local influence that diminishes with distance. It weighs the points closer to the processing cell that will have greater influence than those farther away. A specified number of points, or optionally all points within a specified radius, can be used to determine the output value for each location. IDW interpolation gives values to each cell in the output grid theme by weighing the value of each point by the distance that point is from the one being analyzed and then averaging the values.

Method of “weights” was observed to be a suitable technique, which would have a combined effect of various social risk factors contributing to the incidence of dengue. Based on field observations and review of previous literature of similar studies, weights were then assigned to their associated parameters indicating the degree of an individual risk indicator. In order to maintain uniformity among all social risk indicators, an equal weighing method was used. Combined social risk level map is generated using ERDAS Imagine model maker accordingly.

3.6. Discussion of significant variables

The following significant variables have the positive / negative significant for the dengue incidence cases

3.6.1. Housing pattern/densities

A review of the available literature indicated that in a crowded area, many people living within the short flight range of the vector and its breeding source could be exposed to transmission even if the house index was low. Therefore, higher population density and interconnection of houses could lead to more efficient transmission of the virus and thus increased exposure to infection. The transmission of the disease is normally limited by the flight distance of *Aedes aegypti* during its lifetime. The flight distance of *Aedes aegypti* could range from a few meters to more than 50 meters in a closed urban environment (Morlan HB et al., 1958; Reiter P et al., 1995). In urban environment where interconnections are not very common, the independent nature of houses limits the flight range of *Aedes aegypti* and

reduces the transmission of the disease. The prediction model indicated that the variable connectivity of houses (independent =1, connected = 0) had a negative correlation with dengue incidence.

3.6.2 Frequency of cleaning of water storage containers

The model showed that the variable Frequency of cleaning of water storage containers made a positive contribution to dengue incidence. The *Aedes aegypti* mosquito is a domestic breeder and breeding can occur in water storage containers, which are not emptied and cleaned for sufficiently long periods. The *Aedes aegypti* eggs are normally laid on the damp walls of both artificial and natural containers and they could resist desiccation for several weeks to several months. The eggs hatch when submerged in water. Since water is essential during the first 8 days in the life of mosquitoes, therefore if the frequency of cleaning is more than 8 days, this could contribute to an increase in the abundance of adult mosquitoes and the risk of dengue virus transmission. Whereas, changing water and emptying water storage containers once or twice a week will greatly reduce the risk of dengue fever. It was observed in the study area that people cleaned containers daily, but only those which were used to store water for drinking purpose. However, those containers which were used to store water for other domestic purposes, i.e. washing, bathing, etc., were cleaned infrequently. These containers were normally cleaned after 10-15 days, or even after one month, thus providing ideal ovipositor sites for mosquitoes and subsequent sticking of the eggs. The eggs would then hatch and develop into mosquitoes.

3.6.3 Cleaning and maintenance of drainage/garbage

Frequency of cleaning drainage and removal of garbage, which influences in negative direction The presence of waste and garbage around the household such as cans, car parts, bottles, old used tires and other junk found in the several houses created potential breeding sites. Dumping of solid waste for long periods of time such as 15-20 days supported the breeding of *Aedes aegypti* and increased the transmission of disease. If the frequency of collection and disposal of solid waste by local bodies increases, it would control the *Aedes* breeding and thus would reduce transmission. Similarly the drainage where the water is collected and overflows of tank water is in the side of the house hold also suitable breeding places for the *Aedes*.

3.6.4 Home garden and Flower pot used

The model shows that no of flower pot and home garden had a positive contribution to dengue incidences. The *Aedes aegypti* mosquito is a domestic breeder and breeding can occur in a flower pots and home garden because of water storage in flower pot and home garden.

3.6.5 Awareness in mosquito protection measures

Use of nets, screening of houses, creating smoke with neem leaves, spraying of insecticides and closing of doors and windows were the common protective measures used against mosquitoes. These measures either reduce the number of mosquitoes or provide protection against bites and thus reduce the risk of dengue infection. The model showed that the variable mosquito protection measures had negative association with the dengue incidence, i.e. the more protection measures were used, the fewer incidences there was of dengue.

3.6.6 Frequency of water storage

Open water storage containers provide ideal breeding places for *Aedes aegypti* mosquitoes. During the survey it was observed that portable cement tanks, metallic/plastic drums and overhead/underground tanks were used to store clean water within

premises. Most domestic water storage containers were kept uncovered except for underground tanks.

Different studies indicate that uncovered water containers and pitchers were significantly associated with dengue infection (Koopam JS et al., 1991; Khara A et al., 1993). The regression model indicates that the presence of uncovered water containers makes a positive contribution to dengue incidence. When there is scarcity of water. This scarcity could result in increased storage of water, thereby increasing the risk of dengue incidence and thus holding a positive correlation.

4. SPATIAL MODEL-DENGUE RISK MAP GENERATION

4.1. Weighting of socio-cultural practices

Method of “weights” can be applied to develop a combined social risk category map based on six social risk indicators identified from correlation analysis. Weights were assigned to their associated parameters indicating the degree of an individual risk indicator. In order to maintain uniformity among all social risk indicators, an equal weighing method was used. Weights of 1-3 were assigned to associated practices. For a given social risk indicator, a higher weight (3) was given to the practices with a higher risk of dengue incidence, medium weight (2) was assigned to the one contributing medium risk in the incidence of dengue, and a low score (1) was given to the practice with low risk of dengue incidence. For example, in the case of the risk indicator - “Housing pattern/density”, the lowest value of 1 was assigned to separate house with open space, 2 was assigned to medium House in colony and 3 to joined houses and no open space (Table 1).

S.No	Social risk indicators	Risk score
1	Housing pattern/densities	
	a) Independent house	1
	b) Mixed	2
2	No of flower pots/home garden	
	a) only 1/2 flower pot or small home garden	1
	b) More than 2 flower pots or home garden	2
3	Frequency of cleaning of water storage containers	
	a) 1-4 days	1
	b) 5-15 days	2
4	Cleaning and maintenance of drainage/garbage	
	a) Everyday	1
	b) weekly	2
5	Awareness in mosquito protection measures	
	a) Screens/ close windows	1
	b) Insecticides	2
6	Frequency of water storage	
	a) 1-4 days	1
	b) 5-15 days	2
	c) >15 days	3

Table1. Social Risk indicators and their weight age

Since the socio-cultural practices related to the six social risk indicators varied from household to household, these scores were assigned separately for each of the 37 households belonging to Dengue confirmed Sample (DCS) groups.

4.2 Development of social risk levels

The discriminate analysis approach was used to obtain household-wise social risk scores, and by using module maker social risk scores were translated into social risk levels. To derive risk levels, percentiles technique was used. These risk levels were termed as low, medium, high and very high risk levels respectively with scores of 1, 2, 3, and 4 for the assigned risk levels respectively. For each household, it is necessary to check the predicted risk levels from discriminate scores to their actual class. For this, estimates of the classification function coefficients were used. It was observed that the application resulted in 94.8% correct classification under the risk level categories, which was very positive from statistical consideration.

4.3 Development of a spatial social risk model

As the sample households were spatially distributed and social risk information with regard to these households was collected and analyzed, it could provide spatially distributed social risk levels. The spatial (point data) distributed points with their attributes were input into GIS and a spatial point-wise risk-level map was developed for all six parameters. This was achieved by digitizing spatial locations of houses of Dengue Affected Sample (37 DCS) samples located in the city zone administrative map. On the administrative map of City zone of Delhi, locations of houses of DCS were overlaid. GIS databases were developed separately for DCS groups having information on social risk levels. Inverse Distance weightage technique of interpolation was used to develop a social risk map of the area for six parameters map layer. This provided location-wise social risks of dengue incidence. For this layer map is used to give the new weightage to the parameters. The ERDAS module maker was used to get Analyzed results of risk level map are presented in Figure1.2.

This figure 1.2 (map) shows the spatial distribution of the four social risk levels, which were identified through discriminate analysis. The analysis indicated that a large percentage of the area (50.3%) is falling with high social risk, (39.4%) of the area is falling within very high risk, (10.3%) is falling within medium social

The table 2 shows that no of dengue incidence cases more in very high risk is in comparison with high risk area and medium risk area. This also proves that the dengue incidence prone area is falling in high risk area. The figure 1 shows the comparison of area under different dengue risk levels and no. of incidence cases in percentage.

All maps (i.e. land use /land cover, population density, housing density, buffering on the life span, breeding site and flying distance, solid waste collection points) shows high level social risk. This concludes that the social risk level map shows the high social risk level in highly populated area prone to dengue incidence risk level.

The risk map shows that dengue incidences, with four risk levels i.e. very high, high, medium and low social risks. Out of 127 suspected, probable and confirm cases 112 no. of cases (i.e.88.2%) covering an area of 11.18 Km² (i.e.39.4%) are

falling within very high social risk zone, 14 no. of cases (i.e.10.1%) covering of area 14.2 Km² (i.e.50.3%) in high risk zone, 1 no. of cases (i.e. 1.7%) covering of area 2.9 Km² (i.e.10.3%) in medium risk zone and there are no cases in low risk zone. The risk zone map may help in implementing precautionary and preventive strategies and control incidences of dengue.

Social risk level	Area in percentage (%)	No of cases (%)
Very high risk Area	39.4	88.2
High risk area	50.3	10.1
Medium risk area	10.3	1.7
Low risk area	0	0

Table2. No of dengue cases and area of risk level in (%)

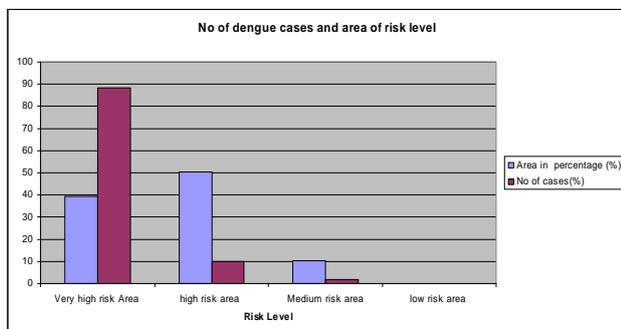


Figure1. No of dengue cases and area of risk level in (%)

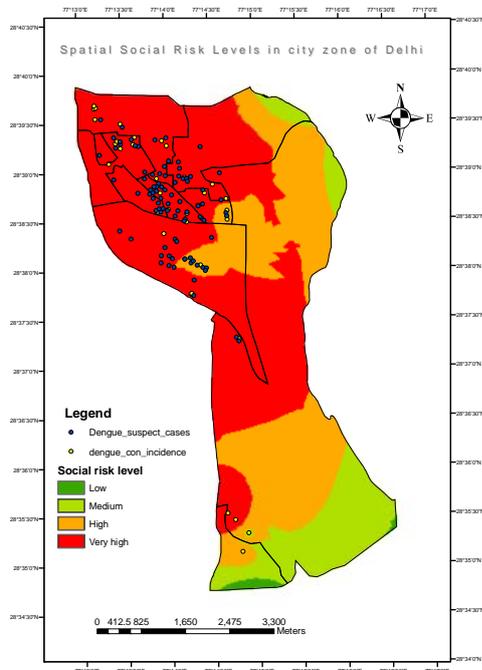


Figure 2.Spatial social risk Levels in city zone of Delhi

5. CONCLUSION

Dengue risk prone area was derived based on socio-cultural factors. The data analysis and modeling shows that the socio-cultural factors such as Housing pattern, frequency of cleaning of water storage containers, frequency of cleaning drainage, use of flower pot/home garden, protection dengue awareness, Uncovered water storage have higher influence on dengue incidences.

Population and house density at ward level with dengue incidence has revealed that dengue generally occurred in areas with high population. It was also found that built up areas and home garden have high influence and constitute to high-risk area.

Significant socio-cultural risk indicators and their relative contribution to the occurrence of dengue incidence are identified by using the correlation and regression analysis.

Land use /Land cover map pattern and socio-cultural practices has a relation with dengue incidences. The study area is highly populated and highly dense houses, interconnection of houses, open space with park, water bodies and fort also contributing for the dengue incidence. The study area also includes with railway station, slum, and office area, which also contribute for the dengue incidence. Prediction map on the basis of significant social risk and incidence of the dengue effect of flying distance, life span of mosquito and urban effect buffering map of study area are same.

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