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The integrated remote sensing and GIS for mapping of potential vector breeding habitats, and the Internet GIS surveillance for epidemic transmission control, and management

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Abstract
Background: Indian sub-continent has not only wealthy landscapes environment to support huge population, but also has big challenging problems of vector borne disease epidemics across the country. India has become host for all kinds of virus of malaria, dengue, chikungunya, and JE, and also endemic host for filariasis parasites. The integrated hybrid techniques of remote sensing, GPS, and GIS are used to map the spatial variation of the vector biodiversity, vector abundance, and the active infection state of vector borne disease transmission, and surveillance towards the epidemic control and management.
Materials and Methods: The Indian IRS satellite data was used to mapping the use/ land cover of metropolitan study area, and was used to mapping of Malaria and JE Vector Mosquito Breeding Habitats. The mosquito potential breeding surface of malaria, dengue, chikungunya, JE and filariasis was calculated for the each ward and which was mapped with graduated colors. The Arc View 3.2, Arc View Spatial analysis and Arc View image analyst, GIS software used to create a systematic grid sampling method for conducting the reconnaissance survey and mapping mosquito breeding surface maps. GARMIN 12XL GPS was used to collect the mosquito reconnaissance survey for mosquito vectors in the city.
Result and Discussion: The total potential breeding surfaces of malaria, filariasis and JE were measured in square kilo meters (sq.km), the habitats positive for dengue and chikungunya vector mosquitoes breeding was calculated in percentage for mapping and the ward wise cumulative value of mosquitoes potential breeding was also estimated for mapping the areas vulnerable for mosquito problems and the extensive of vector mosquito borne disease transmissions. The mosquito's problem was highly associated with population density and the number of houses, households, and perhaps, it was spatially good agreement with ground water tables. A systematic grid sampling was applied to conduct a rapid survey for mapping *Aedes* species mosquitogenic condition in the urban areas and the site coordinates of houses information with breeding habitats positive in the grid sectors was collected using GPS. The virtual GPS under the GIS umbrella was used to conduct a rapid survey with 0.5km distance interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the sectors positives for dengue and chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) breeding habitats (water storage vessels, plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, etc.,) with accurate site specifications, and the mean value of positive habitats was analyzed by quintiles method for mapping the ground situation in the urban settlements.
Conclusion: It is concluded that remote sensing, GPS, and GIS are effectively useful to identify, delineate and mapping of vector mosquitoes potential breeding surface areas and studying the mosquitogenic conditions in the urban agglomeration, and used to control and management of the vector borne disease transmission, perhaps, may also be GIS based surveillance is the best solution for epidemic control and management of the present situation vector borne disease transmission; especially, malaria and dengue epidemic in the country.

Keywords: mosquito breeding habitats, remote sensing and GIS, land use and land cover, vector surveillance

1. Introduction
India has wealthy landscape environment to support the sea change huge population. On the other hand, it has a range of determinant variables fueled for mosquito breeding and vector borne disease epidemics across the country. The mosquito nuisance and the epidemics of mosquito borne disease have been major challenging problems and becomes serious threats to the public health, especially in the past developing cities [1-3, 12, 14-16]. India has become host for all kinds of virus of malaria, dengue, chikungunya, and JE, and also endemic host for filariasis parasites [13].

GIS was used to mapping the environmental determinants of the vector abundance [2, 6], spatial analysis for illuminating the disease transmission, and priority of the areas for mosquito control activities and management [4, 5, 7-14]. It has been major impediment problems for economic outcomes of the country, including the burden of disability adjusted life years (DALY), the social inequalities, physical suffering, and economic loss of the individuals, the yearly expenditure towards the treatment, control and management of the present situation. The present study was designed for utilizing remote sensing and GIS technology for mapping mosquitogenic condition and to achieve the meaningful map guideline for mosquito control in the metropolitan environment [1, 3, 6, 9, 14-16].

2. Rationale of the Study

The mosquito's nuisance becomes major problems in the metropolitan cities in India now days. The endemic situation of vector borne diseases (VBDs) and the sporadic of such diseases, viz; malaria, filariasis, JE, dengue and chikungunya have been most important challenging problems in the urban settlements now days in India [7-16]. The mosquito's nuisance becomes major problems in the metropolitan cities in India; especially city like Visakhapatnam Metropolitan, and it has been increasing day by days. The endemic situation of vector borne diseases (VBDs) and the sporadic of such diseases, known as, malaria, filariasis, JE, dengue and chikungunya have been most important challenging problems in the urban settlements [1, 2, 6, 7-9, 14]. The ward wise mosquito vector breeding surface habitats, and mapping the geographical distribution, vector density and vector abundance of *Anopheles* genus, *Culex* genus and *Aedes* genus vector mosquitoes respectively. Consequently, a significant study was made to make use of IRS indigenous satellite data to identify and mapping the potential surface areas of mosquito breeding habitats, mapping the and land use / land cover classes of metropolitan [7-9, 14-16]. The spatial analysis and mapping of ward wise mosquito breeding habitats for assessing the areas of mosquitogenic conditions for and preparing the priority maps for mosquito vector control [7-10, 14-16]. Thus, the result derived from the study was made clear that the application of remote sensing and GIS technology is reliable, accurate and useful in giving a meaningful spatial solution for the vector mosquitoes control, and thus, enable to vector borne disease transmission control in the urban environment [7-12, 14-16].

3. Aim and Objectives

1. To potential mapping of vector breeding habitats and assessing the vector abundance, using remote sensing and GIS
2. To apply systematic grid sampling procedure for reconnaissance survey for assessing the percentage of positive for dengue and chikungunya vector mosquito breeding habitats
3. To delineate the areas under vulnerable to the risk of epidemic transmission, and thus, priority for the areas and appropriate control strategy for mosquito vector control and management.

4. Materials and methods

Land use/ land cover image with 5m X 5m resolution of the Visakhapatnam metropolitan study area is obtained from a systematic value added hybrid colour composite image of the IRS PAN and LISS III with high spatial resolution of 1:25,000, and the Red and Infrared IRS WiFS Satellite Data is used for Mapping of Malaria and JE Vector Mosquito Breeding Habitats in the countryside environment using ERDAS Imagine (Remote Sensing image processing software). The Arc View 3.2, Arc View Spatial analysis and Arc View image analyst GIS was used for systematic grid sampling methods for conducting the reconnaissance survey and mapping mosquito breeding surface maps. GARMIN 12XL GPS was used to collect the mosquito reconnaissance survey for mosquito vectors in the city. The Visakhapatnam city digital map was prepared on 1:25,000. The mosquito potential breeding surface of malaria, dengue, chikungunya, JE and filariasis was calculated for the each ward and which was mapped with graduated colors. The random sampling ground truth study was conducted for reexamining and checking the mosquitogenic condition in different parts of the Visakhapatnam city, India (Table 1).

5. Study area

The Visakhapatnam metropolitan was selected as the case study which has well connected roads and railways with other parts of the country and is located in the eastern coast of India. The city has 50 wards. The total geographical area is 100sq.km. The total population of the city has about 1.7 million and the average population density of the city is 2658 per sq. km. The city has experienced with temperature between minimum 22 ^{0}C to maximum 34 ^{0}C. The city has received the annual average rainfall 955 mm. The geographical location of the city between 17^0 42' 56" N and 83^0 16' 42" E. The average elevation of the city has 16 feet MSL.

6. Study Design

The study was designed for utilizing the Global positioning Systems (GPS) under the GIS umbrella for conducting systematic reconnaissance survey with 1km interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the potential surface habitats positives for vector mosquito breeding, and hence, produce the map for priority for mosquito control measures in the metropolitan areas. The malaria vector mosquitoes (*Anopheles stephensi*) breeding surfaces (overhead tank, cement tank, sumps, canals, pools, lakes and streams), filariasis *Culex quinquefasciatus* breeding surfaces (drainages, ditches, cesspits, septic tanks, pools, etc,), dengue and chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) breeding habitats (water storage plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, etc.,) were assessed and calculated for mapping of potential breeding surface of mosquitoes in the city, which shows the mosquito abundance and severity of problems in the metropolitan areas (Table 1, Fig. 2, 3 and 4). The map overlay analysis was performed for spatial queries to identify the areas vulnerable to malaria, dengue and chikungunya epidemics and the area of having severe endemic problems of filariasis disease, and thus, proficient to produce the map to arrive ward wise priority for planning for appropriate control measures to barricade the mosquitoes breeding and to prevent the disease transmission [7-11, 14-16] in the urban agglomeration (Fig 6).

7. Geography of the Visakhapatnam city

Visakhapatnam city has the features of hill ranges, isolated hillocks, coastal stretch, Industrial areas, old city dense settlements, and the low lying marshy areas. The city is classified in to four major categories based on the land use /

land cover classes. (i) Coastal region with dense human settlements, (ii) Dense population in the foothill areas, (iii) Marshy areas / Industrial areas with low density population settlements (iv) semi-urban in the peripherals. The hill ranges are covered with thick vegetation and dense scrub and the altitude of the hill rage is 350m to 400m above MSL. The Simhachalam hill ranges is the northern boundary of the city. A number of streams flowing from the hills towards both side of southern and northern direction and which are jointing with Narava Gedda and Meghadri Gedda rivers respectively and both reached the sea form port and dry dock at the mouth of the river. There are few isolated hillocks found in the city boundary areas. The old city is located in between the Kailasagiri Hills (north) and Harbor (south) ward Nos.1-18. The urban settlements are stretched in between the Simhachalam hill ranges and the railway track running east to west parallel to the NH5 (Ward Nos. 35-42). Because of the heavy pressure on the settlements extension and the areal restriction, a new areal extent of human settlement is developed in the Mudasarlova stream valley in the northern side of Simhachalam hill ranges, which has the fan of good fertile agricultural land.

8. Visakhapatnam city land use / land cover settlement pattern

Dense human settlements with thick vegetation, parks, open grounds and road avenues are found in the ward Nos. 16, 17, 36 and 39. Visakhapatnam railway station is situated in the ward No.39. The east to west stretch of settlements is found in the ward Nos. 40, 41, 42, 45, 46, 47 and 48 which are located in the southern side of the Yarada hill rage extended from west to east and the shipyard is located in the ward No.50. The newly developed and the extension of human settlement in the ward Nos. 37, 43, 44, 47and 48 which are previously agricultural land and open scrub. The fishing hamlet is located in the ward No.23 where the reservoir and the parks are located northern side of Simhachalam hill ranges. The area of adjoining to the part of the harbor is oldest settlements found in the ward No.1. The Andhra University is situated and expanded to the ward No.19, 21 and 22. The industrial area is located in western and southern part of the city and most of the industrial area is lying in the ward No.49. The Naval dry dock, I.O.C, and the Coromandel fertilizer factory. The entire area is categorized and featured with mainly marshy and open scrub and the mangroves batch is found in the backwater river mouths (Fig. 1)

9. Result and Discussion

The total potential breeding surfaces of malaria, filariasis and JE were measured in square kilometers (sq.km), the habitats positive for dengue and chikungunya vector mosquitoes breeding was calculated in percentage for mapping (Fig 2, 3 and 4) and the ward wise cumulative value of mosquitoes potential breeding was also estimated for mapping the areas vulnerable for mosquito problems and the extensive of vector mosquito borne disease transmissions. The mosquito's problem was highly associated with population density and the number of houses, households, and perhaps, it was spatially good agreement with ground water tables (Fig 5). The number of wards have heavy mosquito problems, which includes 23, 26, 41, and 44, and followed by 21, 22, 24, 25, 28, 29, 30, 31, 32, and 45 and the remaining are relatively having less mosquito nuisance problems and the disease transmission, certainly, the problem was associated with the population and the households [1-4, 7-11, 14-16].

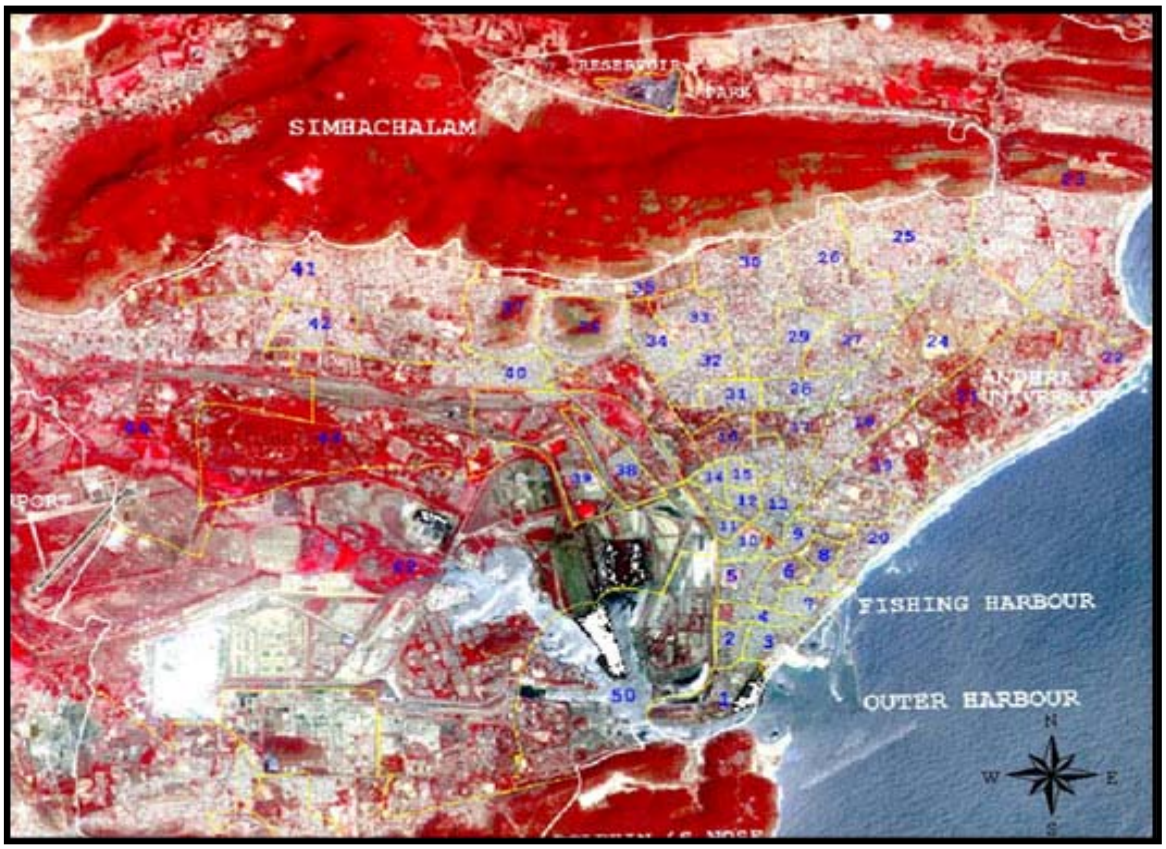

Fig 1: Land use/ land cover image of the study area with 5m X 5m resolution is obtained from a systematic value added hybrid colour composite image of the IRS PAN and LISS III with high spatial resolution of 1:25,000

Table.1: The ward wise mosquito breeding habitats positives for malaria, JE, dengue, chikungunya and Filariasis in the Visakhapatnam metropolitan city in India

Ward No.	No of over Head Tank	Cement tank	No. of Pools	No. of Drainage in the ward	No. of canals	*Anopheles* mosquito breeding (in sq. m)	*Culex* mosquito areas (in sq. m)	*Aedes* mosquito breeding habitats (+ve in%)	Total Population (2001)
1	28	38	1	52	0	299.00	124.00	3.14	12848
2	29	37	0	51	0	295.00	124.00	3.14	12375
3	59	93	0	60	0	454.00	105.60	3.12	12375
4	58	93	0	60	0	452.00	105.60	3.12	13330
5	37	47	0	55	0	310.00	88.80	3.25	12161
6	38	46	0	54	0	310.00	88.00	3.15	11874
7	25	51	0	44	0	161.00	16.80	6.24	21373
8	26	50	0	44	0	158.00	16.00	3.14	12480
9	58	137	2	50	0	482.00	96.00	4.32	14666
10	32	48	0	41	0	301.00	98.40	3.14	10632
11	31	48	0	41	0	301.00	97.60	3.25	12430
12	31	54	1	63	0	251.00	65.60	3.12	10384
13	57	137	1	50	0	473.00	96.80	3.53	13889
14	30	54	0	63	0	241.00	65.60	3.12	12034
15	49	62	0	38	0	215.00	10.40	4.25	14859
16	49	62	0	38	0	213.00	11.20	4.24	13742
17	363	85	2	72	0	1004.00	21.60	4.04	13065
18	363	86	2	73	1.00	1502.00	21.60	4.44	14350
19	437	99	2	66	0	1164.00	3.20	6.23	21796
20	61	165	12	48	1.00	977.00	39.20	4.72	14912
21	764	73	0	46	0	1696.00	73.60	5.32	15123
22	245	64	44	72	2.30	2001.00	61.60	3.92	13907
23	2531	915	10	1	1.60	9809.00	2385.60	4.52	15845
24	667	644	0	86	2.00	3965.00	259.20	8.41	22732
25	1407	244	0	93	0	4282.00	736.80	8.51	28394
26	1460	905	0	154	3.00	7999.00	893.60	9.32	29892
27	330	488	0	26	2.00	2562.00	96.00	9.32	29327
28	652	446	1	77	1.00	3251.00	228.00	8.22	25743
29	1206	302	0	47	2.00	4830.00	717.60	4.32	14496
30	702	144	0	73	4.00	4476.00	711.20	3.14	11716
31	561	558	0	99	0	2477.00	460.00	4.13	14570
32	548	147	0	84	2.00	3371.00	840.00	3.34	13949
33	433	36	0	93	0	1527.00	485.60	4.32	14586
34	48	24	0	37	2.00	1213.00	74.40	4.45	15284
35	49	24	0	37	2.00	1215.00	74.40	4.34	15081
36	23	71	0	125	0	126.00	7.20	3.14	5243
37	18	13	0	91	0	51.00	1.60	8.94	29517
38	90	18	0	42	1.00	755.00	45.60	4.45	14542
39	90	18	0	41	1.00	756.00	46.40	3.56	14482
40	126	54	0	59	0	501.00	156.00	3.54	11294
41	949	153	0	154	4.00	5793.00	1393.60	3.24	13357
42	463	87	0	93	3.00	3566.00	842.40	3.13	13665
43	125	54	0	59	9.00	4998.00	155.20	4.32	15873
44	1016	307	0	366	0	4790.00	1785.60	4.65	15900
45	96	112	0	155	2.00	1617.00	250.40	4.34	12569
46	79	67	0	68	1.00	777.00	41.60	4.53	15834
47	79	67	0	67	1.00	766.00	32.80	4.32	13021
48	17	23	0	73	1.00	562.00	4.00	7.67	17603
49	18	24	0	72	1.00	564.00	3.20	4.32	15210
50	0	0	0	0	0.00	0.00	0.00	5.46	15106

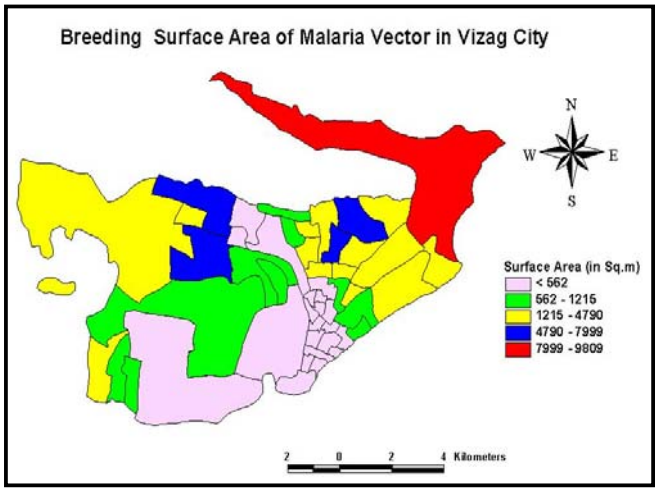

Fig 2: the ward wise breeding potential surface areas of malaria vector mosquitoes

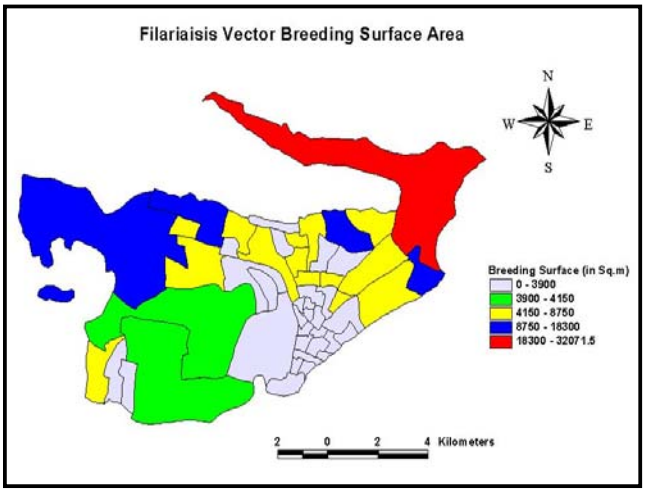

Fig 3: the ward wise breeding potential surface areas of filariasis vector mosquitoes

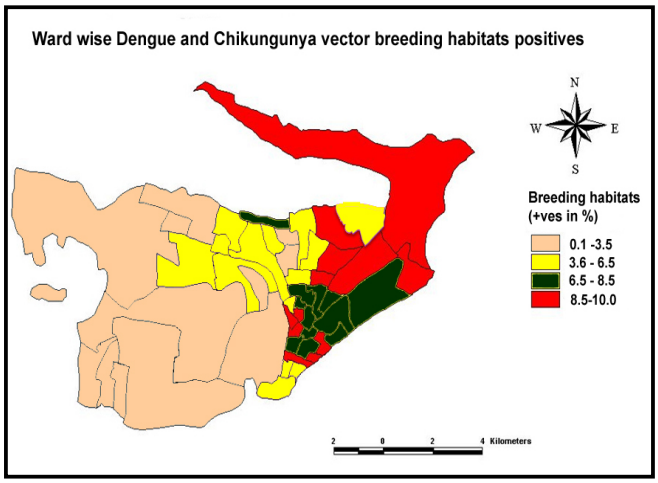

Fig 4: The ward wise breeding potential surface areas of dengue and chikungunya vector mosquitoes

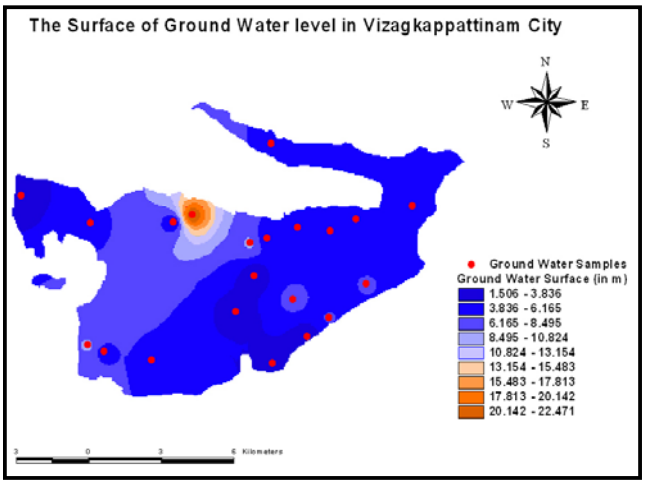

Fig 5: ground water table in the Visakhapatnam Metropolitan city

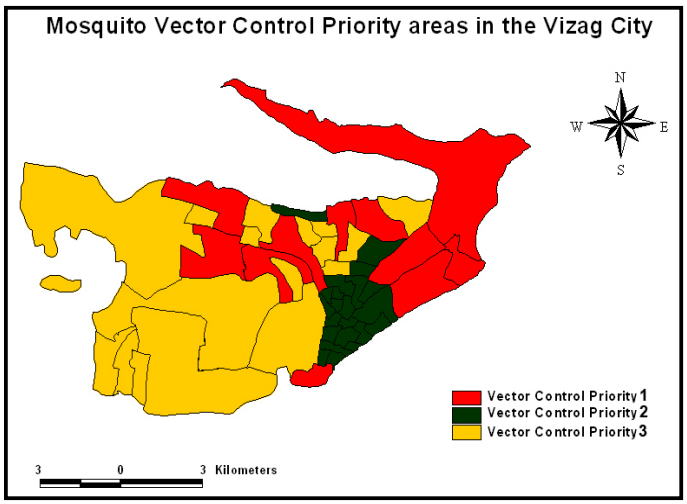

Fig 6: The priority map for planning for appropriate control measures to mosquitoes breeding and to prevent the disease epidemics in the city

10. GIS based vector surveillance and control in the urban agglomerations

The dengue and Chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) flight range between 200 meters – 400 meters, therefore, GIS was used to prepare a (500m X 500m) 0.5km grid map. A systematic grid sampling was applied to conduct a rapid survey for mapping *Aedes* species mosquitogenic condition in the urban areas and the site

coordinates of houses information with breeding habitats positive in the grid sectors was collected using GPS, and the mean value of positive habitats was analyzed by quintiles method for mapping the ground situation in the urban environment. The mosquito breeding habitats of dengue and chikungunya was mapped with graduated colors, using the quantile method. The mean value of breeding habitats was calculated and it was assigned to each grid cells for mapping the percentage of potential breeding habitats in the metropolitan area.

The virtual Global positioning Systems (GPS) was used to conduct a systematic reconnaissance survey with 0.5 km interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the grid sectors positives for dengue and chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) breeding habitats (water storage vessels, plastic and cement containers, tires, plastic cups, coconut shells, tree holes, flower vessels, fridge, stone grinder, etc.,) with accurate site specifications [1-9]. The map overlay analysis was performed for spatial queries to identify the areas vulnerable to dengue and chikungunya disease transmission, and thus, proficient to produce the map for given priority to choose right strategy and appropriate mosquito control measures to barricade the *Aedes* species mosquitoes breeding and to prevent the disease transmission in the urban agglomeration [1-9].

The ultra violet light adult mosquito trap has effective and efficient to collect the adult mosquitoes including the *An. stephensi*, *An. subpictus, Culex vishnui* groups, *Cx. quinquefasciatus, Ae. a*egypti and *Ae. Albopictus, and Armigeres subalbatus.* Since, the adult mosquito (malaria, JE vector mosquitoes) has maximum flight range of 2.5 km, and filariasis vector mosquito has flight range of < 1 km, and and dengue and chikungunya vector mosquitoes (*Aedes a*egypti and *Ae. Albopictus)* has maximum flight range of 600 meters the sites have been selected for setting up the UV light adult mosquito trap in the place of intersection of GIS based grids map with < 2.5 km distance interval, and the sites for fixing gravity adult mosquitoes trap with 0.5 km distance interval for collecting the *Aedes a*egypti and *Ae. albopictus* mosquitoes. The intensive and regular reconnaissance survey has to be conducted in 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. a*egypti and *Ae. albopictus)* and making awareness among the people to prevention measures help to control the disease epidemics. The source reduction of mosquito breding could be provided the safe environment and keep away from the vector mosquito borne disease transmission and for dengue epidemic control in the metropolitan cities in the country.

11. Web mapping GIS for dengue & chikungunya surveillance

The internet GIS provides the most up-to-date data source in the public domain and has the facility to customized embedded mapping of site specific locations, street mapping to the regional level using point, line, area symbols with high accuracy of map properties of shape, size and scale [4, 7-9]. The ArcGIS Java script API, ArcGIS Flex/Flash API, ArcGIS Silverlight API, ArcIMS API, ArcObjects API has the interface facilities of geo-coding references of the objects with online database connectivity or real time data. Web mapping GIS provides the information of case identity / attributes, locations, service route, buffering service coverage and the magnitudes of point, line and the area symbols of different features of thematic map layers. The applications of web mapping Python API could be used for mapping streets, house locations, 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 [4, 7-9, 11]. The web mapping Python API mainly used to customize embedded 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 layers of information for generating the information on prediction / forecasting the dengue outbreaks well in advance [4, 7, 11]. Therefore, the use of web mapping GIS using API must be enhanced and executed in the department of health research entomological research institutes / regional centers for updating the disease epidemiological and entomological information for dengue surveillance and disease control operation [4, 7, 11].

12. The internet health GIS

The application of web mapping GIS using API (application programming interface) has significant role and become essential tool in the dengue surveillance and public health information management for disease control at the national level [4, 7, 11]. The web mapping GIS API technology has been mushrooming globally and most importantly, the web mapping GIS for dengue surveillance which is needed to the public health monitoring in India [7, 11]. The web mapping GIS using API has been readily available to the each and every individual for browsing the information of various sectors, and it could be extended to the health sector for health information management from the public domain of health GIS websites so as enable to make use of the information to the disease control [4, 7, 11]. The web mapping GIS technology is not only assisting to updating and mapping the disease prevalence of dengue cases but, also becoming important in dengue surveillance and public health information management, perhaps, decision making tool for controlling the dengue epidemics as it has the national important. The web mapping API are becoming important, mainly the embedded 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 epidemics [4, 7, 11]. 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 frame work 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 and it could be implemented at the national level [7, 11].

The application of web mapping GIS technology using API (ASP, .Net, html, java, python, CSS, PHP, Arc IMS, Geo ext, C, C++, Visual Basic, Arc objects) for customized embedded mapping is becoming essential and important for user friendly techniques for browsing, spatial structured querying, thematic mapping and table sorting and drawing the information of various aspects including the dengue prevalence, the disease epidemiological and the entomological information [7, 11]. GIS based master plan for mosquito control was found to be not only very low cost, but also rapid methods and accuracy [4, 7, 11], which need to be used in most of the metropolitan cities in India. The sea change increasing population and the unplanned urban developments are creating conducing environment for fueling to huge amount of vector mosquito breeding in the cities in India [7, 11, 14-16].

13. Health Information Management

The user friendly internet GIS using API for embedded mapping of past and present situation of the disease surveillance of dengue prevalence (dengue and dengue hemorrhagic fever), controlling measures; including the vector breeding source reduction measures, ongoing disease control programme, and it has been identified to useful for prediction of the location of disease transmission [7-11]. The web mapping GIS has the interface facilities for browsing, a spatially structured querying, thematic mapping and table sorting and drawing information (demographic features, disease prevalence, disease risk factors and the ongoing disease control operations) of each district in India. Besides the visualization of site characterization, this system allows integration of data from any desktop database software or worksheet to the head office server on ODBC facility [4, 7, 11]. It has facilities to update the data from different nodes or centres and pooled in one place as the nodal office (M Palaniyandi, *et al*., 2014) [7]. The web mapping technique has to be implemented once the entire customized web mapping GIS API to be completed and the critical level of different components of required information to be defined in the core server system at the each regional office of the GIS centre (Fig.7), before it has to be taken into the real life situation and making a decision support tool for disease control operation by means of dengue vector breeding source reduction.

Case history of the occurrences of the dengue cases and the detailed epidemiological information relevant to patient's age, sex, site specification, name of the disease, viciousness of the disease, nature of the disease (migrant or indigenous), occupation, geographical location, reiterate of the disease/ number of times, season and duration of the disease occurrences are carefully mapped with API in web mapping GIS for updating the disease information [4, 7, 11]. In collaboration with public health departments of state governments, the data containing the epidemiological information of dengue epidemics cases, the entomological parameters and the conducing environmental parameters of dengue vector propagations and disease transmission has to be entered in the geo-database engine for web mapping GIS application programming interface (API) for developing a simulation model for prediction of dengue outbreaks at least 2 weeks in advance [4, 7, 11]. The layers of information derived from the web mapping GIS API, provides the datum of knowledge for analyzing the nature, infectious state and situation of the diseases at a particular time point, this information is useful for decision making and provide the guidelines for both vector and disease control measures well in advance (Fig.7).

The virtual GPS under the GIS umbrella was used to conduct a rapid survey with 0.5km distance interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the sectors positives for dengue and chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) breeding habitats (water storage vessels, plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, etc.,) with accurate site specifications. To beyond the all these problems, the available GIS technique was found useful and has provided the datum of useful guidelines for giving priority with site specification of the areas to fixing the adult *Aedes* mosquitoes trap with less than one km distance interval for *Aedes* species adult mosquito collection, and making awareness among the people for source reduction of mosquito breeding to control the present situation and management of the dengue epidemics in the Pondicherry urban areas. In the urban situation, the GPS and GIS based site selection was made to fixing the adult *Aedes* mosquitoes trap with one km distance interval for *Aedes* species adult mosquito collection, and the data was updated for web mapping and dengue health information management for taking prevention measures to dengue epidemic control [7, 9]. It was concluded that the GIS based surveillance is the best solution for epidemic control and disease management of the present situation of dengue epidemic in the country [7-11].

14. The web mapping health GIS in India

The present system is lacking with controlling the disease epidemics, especially dengue, JE and malaria. The present situation needs a plan for control operation in place in advance where the problem of vectors and the occurrence of dengue epidemics in India. Therefore, the ICMR perhaps, strengthen the GIS laboratory in each institute of ICMR with experienced GIS specialist / GIS experts for web mapping GIS using API customized embedded mapping of disease prevalence, entomological parameters, sources of vector breeding habitats, epidemiological information, environmental and climatic risk factors associated with disease epidemics [7-9]. The virtual global positioning systems (GPS) instruments are used for collecting the information on the site specifications of breeding sources of dengue vectors and dengue hemorrhagic fever (DHF) victims nearer to the host availability with real time, reliable and high accuracy. This information must be updated every 2 weeks/ fortnight of the every month and updating the field data in the web mapping GIS [4, 7, 11]. The web mapping Python API mainly used to customize embedded mapping of GPS based information of dengue vector breeding habitats, tiled images of remote sensing data, converting information between geographic site specifications of the information relevant to dengue vector breeding sources / habitats with the geographic links of coordinate of geometric projection [4, 7, 11]. Thus, the current situations the disease problems could be analyzed and given a solution for preventative measure measures and to take appropriate control strategy to prevent the dengue outbreaks, and hence, forecasting the site specification of the horizontal and vertical magnitudes of dengue transmission in India. The highlight of web mapping customized API was recommended for dengue and chikungunya epidemic surveillance and control [7, 11].

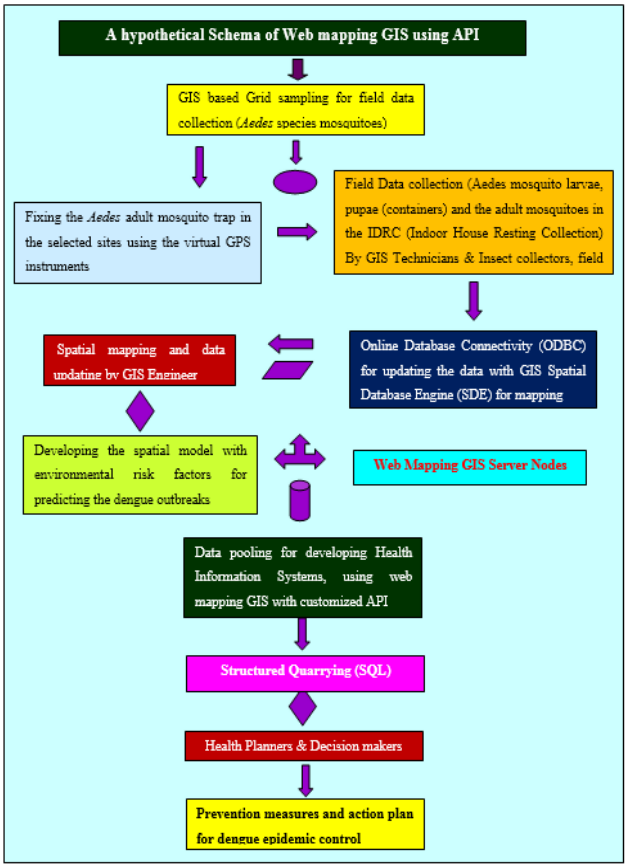

Fig 7: The internet GIS mapping for prediction and prevention of dengue & chikungunya epidemics

15. Suggestion and recommendation to vector control and management

The increase of population, urban agglomerations, and the allied developmental activities are creating conducing environment for fueling to heavy amount of vector mosquito breeding in the cities in India. To beyond the all these problems, the available low cost remote sensing, user friendly GPS and GIS technique are found useful and has provided the datum of useful guidelines for mosquito breeding habitat source reduction to control the present situation and management of the mosquito nuisance in the urban areas. The intensive and regular reconnaissance survey has to be conducted in 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. a*egypti and *Ae. albopictus)* and making awareness among the people to prevention measures help to control the disease epidemics. The source reduction of mosquito breeding could be provided the safe environment and keep away from the vector mosquito borne disease transmission in the metropolitan cities in the country. The utility of remote sensing and GIS has been wide spread application in India to update the design of control methods and introduce required control efforts against vector mosquitoes where the increase of vectors breeding new sites in metropolitan.

The virtual GPS under the GIS umbrella was used to conduct a rapid survey with 0.5km distance interval (grid sampling procedures) for assessing the mosquitogenic condition and for mapping the sectors positives for dengue and chikungunya vector mosquitoes (*Aedes aegypti* or *Ae. albopictus*) breeding habitats (water storage vessels, plastic and cement containers, tires, plastic cups, coconut cells, tree holes, flower vessels, fridge, stone grinder, etc.,) with accurate site specifications. To beyond the all these problems, the available GIS technique was found useful and has provided the datum of useful guidelines for giving priority with site specification of the areas to fixing the adult *Aedes* mosquitoes trap with less than one km distance interval for Aedes species adult mosquito collection, and making awareness among the people for source reduction of mosquito breeding to control the present situation and management of the dengue epidemics in the Pondicherry urban areas. In the urban situation, the GPS and GIS based site selection was made to fixing the adult *Aedes* mosquitoes trap with one km distance interval for *Aedes* species adult mosquito collection, and the data was updated for web mapping and dengue health information management for taking prevention measures to dengue epidemic control.

16. Conclusion

The integrated hybrid techniques of remote sensing, GPS, and GIS are used to rapid epidemiological mapping of the relevant information to understanding the spatial variation of the vector biodiversity, vector abundance, and the active infection state of vector borne disease transmission, disease surveillance, and perhaps, provide the disease epidemiological information along with geo-coordinates of site specification combined with multispectral satellite data of land use / land cover. It is concluded that remote sensing, GPS, and GIS are effectively useful to detection, identification, delineate and mapping of vector mosquitoes potential breeding surface areas and studying the mosquitogenic conditions in the urban agglomeration, and also provides meaningful spatial solutions to control and management of the vector borne disease transmission, perhaps, may also be GIS based surveillance is the best solution for epidemic control and management of the present situation of dengue epidemic in the country.

17. References

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