Urgent need for real time web mapping GIS applications to dengue surveillance for epidemic control and management in India

ABSTRACT

Dengue epidemics has been increased both horizontal and vertical structure across the country since 2006, and hence, urgent need for GIS based dengue surveillance for epidemic control and management in the nation. The dengue epidemic cases and the mortality caused by dengue has become essentially public health important in India, and the situation has become worse since 2006. Dengue cases were clinically confirmed with thousands of cases and hundreds of deaths annually. The report of dengue epidemics is becoming daily news nowadays and it was reported from 24 states and Union Territories in India. The spatial and seasonal occurrence of dengue epidemics were reported across the country during the period of April to November annually, however, the vulnerability of epidemics was reported between the periods of mid-July to mid-November of every year. The geo-environmental and climate variables are fuelling to create a conducive environment for profusion of dengue vector mosquitoes Aedes species *(Ae. aegypti or Ae. Albopictus*). The information relevant to the geographical site specification of dengue vectors breeding habitats, vector abundance, vector density, etc., could be collected using global positioning systems (GPS), and these information are mapped and overlay on the thematic layers of climate variables (Temperature, relative humidity, saturation deficiency and Rainfall) under the geographical information systems (GIS) software platform for spatial analysis (cluster analysis, nearest neighborhood analysis, fussy analysis, probability of maximum and minimum likelihood analysis etc.,) for spatial riskprediction. The Google based internet GIS mapping could be used to embedded web mapping real time situation and updating the information with online data base connectivity (ODBC) within the GIS spatial engine for providing the real time information relevant to the dengue epidemics, and hence, the appropriate precaution measures could be taken to control dengue epidemics in the nation early in advance.

Key words: Dengue epidemics, GPS, web mapping GIS, vector breeding habitats, *Ae. aegypti*, *Ae. Albopictus*, dengue surveillance,socio-economic variables climate factors, geo-environmental determinants

1. Introduction

The dengue epidemics have been steadily increasing to bring the attention of public health important and to become essentially a very serious threat to the public in India[1-4], since 1991. Now, India has become host for all the four types of dengue virus. The dengue epidemics remarkably occurred in different parts of the country[5,6] since 2006, but the huge epidemics were recorded during 2009, 2010, 2011, and 2012, and it is still continuing. The huge epidemics of dengue and the mortality caused by dengue is essentially public health important for the past 2 decades and now, it has become daily news. The dengue epidemics was reported from 13 states / Union Territories in India during 2011, but the clinically confirmed dengue cases were increasingly reported in 24 states and the Union Territories in India[1-4,7-10]. The report of highest number of 37070 cases and 227 deaths was recorded across the country during 2012, and 60 deaths in Tamil Nadu alone is the highest number in the country and 59 deaths in Maharashtra as second position in the country [17,18]. The highest record of 9249 clinically confirmed epidemic cases was reported from Tamil Nadu, 6225 cases in West Bengal, and followed by Kerala was reported 3760 cases, and 3640 cases in Karnataka and 2196 cases in Odisha[10].

During 2013, the dengue outbreak in the country was 55,063 cases and 138 deaths reported till October 2013 and the situation is becoming the worst in the country for the past two decades, and the dengue cases and the death dolls has also been steadily increasing since 2006. The dengue epidemics was reported in 24 States and the Union Territories of India[1-4,7-10], namely, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Haryana, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Meghalaya, Maharashtra, Mizoram, Orissa, Tamil Nadu, Uttar Pradesh, West Bengal, Andaman & Nicobar Islands, Chandigarh, Delhi, Dadra & Nagar Haveli, Daman & Diu and Pondicherry, the epidemic situation in the states and UTs was doubled during 2012 while it was compared to the previous year account to 13 states and Union Territories[7-10]. The dengue epidemics were reported in the months between the periods of April to November annually, however, the vulnerability of epidemics was reported during the months of Mid July to Mid-November of every year, since 2006 [19,20]. The dengue was transmitted by the *Aedes* mosquito's species (*Ae. aegypti* or *Ae. Albopictus*). The dengue virus isolation and identification has been carried out at the 311 government sentinel surveillance hospitals and 14 public referral hospitals working in the 35 states and Union Territories of India[3,7-10]. At present there has no medicine or no vaccine available for the treatment and for cure of dengue fever in the world, and hence, the source reduction of vector breeding habitats and making the awareness among the people for keeping clear environment, proper waste disposal management etc., only could be control the present situation[6,7,16].

The present effort was made for providing the essential guide lines for making a control strategy using GIS based Google's web mapping surveillance tool for dengue epidemic control in India. The information relevant to climate variables (land surface temperature, relative humidity, saturation deficiency and rainfall), vector breeding habitats, the patients history sheets of clinicallyconfirmed dengue cases,the fuelling environmental parameters,water regulations,housing patterns, waste disposal and discarded materials, street structures, vector abundance etc. collected using the GPS (Global Positioning Systems) instruments and recorded in the standard database. The recorded information to be integrated with online database connectivity (ODBC) in the GIS based machine learning engine for real time web mapping, perhaps, used to updating the information for providing the risk ofreal timeedengue epidemics, and hence, the appropriate precaution measures could be taken for control dengue epidemics much early in advance.

1. **Background and Rationale of the study**

Dengue fever is an infectious, epidemic disease, transmitted by the vector *Aedes aegypti*[1-4]. The disease is becoming endemic mainly in tropical regions, where the expansion of urban populations, impoverished and crowded areas, and poor infrastructure create ideal habitats for vector proliferation and consequent spread of the virus[11-15]. Dengue incidence is a seasonal, increasing during the beginning and post monsoon in association with temperature and precipitation[9,10,14,15]. The previous study's reveal that spatial analysis of dengue epidemics have been associated with geo-environmental, climate and socioeconomic determinants in different context according to different geographical areas[6,7]. The study described ecological aspects in the municipality urban areas; the occurrence of dengue was correlated with socioeconomic variables through Pearsons' correlation coefficient[7,14,15]. Moran's global and local indexes were also used to assess the spatial auto-correlation between dengue and the variables that significantly correlated with the disease.[7,14,15]. The multiple linear regression models and the conditional auto-regression spatial model were used to analyze the relationship between dengue and socioeconomic variables[6,7,14,15]. Dengue and chikungunya epidemics are being reported from the coastal districts of Pondicherry and Tamil Nadu where the areas were marked for being prone to tsunami and cyclone, since it is associated with the huge number of containers of damaged household things in the coastal areas suitable for *Ae. aegypti* mosquitoes breeding[6,7,14,15]. The chikungunya in Kerala was most associated with massive number of coconut shells used for collection of rubber milk in the rubber plantation in Kerala, and the massive pineapple cultivation in the state also fueling for dengue and chikungunya vector profusion in the state Kerala, which has been the most suitable climate condition (temperature and relative humidity) for year round enormous quantity of *Ae. albopictus*, mosquitoes breeding during the Southwest monsoon in south India. Productivity of defective Rainwater harvesting structures (RWHS) was fuelled for dengue vector breeding and vector population profusion of a huge number of breeding habitats in the domestic and peripheral domestic areas[6,7]. The defective rainwater harvesting structure accounted to 20 to 35%, and has been supporting profusion of dengue and chikungunya vector mosquitoes (*Aedes* species) breeding of 12 percent of the total breeding habitats in the both urban and rural areas in Tamil Nadu state and Pondicherry union territory of India. Productivity of defective Rainwater harvesting structures (RWHS) was fuelled for dengue vector breeding and vector population profusion) huge numbers of breeding habitats in the domestic and peripheral domestic areas[7]. The chikungunya in Kerala was most associated with massive number of coconut shells used for collection of rubber milk in the rubber plantation in Kerala, and the massive pineapple cultivation in the state also fuelling for dengue vector profusion in the state, which has been the most suitable climate condition (temperature and relative humidity) for year round enormous quantity of *Ae. albopictus*, mosquitoes breeding during the monsoon[7].

Dengue and chikungunya epidemics were reported across the country[3,10] especially from the coastal districts of Pondicherry and Tamil Nadu where the areas were marked for prone to tsunami and cyclone, since it was associated with the huge number of containers of damaged house hold things in the coastal areas suitable for *Aedes aegypti* mosquitoes breeding. On the one hand, the dengue and chikungunya epidemic situation in the country has increased in recent years, on the other hand, vaccination or immunization or direct medicine is not available for treatment in the world. Dengue and chikungunya virus identification and isolation was carried out at the 311 government sentinel surveillance hospitals and 14 public referral hospitals working in the 37 states and the Union Territories of India as of 2014. India has now become a host for all the four types of DEN1, DEN2, DEN3, and DEN4 dengue virus[3,7,10,16].

The common person is not aware of a symptomatic dengue and chikungunya fever and also does not know the place of diagnostic centers and has not easy access to the hospitals for treatment. As per the WHO guidelines, the physician and patient ratio is minimum of 1:1000, whereas, 0.4/1000 ratio is available in India, it is below the normal ratio (WHO 2010) and therefore, there is an urgent need for real time web mapping GIS at the district level dengue diagnostic and treatment centers and which is most important and urgent need for the dengue surveillance in the country. A systematic grid sampling using GPS for studying the socioeconomic and environment in the epidemic regions in the country, and for real time web mapping application to analysedengue epidemic transmission pattern in the country, and thus, develop an early warning systemsfor dengue vector source reduction, epidemic control and management at the national level.

2.1. The environmental determinants of dengue epidemics in India

Dengue and chikungunya epidemics have been major challenging problems and have become essentially a public health importance to apply a control strategy in the countries where tropical region of Asia especially in India for the past two decades. Dengue is transmitted by the *Aedes* genus (*Aedes aegypti* or *Ae. Albopictus*) mosquito vector where the environmental factors like humidity, temperature, and rainfall are known determinants of dengue vector development[6,7,15]. The manmade and environmental determinants have been creating conducing environment for the occurrences of epidemics across the country. The huge dengue epidemics was reported in the country, especially during the past two decades, because of the environmental determinants of sea changing population, settlement developments, improper waste management, irregular drinking water supplies, uncertainty of climate change etc., changing the human settlements environment and are supporting the increasing dengue vector *Aedes* mosquitoes (*Ae. aegypti* or *Ae. Albopictus)* breeding, and thus, the huge dengue epidemics in the country[6,7].

2.2. The environmental determinants of dengue vectors in India

1)The sea change population rapid growths leads to the unplanned towns and settlements development, 2) the increase of waste disposals of domestic and the industrial products (tin, plastic cups, coconut shells, tires, plastic drums, iron containers, plastic and glass bottles, unused stone grinders, damaged /unused vessels, etc,) leads to the dengue vector breeding sources, 3) the regulation of irregular drinking water supply and it was supplied once in a week or 10 days interval, and hence, the village people have practice of drinking water storage in the big plastic container, big metal or plastic vessels,tin, cement tank, mud pots, rubber container etc., 4). The replacement of bottled cool drinks by consuming the tender coconut is welcome, but, a gigantic level of disposal of tender coconut cell found in the major cities alongside of highways where the place of floating population has been important for tourist attractions and, the fruits vendors, coffee bars, hotels and the petty shop business in the highways, serve them cool drinks and tea, coffee milk *etc.*, in the disposal cups. 5). There were a large number of domestic animals found (monkey, buffalo, donkey, dong, cat, rat, cow, goat, *etc*.,) in the affected villages as known hidden hosts of dengue and chikungunya virus load. 6). the lack of awareness of the common people about the vector mosquitoes, disease transmissions, and presents of dengue vector breeding habitats around the domestic peripherals. 7) Continuous rainfall failure in the country for the last 6 years, and consequently, irrespective of different socioeconomic and the landscape environmental condition, the dengue epidemic was reported in different states and the UTs across the country brings much attention, since 2006.

2.3. Climate variables and dengue epidemics

1) The climate variables (temperature, relative humidity, rainfall and saturation deficiency) have been playing a vital role in the dengue epidemics in different parts of the country[6,7]. The climate determinants have complete control over the epidemics. The dengue epidemics were mostly occurred in the semi-arid, sub humid, humid and tropical regions of the climate zones in the country. Based on the current situation of dengue epidemics in different parts of the country, the map overlays provides the results of a spatial model fitted with the mean annual temperature range between 17^0C to 27^0C and the monsoon relative humidity of 60% to 80 percent, and the GIS spatial model has a very good agreement and the climate variables have been most associated with the relative abundance of the *Aedes* species during the monsoon season[6,7]. The environmental parameters include the breeding habits suitable for profusion of vector breeding throughout the year, however, the climate variable during the monsoon season and the environmental parameters have complete control over the huge epidemics of dengue cases in the country[6,7]. The independent climate variables of temperature, relative humidity, saturation deficit and the monsoon rainfall variables have been providing the suitable environment for *Aedes* species vector abundance. The environment during the monsoon season of both southwest and the northeast monsoon from April to November almost 8 months period has been providing conducive environment fueling for profusion of *Aedes* mosquito species breeding[6,7,9,10], however, the vulnerability of epidemics reported during the months of Mid July to Mid-November period every year. 2). the epidemics of dengue were reported from the coastal districts of Pondicherry and Tamil Nadu where the areas was marked for prone to tsunami and cyclone, and hence, the huge abandon of houses and it was associated with the huge number of containers of damaged house hold things in the coastal areas suitable for *Aedes aegypti* mosquitoes breeding. 3). The dengue and chikungunya in Kerala ismostly associated with the massive number of coconut cells used for collection of rubber milk in the rubber plantation in Kerala, and has most suitable climate condition (temperature, relative humidity, rainfall and saturation deficiency) for *Ae. Albopictus* mosquito breeding throughout the year and thus, the epidemics have been increased during the monsoon[6,7,9].

3. Insufficient, Underutilization (or) improper management of resources

1) The insufficient number of public health entomologist i.e. more than 65% of the medical entomologist post have kept vacant across the country, 2) the absence of interlinks between the public health departments, town planning departments, PWD departments, and the

municipalities 3) The negligence of government sectors to approach for action plan precaution measures to prevent dengue epidemics in advance 4) based on the newspaper source, the absence / negligence of block wise periodical entomological survey of dengue vectors for source reduction of vector breeding habitats with the minimum period of 10 days or two weeks interval and, 5) the lack of awareness of the common people are causing the collective responsible for creating conducing environment for fueling for propagation of dengue vectors abundance and dengue epidemics in different part of the country.

4.Study design for systematic household dengue vector surveillance

A GIS based systematic grid sampling design with < 1 km distance could be applied to field survey and household data collection. The study sites cover 10 percent of the villages from each district and 10 percent of the wards / blocks must be selected from each urban centre, and 10 percent of the hose hold population to be covered for socioeconomic surveys both in the rural, semi-urban, and urban settlements. A set of random numbers could be generated for selection of study sites, using EpiInfo software. The clinical data could be collected from the PHC or DHC districts headquarters. A handheld GPS has to be used for household field data collection, the hose hold of clinical case data and the field data. The socioeconomic and the environmental variables field data could be collected using the structured questionnaire. The data could be captured in to the MS excel or geo-database engine for geospatial analysis and for mapping the spatial relationship between the socioeconomic, environmental variables and of vector breeding habitats, and hence, achieving the GIS based solution for dengue epidemic control and management in different landscape environment and the cultural regions in the country.

4.1.GIS for systematicdengue vector breeding habitats survey and source reduction

The applications of GIS is not only assisting in updating and mapping the disease prevalence of dengue cases but, also an essential tool for dengue surveillance and be a public health information management system, perhaps, decision making tool for controlling the dengue epidemics much early in advance. Dengue epidemics have become public health important at the national level and hence, the full-fledged year round epidemic surveillance tool must be a urgent need for disease monitoring and management. GPS, one of the components of GIS has been assisting to conduct a survey, and it has the inbuilt facilities to collect the information continuously with 500 points of geographical coordinates (site specifications), altitude, tracking speed and directions simultaneously. The dengue vector mosquito's maximum flight range is less than 600 meters and the *Aedes* species has the outdoor resting habitats and is the day biting mosquitoes. The reconnaissance survey has to be conducted in the nearest house of closeness to the intersection points of 100 meters grid samples (or) survey at every 10^{th} house in the village (or) town settlement clusters, because of the size of the government approved house plots in Tamil Nadu and Pondicherry are 30'X60' or 40'X60' (the length of the streets are approximately 300 to 400 feet's / 100 meters). The available GPS instruments have the inbuilt error of (+) or (–) 100 meters. Therefore, the GPS instruments could be used to mapping the dengue vector breeding habitats with site specifications of house locations with intervals of 100 meters. The global positioning systems (GPS) could be used for mapping the dengue vector breeding habitats (water storage plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, aquifer areas, drainage, sampled wells, pools / tanks) including the house locations, streets, house type, locality / areas., etc., with interval of 100 meters or at every 10^{th} house, these collected information are accurate and adequate for mapping vector density, vector abundance and clusters, and thus, these GIS based mapping information could be a datum of baselines for decision making and action plan for dengue breeding habitats source reduction, as well, possibly these information could be mapped with specific map projection under the GIS platform for mapping the site specifications of probable disease transmission earlier in advance.

5. Meteorological information

The dengue epidemics was reported throughout the year, but the number was comparatively very less for example, 1611 cases till the end of the month of march 2012, the severity epidemic was started from the month of April onwards, but the vulnerability of the epidemic cases was reported from July to November in the country[6,7,9,10], and the same spatial and temporal trend has been recorded every year. The epidemics situation was spatially correlated with breeding sources, and associated with absence of periodical entomological survey, lack of awareness, unplanned settlement developments etc., the heaviness of the dengue epidemics was highly associated with climate variables (monsoon season, temperature, relative humidity, rainfall and saturation deficit). Therefore, the present day availability of meteorological data derived from the ocean and atmospheric administration satellites could be used to calculate the CCD (cold cloud cover duration), LST (land surface temperature), SST (sea surface temperature) of the daily weather conditions, (temperature, atmospheric pressure, clouds, etc.,) could be used to develop a geospatial modeling for analysethe situation of the epidemics periods and predicting the magnitudes of the disease, spatial diffusion and direction with reference to space and time. This information could be used to web mapping GIS API using Python for spatial prediction and to take action plan for dengue vector breeding source reduction and prevention measures at least 7 days in advance.

6. Web mapping GIS for dengue epidemics control

The application of web mapping GIS using API (application programming interface) has widely used in commerce, engineering, agriculture, services, trade roots, service covering, business networks, police and law enforcement, fire and rescue operations, forestry, fisheries, settlements, planning, environment, etc The web mapping GIS API technology is mushrooming globally and most importantly, dengue surveillance which could be essential tool in the dengue surveillance and public health information management at the nation level. The web mapping GIS using API could be made available readily to each and every individual for browsing the information from the public domain of health GIS websites. The web mapping API are becoming important, mainly the embed customized web mapping GIS technology (ASP, .Net, html, java, python, CSS, PHP, Arc IMS, Geo ext, C, C++, Visual Basic, Arc objects) has user interface facilities for browsing, spatial structured querying, thematic mapping and table sorting and drawing the information of epidemiological data, demographic features, disease infection / disease prevalence and the geo-climatic environmental significant risk variables associated with dengue vectors and dengue epidemic transmission.

The web mapping GIS technology is not only assisting to mapping the disease prevalence of dengue epidemic cases, but also, used for updating the real time data, and hence, it has been important role in both dengue epidemics and vectorsurveillance, ofcourse, it could be a public health information management system, perhaps, and becoming the essential tool for choosing a appreciate control strategy, and decision making for management of the dengue epidemics well in advance as it has the national important. The applications of web mapping Python API was used for mapping streets, house locations, water storage plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, aquifer areas, drainage, sampled wells, pools / tanks, tiled images, etc., converting information between geographic geometric projection and the object information, and hyperlinks of spatial and non-spatial data. The web mapping / internet GIS Python API has mainly been used to customize embed mapping of site specifications of breeding habitats of dengue vectors (*Aedes aegypti* or *Ae. albopictus*). The web mapping Python API technology could be used for mapping the disease epidemiological information, entomological information, breeding habitats and determinants of risk variables, and thus, generate the thematic map layers of information for spatial prediction of dengue outbreaks well in advance with reference to space and times.

The web mapping GIS has user interface facilities for browsing, spatial structured querying, thematic mapping and table sorting and drawing the information of epidemiological data, demographic features, disease infection / disease prevalence and the geo-climatic environmental significant risk variables associated with dengue epidemics This web mapping information could be essentially useful for the ongoing disease control operations and useful for decision making tool for dengue epidemics control measures in future at the national level. Besides, the GIS tool allows the online database connectivity (ODBC) for updating and mapping the real time epidemiological information for quick and clear visualization of the disease with site specifications from anywhere in India, and thus, a conceptual framework of the present study of web mapping GIS application programming interface technology could be used for mapping and updating the real-time epidemiological information for monitoring the spatial distribution of dengue cases and action plan for control measures by source reduction of vector breeding at the village level / block level and it has to be implemented in collaboration with district public health departments of state governments for implementing the dengue disease control operation at the national level successfully (Fig.1). This web mapping technology could provide the information which is essentially useful for decision making for accomplishment of prevention measures at the local or block level, so as it could be useful for extending through the local administration for implementing the dengue epidemics control measures at the national level.

7. General discussion

Geographical coordinates of addresses of cases and controls are obtained directly in the field, using a hand held Global Positioning System (GPS) with an average accuracy of 100 meters. Geographical coordinates of residence of cases and living conditions, breeding habitats are digitized and visualized on a digital cartographic database of the study area (UTM projection), which contain, among other information, streets, blocks and Health Districts. The multiple regression models used in this study will provide relationships between variables related to mosquito breeding sites and the transmission of dengue fever, including both mild and severe cases. The use of generalized additive models and multinomial logistic analysis may provide the datum of guidelines to identify specific spatial transmission patterns. The spatial component of transmission could be isolated, after controlling for variables of interest, thus contributing to future studies that consider new hypotheses and determinant variables in the analysis.

These differences, both in terms of amplitude of the area and in probability of epidemic risk index values, are to suggest different disease dissemination mechanisms with different cultural regions in the country. The expected result also be provided that socioeconomic and environmental condition in the study region, estimates for identifying the socioeconomic and environmental key variables associated with dengue and chikungunya epidemics, visualizing the risk of epidemic and vulnerable areas, estimates the population at risk of exposure to the epidemic, prioritization of areas / wards / blocks for vector control and management, GIS based dengue surveillance and Google internet GIS mapping towards the achievements and reached spatial solution to dengue vector breeding source reduction and for epidemic control and management effectively.

7.2. Suggestions and solution

It is well known fact that no medicine or no vaccine is available for treatment of dengue fev er in the world (WHO 2010), and hence, the source reductions of vector breeding habitats are the best way of controlling both disease epidemics. The streetwise intensive and regular reconnaissance survey has to be conducted at every 10^{th} house (or) intersections of grids samples at 100 meters with the interval period of once in 10 to 15 days. During the visit, an entomological survey could be carried out in the household peripherals, and larvae densities (number of breeding sites for positive *Aedes aegypti* per 100 households) could be analyzed. This is the standard larva indicator that has been used as a parameter in most of the dengue fever control programs in the country. For each of the dengue fever cases, the following information could be obtained from the health centers as well, from the individual's households. Clinical data could also be used for classifying dengue fever cases according to severity into two groups: mild dengue fever, or a systematic (dengue fever without any warning signs, without spontaneous or induced bleeding by the tourniquet test) and *severe dengue fever* (dengue fe ver with warning signs and/or positive tourniquet test and/or bleeding and/or any other signs of severity). The collected information has to be updated in the GIS spatial data engine and it has to have customized internet GIS API for embed mapping for user friendly public domain so as the programmer and planner could make use of the structured query data and maps for decision making and action plan for controlling the epidemic situation. The first priority has to be given for survey in the major cities in the highways where the floating population of tourist attractions, and further, the survey may be perhaps extended to the areas of villages and small towns located in the buffer zones of 15KM to 25KM radius along the highways.[1] The observance of interlinks between the public health departments, town planning departments, PWD departments, and the municipalities for dengue surveillance for real time mapping of the collected information using Google internet GIS mapping for situation analysis.

The survey could be conducted by the NVBDC (National Vector Borne Disease Control), a nd the regional entomological research centers in collaboration with the public health departments of state governments, NGO’s (Non-Government Organizations) and the SHG (Self Help-Groups) for source reductions of vector breeding habitats and fogging in the breeding areas with environmental safety guidelines for controlling profusion of *Aedes* species vector mosquitoes. The National Vector Borne Disease Control (NVBDC) and the ICMR regional entomological research centers have to conduct the series of workshops /trainings for the school / college NSS and NCC coordinators for the source reduction of dengue vector breeding. The GIS based systematic grid sampling or reconnaissance survey has to be conducted for every 10^{th} house in the street (or) door to door survey must be carried out for source reduction. It has to be implemented through the leaders of Town / Village leaders (i.e., ward members, councilors, presidents, and the chairmen), and consequently, the clusters of problematic areas could be identified for prevention measures. The data pertaining to the vector density, temperature, humidity, house locations, breeding site specifications etc., has to be entered in to the GIS software platform for situation analysis and for spatial prediction of epidemics at least under the geographical information systems (GIS) software platform for spatial analysis (cluster analysis, nearest neighborhood analysis, fussy analysis, probability of maximum and minimum likelihood analysis etc.,) for prediction of disease epidemics well in advance i.e. atleast 7 days in advance[6,7].

8. Conclusion

The application of GPS under the GIS spatial engine umbrella could be useful to thematic mapping of the site specification of houses, breeding sources (breeding habitats), climate conditions (temperature, relative humidity, rainfall and saturation deficit), dengue vector mosquito's abundance and vector density. The web mapping GIS API could be used for updating the real time periodical information relevant to the dengue cases, breeding sources, and the vector density. The spatial analysis could be used for delineating the areas under vulnerable for dengue transmission and the areas could be marked for prevention from dengue epidemics well in advance. Based on the GIS spatial analysis results, the areas could be given priorities for vector breeding source reduction and appropriate prevention measures for dengue outbreaks. GIS could assist the programmer to take necessary action to control the situation from the headquarters. Real time internet mapping of dengue epidemic transmission in the country, and thus, develop a GIS based early warning systems towards the dengue vector breeding habitats source reduction, and a protective measures against dengue vector biting, and to be calling attention to the importance of dengue transmission in different socioeconomic and cultural regions, and thus, prevent measures to achieve the dengue epidemic control and management at the grass root level.

Disclaimer (Artificial intelligence):

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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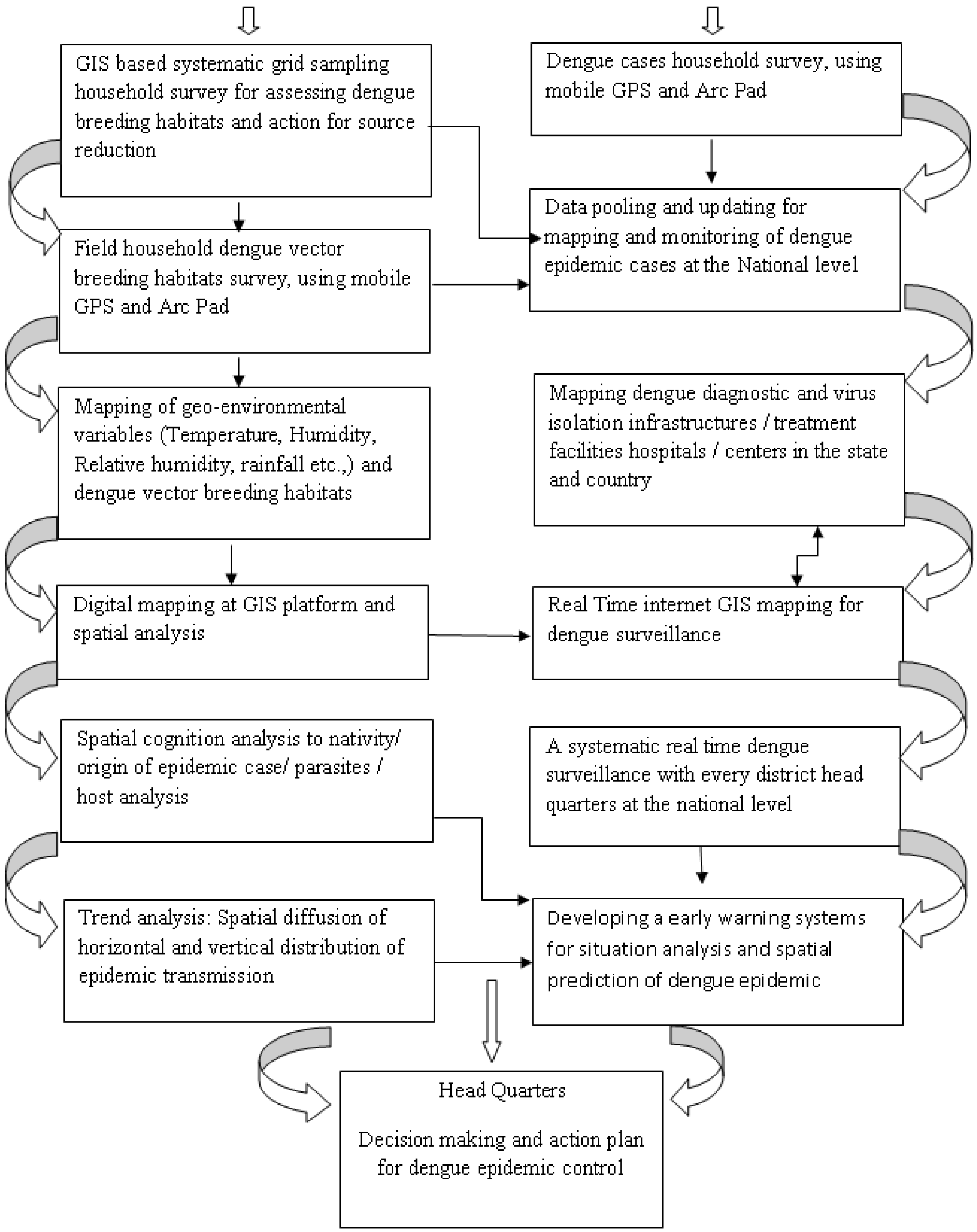
Fig.1:Flowchart showing the Google based internet GIS mapping for dengue surveillance


GIS based systematic grid sampling household survey for assessing dengue breeding habitats and action for source reduction
Dengue cases household survey, using mobile GPS and Arc Pad
Field household dengue vector breeding habitats survey, using mobile GPS and Arc Pad
Data pooling and updating for mapping and monitoring of dengue epidemic cases at the National level
Mapping of geo-environmental variables (Temperature, Humidity, Relative humidity, rainfall etc.,) and dengue vector breeding habitats
Mapping dengue diagnostic and virus isolation infrastructures / treatment facilities hospitals / centers in the state and country
Digital mapping at GIS platform and spatial analysis
Real Time internet GIS mapping for dengue surveillance
Spatial cognition analysis to nativity/ origin of epidemic case/ parasites / host analysis
A systematic real time dengue surveillance with every district head quarters at the national level
Trend analysis: Spatial diffusion of horizontal and vertical distribution of epidemic transmission
Developing a early warning systems for situation analysis and spatial prediction of dengue epidemic
Head Quarters
Decision making and action plan for dengue epidemic control