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SOCIO-ECONOMIC AND ENVIRONMENTAL DETERMINANTS OF DENGUE AND CHIKUNGUNYA TRANSMISSION: GIS FOR SURVEILLANCE AND EPIDEMIC CONTROL - A SYSTEMATIC REVIEW

Geography

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ABSTRACT

The geographical distribution and seasonal variations of dengue and chikungunya vector abundance and epidemic transmission have completely been controlled by the socio-cultural, economic, and the environmental variables. Dengue and chikungunya, are arboviral infections transmitted mainly by *Aedes aegypti* and *Ae. albopictus m*osquitoes, and emerging as the most important mosquito-borne viral disease, having a worldwide distribution in tropical and many subtropical areas. 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. Dengue and chikungunya are seasonal disease (in general), whose incidence increase during the months of highest temperature and precipitation. The dengue epidemic is spatially associated with socio-cultural, economic, and environmental determinants and the context varies according to different geographical areas. Geographical information systems (GIS) based systematic housing and population survey with aid of GPS has been used to collect data pertaining to risk factors affecting dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS), and its association with vector distribution. The spatial distribution of the dengue fever is determined by the geographical extent of the vector or reservoir hosts and their habitat priorities. Change in land-use permits the colonization of new habitats and is strongly related to the dengue incidence. The *Aedes aegypti* mosquito, a primary vector of dengue is now present in > 20 European countries. The other vector species contributing to dengue outbreaks include *Ae. albopictus*. A GIS based rapid entomological survey and active community participation for vector breeding source reduction, and web mapping GIS for permanent dengue surveillance could be used to grip the epidemic successfully.

KEYWORDS

Chikungunya; community survey; dengue; dengue surveillance; socio-economic and environmental determinants; web mapping GIS

INTRODUCTION

The geographical distribution and seasonal variations of dengue and chikungunya vector abundance and epidemic transmission have completely been controlled by the socio-cultural, economic, and the environmental variables[1-6, 8, 34-37, 43]. Dengue and chikungunya are arboviral infections transmitted mainly by *Aedes aegypti* and *Ae. albopictus m*osquitoes, and emerging as the most important mosquito-borne viral disease, imposing huge economic burden. In 2012, dengue was rated as the most important mosquito-borne viral disease with high epidemic potential across the world[6, 8, 14, 24, 46]. In the past 50 years, there has been a 30-fold increase in dengue cases world-wide[6, 52-54]. Dengue is an acute viral disease that causes fever, severe headache, bone and joint pains, nausea, vomiting, and prostration. In severe cases, it may cause/lead to hemorrhagic manifestations, shock, and death[1-6, 14, 46, 50, 52]. 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. Dengue incidence is seasonal, increasing during months of highest temperature and precipitation [15, 35, 40, 43]. The spatial analysis of dengue epidemic is carried out in relation to the socioeconomic variables context according to different geographical areas[2, 11, 16, 25, 44]. The other vector species contributing to dengue outbreaks include *Ae. albopictus*. The spatial distribution of the dengue fever is determined by the geographical extent of the vector or reservoir hosts and their habitat priorities. Change in land-use permits the colonization of new habitats and is related strongly to the dengue incidence [9, 14, 20, 23, 24, 35, 40, 47].

GEOGRAPHICAL DISTRIBUTION OF DENGUE EPIDEMICS

Dengue and chikungunya are global public health problem, with 2.5 billion people at risk and 50 to 390 million yearly infections[1-6, 11, 20, 40-43, 53, 54]. Dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS) have been endemic in the Southeast Asia, Western Pacific, Africa, Sri Lanka, South America and eastern Mediterranean for more than 100 years[6, 11, 29-34, 48, 54]. But, the situation was not very serious in India till 1990[34-43]. The first case of dengue was clinically confirmed and reported in India during 1989. From 1991 onwards, the epidemics of dengue steadily increased to become a serious public health problem in India. Now, India has become host for all the four types of dengue virus[20, 29-30, 46, 50, 52]. There are four known serotypes of dengue virus, namely DENV1, DENV2, DENV3 and DENV4. The DENV2 and DENV3 are the serotypes mainly found in Indian subcontinent[46, 49-50]. Recently, there are reports of a 5th serotype of dengue virus transmitted by the *Ae. aegypti* mosquito, the primary vector of dengue present > than 20 European countries [6, 52].

Gaining the spatial knowledge to better understand the distribution of epidemic cases in association with dengue vector breeding sources, vector density in reference to space and time, and it is important to develop spatial databases[23-24, 34, 42] and to analyze this information with climatic, geo-environmental, entomological and socioeconomic risk factors for a given area. Geographical information systems (GIS) based systematic housing and population survey with aid of virtual GPS is useful for collecting data for the study of factors affecting dengue fever (DF) and its vector distribution[7, 9, 12, 17, 20, 34, 36, 39]. Since, there is no drug or vaccination available to cure the DF; the most pertinent option for prevention is controlling epidemic transmission, monitoring the vector mosquito (*Ae. aegypti*) and destruction of suitable breeding environments[23, 32, 35-36, 45]. The role of remote sensing and GIS is increasing in providing the important datum of base line for formulating dengue control activities, assessing changes in transmission in different environmental setup over time and determining resources to control prevalence, particularly in areas having high and moderate risk of dengue epidemic transmission[7, 20, 41-43, 48].

GLOBAL BURDEN OF DENGUE

The incidence of dengue has grown dramatically around the world in recent decades. Over 2.5 billion people *i.e.* > 40% of the world's population are now at risk of dengue. About 50 –100 million new infections are estimated to occur annually across the world[1-6, 54]. Before 1970, only nine countries had experienced severe dengue epidemics[54]. The disease is now endemic in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, South-east Asia and the Western Pacific. The American, South-east Asia and the Western Pacific regions are the most seriously affected. Cases across the Americas, South-east Asia and Western Pacific have exceeded 1.2 million cases in 2008 and over 2.3 million in 2010. The Americas alone recorded 1.6 million cases during 2010, of which 49,000 cases were severe dengue fever leading to death,. Not only is the number of cases increasing as the disease spreads to new areas, but explosive outbreaks are also occurring. The threat of a possible outbreak of dengue fever now exists in Europe as local transmission of dengue has been reported for the first time in France and Croatia in 2010, and imported cases have been detected in three other European countries. A recent outbreak of dengue on Madeira Islands of Portugal has resulted infection spread in over 1800 cases; and imported cases were detected in five other neighboring countries in Europe apart from mainland Portugal. An estimated 500,000 people with severe dengue require hospitalization each year, a large proportion of whom are children, and about 2.5% of those affected are succumbed to death [6, 54].

DENGUE TRANSMISSION

The *Ae. aegypti* mosquito, a primary vector of dengue virus transmission, prefers human blood, and is a daytime feeder; its bite

goes largely unnoticed by humans and it often bites several people in a short period of time [1, 4, 12, 21-22, 27, 52]. The virus is transmitted to humans through the bites of infected female mosquitoes. After virus incubation for 4–10 days, an infected mosquito is capable of transmitting the virus for the rest of its life. Infected humans are the main carriers and multipliers of the virus, serving as a source of the virus for uninfected mosquitoes. Patients who are already infected with the dengue virus can transmit the infection (for 4–5 days; maximum 12 days) via *Aedes* mosquitoes after their first symptoms appear[46, 52]. The mosquito thrives in urban environments[12, 27, 31,49,51], breeds in stagnant water that often accumulates in discarded man made containers, tree holes, crab holes, animals footprint, coconut shells, pineapple leafs segments, *etc*. Unlike other mosquitoes *Ae. aegypti* is a daytime feeder; its peak biting periods are early in the morning and in the evening before dusk [2,8,13,14,37,40-43,52]. *Aedes albopictus*, a secondary dengue vector in Asia, has spread to North America and Europe largely due to the international trade in used tyres (a breeding habitat) and other goods (*e.g.* bamboo)[54].

Symptoms and characteristics of dengue

Dengue fever is a severe, flu-like illness that affects infants, young children and adults, but seldom causes death. Dengue should be suspected when a high fever (104°F) is accompanied by two of the following symptoms: severe headache, pain behind the eyes, muscle and joint pains, nausea, vomiting, swollen glands or rash. Symptoms usually last for 2–7 days, after an incubation period of 4–10 days after the bite from an infected mosquito[46, 49-54]. Severe dengue is a potentially deadly complication due to plasma leaking, fluid accumulation, respiratory distress, severe bleeding, or organ impairment. Warning signs occur 3–7 days after the first symptoms in conjunction with a decrease in temperature (< 38°C) and include severe abdominal pain, persistent vomiting, rapid breathing, bleeding gums, fatigue, restlessness and blood in vomit. The next 24–48 h of the critical stage can be lethal; hence, proper medical care is needed to avoid complications and risk of death[14,22,52].

SYMPTOMS AND CHARACTERISTICS OF CHIKUNGUNYA

Chikungunya fever caused by an alphavirus virus (CHKV), is transmitted by the infected female *Aedes* mosquitoes. The process of transmission cycle is similar to the dengue virus transmission; and after virus incubation for 4–10 days, an infected mosquito is capable of transmitting the virus for the rest of its life. Infected humans are the main carriers and multipliers of the virus, serving as a source of the virus for uninfected mosquitoes[10, 26]. Infected patients can transmit the infection (for 4–5 days; maximum of 12 days) through the *Ae. aegypti* mosquitoes after their first symptoms appear. However, chikungunya, which has dengue-like symptoms of very high fever and rash, is highly contagious and disabling. The name itself is Swahili for "that which bends up", a reference to the positions those afflicted with the illness are forced into because of the severe pain in their joints. However, the fever is so severe and ruthless, with symptoms of joint pains, severe back pains, > 104° F temperature , squeeze he affected patients, dangerous harsh, and so complicated in nature[10,28].

GLOBAL DISTRIBUTION OF CHIKUNGUNYA

In recent years, chikungunya has been reported from the country of Mayotte in southern Africa, Mauritius and Seychelles. European countries like France, Germany, Italy, Norway and Switzerland have reported imported cases.. The experience of epidemics has been reported regularly in the countries of Africa, the Americas, the Eastern Mediterranean, South-east Asia and the Western Pacific. The Americas, South-east Asia and the Western Pacific regions including the southern part of India were the most seriously affected (during 2006) and several epidemics have occurred every year since then [26,40,53-54].

THE OUTBREAK OF DENGUE AND CHIKUNGUNYA IN INDIA

The increasing number of dengue cases imported from endemic countries and autochthonous transmission of dengue in non-endemic areas highlight the importance of global collaboration to manage dengue epidemic, especially the epidemic situation that has arisen in India[14, 34-43, 49] after 2006. The dengue and chikungunya epidemic situation in the country has increased in the recent years, demanding urgent need for mapping the dengue and chikungunya transmission status in the country, with close monitoring of the disease epidemics. To achieve the intensive vector control and management towards the control of dengue epidemic, modern and reliable tools are needed for surveillance of disease transmission in the country[7,34,36,39,41,48]. Dengue and chikungunya epidemics have been reported from the coastal districts of Puducherry and Tamil Nadu states, mainly from tsunami and cyclone prone areas, since these coastal areas are associated with flow of huge number of damaged household containers, suitable for *Ae. aegypti* mosquito breeding[14,19,40,43]. The chikungunya spread in Kerala state was most associated with massive number of coconut shells used for collection of rubber milk during the rubber plantation and the massive pineapple cultivation in the state also fueled dengue and chikungunya vector profusion in the state Kerala, which has the most suitable climate condition (temperature and relative humidity) all year around, enormous quantity of *Ae. albopictus*, mosquitoes breeding during the Southwest monsoon in south India. Productivity of defective rainwater harvesting structures (RWHS) fuelled dengue vector breeding and vector population profusion of huge number of breeding habitats in the domestic and peripheral domestic areas[31, 40]. The defective RWHS accounted for 20 to 35%, and has been supporting profusion of dengue and chikungunya vector mosquitoes (*Aedes* species) breeding of 12 per cent of the total breeding habitats in the both urban and rural areas in Tamil Nadu state and Pondicherry union territory of India[14,19,40-43].

PREVALENCE OF CHIKUNGUNYA EPIDEMICS IN INDIA

A huge chikungunya epidemic occurred in South India during 2006. In Total, 213 districts in 18 states/UTs of India with people suspected with chikungunya fever admitted in the hospitals, 15,504 blood samples were screened, and clinically confirmed cases were reported. And the major epidemic was reported from 18 states / UTs with 14277 clinically confirmed cases across the country[26,40] during 2012. The situation is changed now in India, and has become endemic country. Climate, landscape, and the environment was suitable for survival, longevity and profusion of *Aedes* mosquito vector, as well as dengue and chikungunya virus. As a result, the report of epidemic cases occurred during 2006 has gained national public health importance in India, since then[28]. It was observed that the epidemic trend has declined, but, it was replaced with dengue epidemics. A huge vector population was found in the domestic and peripheral domestic containers, and was enormous number of domestic animals (monkey, buffalo, donkey, dong, cat, rat, cow, goat, etc.) also found in the affected villages as known hidden host of dengue and chikungunya virus load[28,40,43].

PREVALENCE OF DENGUE EPIDEMICS IN INDIA

The dengue and dengue hemorrhagic fever (DHF) have been endemic in the Southeast Asia, Western Pacific, Africa, Sri Lanka, South America and Eastern Mediterranean for > 100 of years[6, 47]. But, the situation was not very serious and it was almost insignificance before 2006 in India[14, 20, 49]. The first isolation of dengue virus was reported in Calcutta city, India, during 1945–46. The first dengue epidemic was reported during 1963–64, which gradually spread from the country's southern regions to its northern states and progressively to the whole country[14] by 1968. India has experienced extensive dengue epidemics each followed by endemic/hyper endemic years, with a shift in dengue epidemiology in 1996, introducing the first major epidemic of dengue fever, dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS). Since then, India has regularly experienced dengue epidemic with increasing magnitude in the recent years making it a essentially an important public health concerns in India. India has become host for all the four types of dengue virus. The situation almost doubled during 2012 when it was reported from all over the country, which later turned into major epidemic[46] during 2015.

HEALTH CARE FACILITIES FOR DENGUE AND CHIKUNGUNYA TREATMENT IN INDIA

On the one hand, dengue and chikungunya epidemic situation in the country has increased in recent years; while on the other hand, there is very meagre progress towards development of vaccination or immunization technique or direct medicine availability for treatment. As on 2014, dengue and chikungunya virus identification and isolation is being carried out at the 311 government sentinel surveillance hospitals and 14 public referral hospitals operational in 29 states and seven Union Territories of India. The country is host to all the four types of dengue viruses,[52] where the physician to patient ratio is 0.4:1000, which is very less in comparison to the normal ratio (1:1000), and therefore, there is an urgent need for studying the socioeconomic and environmental aspects of the dengue vector so as to design appropriate control measure[1-6,9,12-14,16,18,44,53].

GPS under the umbrella of GIS for systematic survey of dengue and chikungunya

A GIS based cross-sectional survey was carried out to assess the knowledge, awareness and preventive practices (KAP) of DF among a selected community in Puducherry urban, India, following the major dengue outbreak during 2012 ; a systematic grid sampling was applied to conduct an epidemiological survey in the 400 households selected from the four important blocks of most affected areas[40]. The study described ecological aspects in the municipality urban areas; and the occurrence of dengue was correlated with socioeconomic variables through Pearson's' correlation coefficient. Moran's[36] global and local indexes were also used to assess the spatial auto-correlation between dengue and the variables that significantly correlated with the disease. The multiple linear regression models and the conditional auto-regression spatial model were used to analyze the relationship between dengue and socioeconomic variables [15,40,44].

Considering socio-demographic, ecological, case severity, and household infestation variables, the relevant information were collected by in-home interviews and inspection of living conditions in and around the homes[4,5,8,12,22]. It was observed that the larvae and pupae of both dengue and chikungunya vector species (*Ae. aegypti and Ae. Albopictus)* were found in enormous numbers in the clustered human settlement areas[34-37]. Though, the regions are relatively developed and economically wealthy, however, the municipality areas in the urban settlement experienced highest incidence of dengue fever and suffered severely with epidemic problems every year[36], since 2006.

A systematic grid sampling for rapid survey for mapping of Aedes vector density: Many factors have been associated with circulation of the DF virus and vector, although the dynamics of transmission are not yet fully understood. However, dengue vector mosquito abundance is strongly associated with high human population density, high building density, and low income neighbourhood community, low standard of living quality[4, 8, 34-37, 40]. The manmade environment in the urban/rural settlement areas (domestics and peripheral-domestics areas) has created the conducing environment fueling the propagation of chikungunya vector mosquitoes breeding[1-6,10,14,16,22,25]. Vector density indices, such as household index, container index and breteau index are indicators that are accepted to compare relationships of vector species to habitats. The larval density data is considered more efficient in real-time indication of a future epidemic as compared to the use of dengue case data based on occurrence of asymptomatic infections. The female mosquito prefers human blood while the male mosquito likes nectar feeding. The dengue and chikungunya vectors fly short distances and majority of the population remains within 200 m[18-19,34]. A systematic community survey was carried for the spatial assessment of density of immature dengue vector mosquitoes in the clustered human settlement areas. A GIS based (0.5 x 0.5 km) grid sampling survey was carried to assess the density of mosquito breeding habitats of dengue and chikungunya[34, 40-43]. It was found that dengue and chikungunya immature vector mosquitoes spatially correlated with dense population, and low income group of settlements found in the urban agglomeration was statistically significant[34,40-43], the findings are strongly supported by the similar studies [9,14,24,37,45,49]

A systematic grids sampling survey for assessing socio-cultural, economic, and environmental risk variables: A virtual GPS was used to conduct a rapid survey with 0.5 km distance interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the sectors positives for dengue and chikungunya vector mosquitoes (*Ae. aegypti* or *Ae. albopictus*), breeding habitats (water storage vessels, plastic and cement containers, tyres, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, *etc*) with accurate site specifications[1-54]. The adult mosquito trap was effective and efficient to collect the dengue and chikungunya vector adult mosquitoes[50]. It is well known fact that the *Aedes* species (*Ae. aegypti or Ae. Albopictus*) adult mosquito's flight, range from 200 – 400 m; the sites were selected for setting up the adult mosquito trap with < 1 km distance interval, so as to collect the maximum number of adult mosquitoes from all the directions (*i.e.* the selection of alternative intersection points, based on the grid map with 0.5 x 0.5km distance)[34, 36,40,43]. The household population perception and knowledge on dengue vector breeding habitats and personal protection measures among the common people in the urban areas was assessed[34,36,40] .

The socioeconomic and the environmental variables in association with dengue transmission considering people perception of the individual-level of awareness, the result shows that lack of knowledge of community people perception on dengue vectors breeding[30,40,49], epidemic transmission and protection or preventive measures and the number of unprotected containers in and around their houses. Knowledge of development sites was positively associated with unprotected containers. No relationships existed between knowledge of dengue and adult mosquito reduction practices. A higher number of unprotected containers increased the likelihood of the house with one or more adult *Ae.aegypti*[30,49]. Surprisingly, houses of respondents that used mosquito coils or had screening on doors and windows were significantly more likely infested with *Aedes* immature species and adult dengue vector (*Ae. aegypti, and Ae. albopictus*)[18-19,21]. The GIS based systematic grid sampling methods used can be implemented as routine procedures for control and prevention[32,36,37,48,50]. A concerted intervention in the medium- and high-risk level blocks identified in this study could be highly effective in dengue vector habitats source reduction towards the control and management of epidemic transmission in the urban areas[18,21,27,28,36,44].

The lack of awareness of the common people about the vector mosquitoes, their breeding habitats, disease transmissions, source reduction of theirbreeding habitats, lack of prevention measures against mosquito bites, low level of education due to low income or poor economic condition, clustered unhygienic settlements are playing important role in dengue epidemics[1-5,18,19,21,34,36]. Similarly, moderate rain during the summer, a week interval of drinking water supply, absence/negligence of block wise periodical entomological survey of dengue vectors for source reduction of vector breeding and lack of awareness among the common people were collectively responsible for creating conducive environment for fueling the propagation of chikungunya vectors and chikungunya epidemics in different part of the country during 2012.Hence, community-based dengue prevention programs is essential for making awareness among the common people so as to control epidemic transmission successfully[16,36,53].

CLIMATE VARIABLES ON DENGUE AND CHIKUNGUNYA TRANSMISSION

The global climate change has influenced the increase of *Ae. aegypti* mosquito, the primary vector of dengue is spread and extent to newer regions and now present in >20 European countries in addition to Asian countries[52]. The other vector species contributing to dengue outbreaks include *Ae. albopictus*. The spatial distribution of the dengue fever is determined by the geographical extent of the vector or reservoir hosts and their habitat priorities. Changing precipitation patterns and temperatures largely affect the ecology of vector-borne diseases including dengue and chikungunya[15, 40]. In the arid and semi-arid regions of India, rainfall is a determining factor for inter-annual variability of dengue fever. The rising temperature too, has a great impact on the abundance of dengue *Aedes* vector mosquitoes. The influences of climate variables (temperature, rainfall, saturation deficiency, relative humidity) in the middle and South America, Africa, and the South-east Asian regions have created ideal breeding conditions for the dengue vectors profusions. These regions are having maximum breeding environments and growth opportunity for the mosquito vectors; especially, *Aedes* mosquitoes[52].

Bio-geo environmental risk factors of dengue transmission: The occurrence of dengue epidemic is determined by multiple factors, including climate, landscape, and the environmental dimensions that affect the population biology, development, and behavior of vectors, as well as dimensions that determine the population biology and natural history of the viruses, and even the behavior of humans. The known occurrences of *Aedes* species are related to raster (grid format) geospatial datasets describing aspects of the climate, landscape, and the environmental landscape, to derive a quantitative multivariate model. The relationship between the drinking water supply and dengue vector density has statistically significant with chi-square χ^2 test, (P value <0.05), similarly, the relationship between the disposal cups, manmade containers, and plastic or metal containers with immature dengue vector density has found significant. There were a large number of domestic animals found (monkey, buffalo, donkey, dong, cat, rat, cow, goat, etc.) in the affected villages of Andhra Pradesh, Tamil Nadu, Maharashtra, Pondicherry and Uttar Pradesh, as known hidden host of dengue and chikungunya virus load.[40-43,52] The chikungunya in Kerala was most associated with massive number of coconut cell using for collection of rubber milk in the rubber plantation in Kerala, and the massive pineapple cultivation in the state also fueling for dengue vector profusion in the state, and has been most suitable climate condition (temperature and relative humidity) for year

round enormous quantity of *Aedes albopictus,* mosquitoes breeding and high number in the southwest monsoon [40-43,52].

Dengue and chikungunya epidemics 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 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[40,43]. The chikungunya in Kerala was most associated with massive number of coconut cell using for collection of rubber milk in the rubber plantation in Kerala, and the massive pineapple cultivation in the state also fueling for dengue vector profusion in the state, which has been most suitable climate condition (temperature and relative humidity) for year round enormous quantity of *Ae. Albopictus,* mosquitoes breeding and high number in the southwest monsoon[40-43].

DENGUE AND CHIKUNGUNYA EPIDEMIC CONTROL AND MANAGEMENT

Dengue vector control and management in the urban settlements:

The intensive and regular reconnaissance survey has to be conducted with the interval period of once in 10 to 15 days in the major cities for source reduction of dengue and chikungunya vector mosquito breeding habitats and keep away from aggressive day biting mosquitoes (*Ae. aegypti* and *Ae. Albopictus)* and making awareness among the people to prevention measures help to control the disease epidemics[12,13,18,27,28,36,50,51]. The source reduction of mosquito breeding could be provided the safe environment and keep away from the dengue and chikungunya disease transmission in the Pondicherry urban areas. Thus, the utilization of GIS technology for site selection of fixing the adult mosquito collection and the combined intensive vector control measures enable us to design a master plan for mosquito control in the city with low cost is achieved successfully[34-37]. This information must be updated every 2 weeks/ fortnight of the every month and updating the field data in the web mapping GIS[13,17,20,39,41,48]. Web mapping GIS and dengue health information management systems for taking prevention measures to dengue epidemic control could be achieved.[13,39]

DENGUE VECTOR CONTROL AND MANAGEMENT IN THE RURAL SETTING:

The result 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[7,9,12,17,20,41,43,48] estimates the population at risk of exposure to the epidemic, prioritization of areas / wards / blocks for vector control and management, GIS based spatial solution for vector control and management and a protective measures against dengue vector biting, and to be calling attention to the importance of dengue transmission at work, schools and other public spaces[1,21,41,52]. The spatial component of transmission could be isolated, after controlling for variables of interest, thus contributing to future studies that consider new hypotheses and added variables in the geospatial analysis to classify the areas as whole at different level risk of epidemic transmission[1,21,41,52].

A COMMUNITY BASED ENVIRONMENTAL APPROACH FOR VECTOR CONTROL

A innovative community-based vector control intervention[4, 19], social participation and eco-bio environmental approach for vector control[47], ecosystem management in the clustered human settlements for prevention of dengue epidemic in the low and middle income groups [18,22] and long lasting insecticide treated house screen and targeted treatment of productive breeding sites for dengue vector control for vector control and management in the urban areas[5,27,28,34-37] towards the improved epidemic prevention and management[5, 36] have generated evidence on the feasibility and significantly, community based approach to vector control is locally adopted to success of vector reduction more than 85 percent, “mosquito proofing” houses has been employed to keep away from human contact with mosquito bites and provide personal protection in the home as long lasting treated bed nets observed as a fundamental techniques of malaria control in the early 1900 and “mosquito proofing houses” using windows and door screen has been applied where mosquito nuisance and disease transmission are a highly problematic one[27-28] however, the challenging problem of malaria, JE, and dengue are reported in the tropical countries. India, for instance, the people are exposed to mosquito bites in the rural setting when they are going outside to agricultural land (rice field, rubber plantation, pine apple / banana plantain, / or going to forest for collecting fuel wood/ or for collecting medicinal plants, as well in the urban setting people going to outside for professional, secondary and petty jobs, and therefore, the bio-geo environmental approaches are to be applied to mosquito control and to prevent the mosquito borne disease transmission[19,23].

Social participation and environmental management methods have improved dengue vector control and was feasible and has significantly reduced vector densities. Apart from the community participation and the novel environmental management methods, web maps offering GIS analysis have been frequently used in commerce, engineering, agriculture, business networks, law enforcement, forestry etc. However, web maps using GIS analysis for disease surveillance and health information management systems in India is less than 10% of all GIS applications. There is an urgent need of web maps that could use GIS analysis to depict how chikungunya and dengue spread across India. The layers of information would enrich these maps further. The detailed maps showing the pattern of disease transmission, and the information could be guidelines for controlling measures including the source reduction of vector breeding habitats. The epidemiological information of chikungunya and dengue cases, entomological information, breeding habitats and the environmental determinants of climate variables has been updated for overlay analysis with the geographical distribution of disease epidemic maps, and thus, generate layer's information for spatial prediction of disease epidemics in the country. The updated information relevant to the chikungunya vector density, temperature, relative humidity, saturation deficit, precipitation, house locations, breeding site specifications etc. has been entered / captured for the web mapping GIS engine for monitoring the real time situation in the both urban and country side villages in the country.

Apart from preemptive measures, Latin America, China, South Korea, Japan and Vietnam, have implemented bio-geo environmental strategies to check the spread of vector borne diseases viz. malaria, JE and dengue[21]. Vietnam, for instance, adopted and implemented bioenvironmental strategies to use a small crustacean, called *Mesocyclops aspericonis*, released in the water storage containers to grip the dengue vector breeding 95 per cent as well epidemic[21], during 1993 and the similar method of environmental friendly approach is used all over the world. China, for instance, was used *Wolbachia* bacteria and released half-a-million *Wolbachia* infected mosquitoes and the research has shown that bacteria infected mosquitoes become sterile, and hence, the result obtained from the sample site is good enough source reduction[21], and the same method was used in Rio de Janeiro (in 2014) and Brazil (May, 2015).

BIO-GEO ENVIRONMENTAL MANAGEMENT STRATEGY TO VECTOR CONTROL:

The integrated bio-geo environmental methods and community based approaches are applied for vector control, and have significant and locally appreciated, adopted, and implemented in Latin America, China, and Vietnam[21]. Now, this excellent method is adopted and used all over the tropical countries of the world. A innovative community-based vector control intervention[19], social participation and eco-bio environmental approach for vector control[47], ecosystem management in the clustered human settlements for prevention of dengue epidemic in the low and middle income groups[18] and long lasting insecticide treated house screen and targeted treatment of productive breeding sites for dengue vector control for vector control and management in the urban areas towards the improved epidemic prevention and management[5,34-37] have generated evidence on the feasibility and significantly, community based approach to vector control is locally adopted to success of vector reduction more than 85 %, “mosquito proofing” houses has been employed to avoid human contact with mosquito bites and provide personal protection in the home as long lasting treated bed nets observed as a fundamental techniques in early 1900, and insecticide treated curtains are used in Thailand to give personal protection and keep away from the dengue vector bites[5,21,27,30], and “mosquito proofing houses” using windows and door screen has been applied where mosquito nuisance and disease transmission are a highly problematic one [5, 29-30], however, dengue and chikungunya are reported in the tropical countries. In India, for instance, the people are exposed to mosquito bites in the rural setting when they are going outside to agricultural field and to forest for collecting fuel wood/ or for collecting medicinal plants, as well in the urban setting people going to

outside for professional, secondary and petty jobs, and therefore, the bio-geo environmental approaches are to be applied to mosquito control and to prevent the mosquito borne disease transmission[19-20]. A community based social participation and environmental management methods have improved the source reduction of dengue vector breeding habitats, and hence, control *Aedes* adult mosquito and has significantly reduced vector densities.

Apart from preemptive measures, Latin America, China, South Korea, Japan and Vietnam, have implemented bio-geo environmental strategies to check the spread of vector borne diseases viz. malaria, JE and dengue. Vietnam, for instance, adopted and implemented bioenvironmental strategies to use a small crustacean, called *Mesocyclops aspericonis*, released in the water storage containers to grip the dengue vector breeding 95 per cent as well epidemic[18,19,20,21] during 1993, and the similar method of environmental friendly approach is used all over the world. China, for instance, was used *Wolbachia* bacteria and released half-a-million *Wolbachia* infected mosquitoes and the research has shown that bacteria infected mosquitoes become sterile, and hence, the result obtained from the sample site is good enough source reduction, and the same method was used in Rio de Janeir in 2014, and in Brazil, May, 2015, and therefore, it is recommended for implementation of these novel strategies to vector mosquito control and management[19-22].

GIS FOR EPIDEMIC CONTROL AND MANAGEMENT

Actually, the authorities have enough data on both the diseases as well as plenty of health service resources in the country. Perhaps, up to date public domain is not available to update the patient's information and place of epidemic epicenters. The public health care system must be established to disease surveillance and health information systems available to the public and physician to make use of the resource centers for immediate and to access for appropriate treatment in right time[41]. The information details of the epidemiological information and the information of following; where did the outbreak take place? What was the pattern in which the diseases spread across the country? What kind of people was hit most severely? What were the environmental determinants? How much casualties did each district witness? We have answers to almost all these questions. All this information could very well be utilized to generate maps that could give a crystal clear understanding of the "how", the "when", the "where" and the "how much" questions? GIS could really come in handy! It has not only been assisting in mapping of diseases but also has become an important supporting tool for disease surveillance and public health information systems[41].

Web mapping technology is offering GIS analysis for the potential use of resource allocation, monitoring and management. It has been adequately and frequently used in commerce, engineering, agriculture, business networks, law enforcement, forestry, environment, town planning, oil resource, road networks, etc. However, web maps using GIS analysis for disease surveillance and health information management systems in India is less than 10% of all other GIS applications. There is an urgent need of web maps that could use GIS analysis to depict how filariasis, malaria, JE, dengue, chikungunya and visceral leishmaniasis spread across the country. The layers of thematic information including the both epidemiological and the entomological data would enrich these maps ever further for planning towards the elimination of the disease. These detailed maps of the updated the real time data showing the direction, duration and pattern of disease transmission, and is playing a vital role in source reduction of vector breeding and disease transmission in advance[13,39].

The system would allow integration of data from any desktop, database, software or worksheet. It will facilitate updating of data from different nodes or centers. Nodal offices will be able to collate the data within no time. Mapping past and present situation of the chikungunya and dengue surveillance will enable the administrative and the healthcare system to control the wildfire-like spread of these diseases. It could be used to map site specifications of malaria, JE, filariasis, dengue, chikungunya and visceral Leishmaniasis epidemic transmission, vector breeding habitats, epidemiological details and the determinant variables. Perhaps, the vector borne diseases in association with climatic, landscape, and the environmental variables, and the information relevant to the vector abundance provides datum of guide lines to mapping of vertical and horizontal structure of the disease transmission risk and to assess the community of the people at risk disease infection in different parts of the country.

The web mapping GIS application programming interface (API), using ASP, Java, python, .net, Arc IMS, *etc*, could be used for converting the information between geographic geometric projection, the object information, and hyperlinks of spatial and non-spatial data. This technology could be essentially useful for the ongoing disease control operations and for decision making tool for chikungunya epidemics control measures in future at the national level. The GIS tool could allow the online database connectivity (ODBC) for updating the real time data including the health service resource availability and epidemiological information for quick and clear visualization of the disease with site specification from anywhere in India within no seconds of time interval, and hence, make use of the health resource service potentially, and choose appropriate control strategy for both vector and disease control and management in the country, successfully[13,39].

CONCLUSION

Climate, landscape and the environments determinant variables (dry weather followed by moderate to heavy rainfall during summer and monsoon season) are playing important role and has influence on the epidemic transmission across the country. The application of remote sensing and GIS is potentially useful for stratification of transmission risk areas, and perhaps, useful for epidemic control and management. Perhaps, the system would allow integration of data from any desktop, database software or worksheet. It will facilitate updating of data from different nodes or centers. Nodal offices will be able to collate the data within no time. Mapping past and present situation of the chikungunya and dengue surveillance will enable the administrative and the healthcare system to control the wildfire-like spread of these diseases. It could be used for converting the information between geographic geometric projection and the object information, and hyperlinks of spatial and non-spatial data. The integrated remote sensing and GPS under the GIS umbrella, and the expert technology could be essentially useful for the ongoing intensive disease control operations across the country, allowing to choose the appropriate measures for dengue and chikungunya epidemics control and management. It further, provides the information to programmers to implement measures to hold up shifting of epidemic transmission in the newer areas, active confiscate measures to tackle the present situation and provide datum of visual guidelines to management in future at the national level. The GIS tool could facilitate the online database connectivity (ODBC) to update the real time data including the health service resource availability, and mapping the epidemiological information for quick and clear visualization of the disease with site specification from anywhere in the country within no seconds of time interval, and to update both horizontal and vertical magnitude of spatial movements and of periodical shifting across the country, as well in the world.

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