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Mapping land use/land cover and malaria mosquitogenic condition, and linking with epidemic transmission in the urban settlements using remote sensing and GIS

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Abstract
Mosquito nuisance and the urban malaria become very big problems in the urban settlements in India. A significant study was made to mapping the potential surface areas of mosquito breeding habitats, mosquito breeding surface areas, ground water level, and land use / land cover classes, and linking with ward wise malaria cases. The indigenous satellite data of value added hybrid colour composite imagery of IRS 1D PAN and LISS III was used for preparing land use / land cover map. The Arc View spatial analysis and image analyst GIS software was used for mapping and overlay analysis. Performing the spatial analysis enabled for reexamining mosquito breeding habitats, and assessing the mosquito breeding surface areas for mosquito control in the city on priority basis. Thus, the result was made clear that the application of remote sensing and GIS is sensible and feasible to malaria epidemic control in the urban environment.

Keywords: Remote sensing and GIS, spatial analysis, land use / land cover, urban malaria, mosquito breeding habitats, vector control and management

1. Introduction
The urban agglomerations, urban sprawl, and the allied urban growths are the witness of constructive developments of the country. However, the environmental concern, the mosquito nuisance and the urban malaria become big challenging problem in India [13, 14]. The annual prevalence of malaria is estimated 75 million and the death rate of 8 lakhs during the year 1953, and it is gradually reduced to 1.04 million cases and a death rate is 890 in the year 2006. Though a significant result was obtained by the national malaria programs, the urban malaria is a challenging problem in India [1, 3, 10-16, 18]. The public health departments are adopting various vector control measures and applying appropriate disease strategy for implementing the different way of control measures for controlling both the vector control and the vector borne diseases especially malaria in the urban areas in all over the country [10-16]. The conventional way of assessing the malaria vector mosquito problems in an urban area at a particular time point is not possible because, it is time consuming, imprecise, huge expenditure, and is employing enormous manpower [1-3, 18]. Currently, the public health programmers and the environmental scientists are choosing the remote sensing, GIS and GPS technology for delineating mosquitogenic conditions and linking the urban land use / land cover variables with mosquito abundance and the malarias, [1-7, 10-13, 20-22] examine the close association between the environmental changes[1-4,8,9,12] and the malaria prevalence [7-8, 10-14] and the influence of climate variables and malaria epidemics [4-7, 10-13, 15, 16-18, 25, 26]. The applied remote sensing and geographical information systems has the significant role in ready had user friendly meaningful solution to the programmers for the malaria control [1, 3, 9, 15, 18]. in the replacement of conventional way of spatial assessment of problem of *Plasmodium falciparum* and *Plasmodium vivax* malaria in the metropolitan city. Remote sensing and GIS are playing important role in detection, identification, mapping and classification of mosquito larval habitats [1-5, 7-9, 12, 14-16, 20-22]. And also has the significant role in delineating and mapping the mosquitogenic conditions in the urban environment, [6, 7, 10-16, 20-22]. mapping the environmental variables [16-19, 26, 27] land use / land cover classes, [5, 10, 12-16, 20-22], mosquito breeding habitats, [7, 9, 12-16, 25] breeding surfaces areas, [7, 8, 25] mapping the ground water level, ward wise settlement analysis, and mapping the ward wise *Plasmodium falciparum* and *Plasmodium vivax* malaria

cases. The application of remote sensing, GIS and GPS are not only used for identifying, delineating and mapping the mosquitogenic conditions, [1-3, 5, 12-16, 23-25] but also applied to the study of spatial relationship between the occurrence of malaria cases and the environmental variables [1, 2, 4-7, 12, 19, 20-22, 25-27].

The present study was undertaken during the period of 2003-2005, and the objectives are four fold, viz., to study ward wise mosquitogenic conditions in the Vizagkapattinam city, to analyze the spatial relationship between the potential breeding surface of the malaria mosquito and ward wise malaria cases, to study the spatial relationship / spatial link between the land use/ land cover categories of satellite data, mosquitogenic condition, and the malaria epidemic cases, and finally, GIS based decision to finding the areas are vulnerable to malaria mosquito, and hence, appropriate control measures in the given areas on the basis of priorities.

2. Study area

Vizagkapattinam is the second largest most important industrial and port city of Andhra Pradesh state which is located in the eastern coast of India and it is well connected by roads and railways with other parts of the country. The city corporation is divided into 50 numbers of wards and which are numbering from 1 to 50 (Fig.1). The total geographical area is 100sq.km. The ward No.15 has the lowest geographical area of 13.85 Ha, and the ward No. 49 has highest geographical area of 1946.87 Ha. The total population of the city is 1.3 million (approximately) and the average population density of the city is 2658 per sq. km. The city is experienced with 22 ^{0}C minimum temperature and 34 ^{0}C maximum temperature. The city is receiving rainfall by both southwest monsoon and northeast monsoon and it receives the annual average rainfall 955 mm. The geographical location of the city is between 17^0 42' 56" N and 83^0 16' 42" E. The average elevation of the city area is 16 feet Mean Sea Level (MSL).

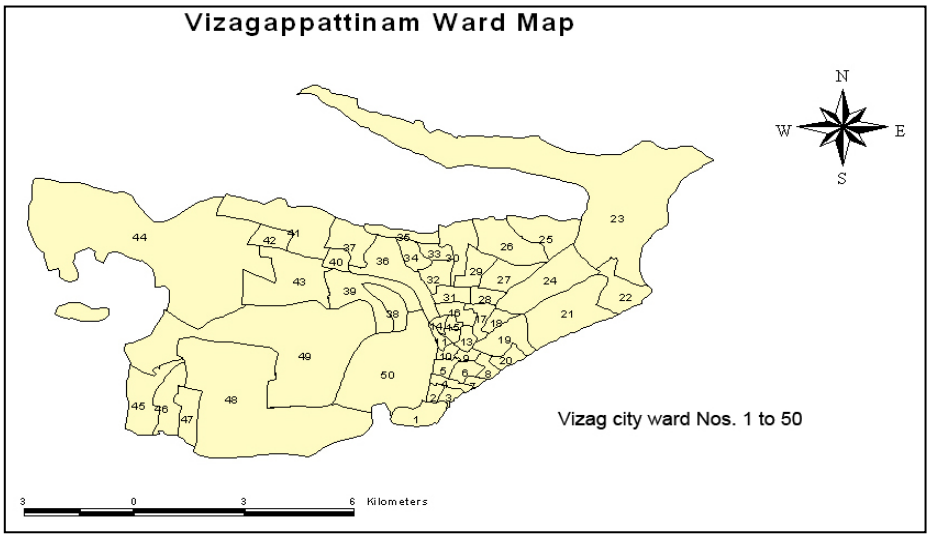

Fig 1: Study area of Vizagkapattinam ward map showing ward Nos. 1 - 50

3. Materials and Methods

A digital map of Vizagkapattinam city ward boundary was prepared on 1:25,000 scale using Arc View 3.2, Arc View Spatial analysis and Arc View image analyst GIS software and the ward number is indexed. The malaria cases of both *Plasmodium vivax* and *Plasmodium falciparum* are collected from the department of entomological survey, Vizagkapattinam city corporation, Andhra Pradesh. The database of ward wise *Plasmodium vivax* and *Plasmodium falciparum* malaria cases are developed and were imported to the GIS platform for digital mapping. Malaria mosquito potential breeding surface area was calculated for the each ward and which was mapped with graduated colors. GARMIN 12XL GPS intrument was used for the collection of water level sample points for mapping ground water level. The random sampling procedure was applied to the ground water samples and 21 samples of both winter and summer season were collected from all the 50 wards and which were mapped on the ward map 1: 25,000 large scale. The India remote sensing satellite data of IRS 1D PAN (5m spatial resolution) and LISS III data (23.5m resolution) is used for digital image processing of the land use/ land cover classification. A derived 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 classification of the merged product of the IRS PAN and LISS III was carried with high spatial resolution of 1:25,000 map scales. The land use land cover areas were calculated and the characteristic of the image was analyzed with the mosquitogenic conditions and the malaria cases. Detailed ground truth / field verification was carried out using GARMIN 12XL GPS for reexamining, checking, land use/ land cover categories and the interpolation of water level with mosquitogenic condition and malaria cases in different time points (Table.1).

4. Results and Discussion

The present study is designed to addressing the malaria mosquito problems and potential malaria mosquito breeding surface areas including the open wells; over head water tank, pools or tanks, reservoirs or lakes, rivers and streams, canals and which were carefully registered. The total surface areas of each land marks were correctly calculated and the data was attached to the ward base map of the Vizagkapattinam city. A systematic digital mapping of each variable was digitally mapped and it was superimposed with ward wise malaria cases both P.vivax and P. *falciparum.* A spatial topology was made for ascertaining the spatial relationship between the malaria cases and the environmental variables. It was observed that the disease patterns have a spatial autocorrelation and a close association with the urban environmental sanitation, water supply, waste disposal, housing patterns, housing density, mosquitogenic condition, and urban land use / land cover classes of remote sensing images (Fig.2).

Vizagkapattinam 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 into four major categories based on the land use / land cover classes. (i) The coastal region has 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 scientific approach of the spatial analysis of superimposing the thematic information by importing the layers of maps, using the GIS software, the classification of the areas to ward wise priority for implementing the malaria mosquito control program in the city has significant result.

Fig 2: 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

4.1 Geography of the Vizagkapattinam city

Vizagkapattinam 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 into four major categories based on the land use / land cover classes. (i) The 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 the both side of southern and northern direction and which are jointing with Narava Gedda and Mehadri 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 is 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.

Table 1: Ward wise mosquito breeding potential surface areas, *Plasmodium vivax*, and *Plasmodium falciparum* and the total malaria cases

Ward Nos.	No. of open wells	Areas (in sq. m)	No. of Over Head Tank	Cement tank	No. of Pools	No. of Drainages in the ward	No. of canals	Malaria vector breeding areas (in sq. m)	Malaria *Plasmodium Vivax*	Malaria *Plasmodium falciparum*	Total Cases	Total Population (2001)
1	155	124.00	28	38	1	52	0	299.00	30.00	2.00	32.00	12848
2	155	124.00	29	37	0	51	0	295.00	74.00	5.00	79.00	12375
3	132	105.60	59	93	0	60	0	454.00	69.00	5.00	74.00	12375
4	132	105.60	58	93	0	60	0	452.00	153.00	9.00	162.00	13330
5	111	88.80	37	47	0	55	0	310.00	119.00	1.00	120.00	12161
6	110	88.00	38	46	0	54	0	310.00	141.00	11.00	152.00	11874
7	21	16.80	25	51	0	44	0	161.00	383.00	39.00	422.00	21373
8	20	16.00	26	50	0	44	0	158.00	249.00	17.00	266.00	12480
9	120	96.00	58	137	2	50	0	482.00	122.00	6.00	128.00	14666
10	123	98.40	32	48	0	41	0	301.00	355.00	11.00	366.00	10632
11	122	97.60	31	48	0	41	0	301.00	177.00	7.00	184.00	12430
12	82	65.60	31	54	1	63	0	251.00	150.00	5.00	155.00	10384
13	121	96.80	57	137	1	50	0	473.00	129.00	11.00	140.00	13889
14	82	65.60	30	54	0	63	0	241.00	58.00	4.00	62.00	12034
15	13	10.40	49	62	0	38	0	215.00	84.00	7.00	91.00	14859
16	14	11.20	49	62	0	38	0	213.00	78.00	3.00	81.00	13742
17	27	21.60	363	85	2	72	0	1004.00	117.00	3.00	120.00	13065
18	27	21.60	363	86	2	73	1.00	1502.00	135.00	7.00	142.00	14350
19	4	3.20	437	99	2	66	0	1164.00	89.00	6.00	95.00	21796
20	49	39.20	61	165	12	48	1.00	977.00	133.00	8.00	141.00	14912
21	92	73.60	764	73	0	46	0	1696.00	108.00	6.00	114.00	15123
22	77	61.60	245	64	44	72	2.30	2001.00	150.00	5.00	155.00	13907
23	2982	2385.60	2531	915	10	1	1.60	9809.00	226.00	23.00	249.00	15845
24	324	259.20	667	644	0	86	2.00	3965.00	408.00	63.00	471.00	22732
25	921	736.80	1407	244	0	93	0	4282.00	70.00	9.00	79.00	28394
26	1117	893.60	1460	905	0	154	3.00	7999.00	276.00	23.00	299.00	29892
27	120	96.00	330	488	0	26	2.00	2562.00	441.00	61.00	502.00	29327
28	285	228.00	652	446	1	77	1.00	3251.00	207.00	19.00	226.00	25743
29	897	717.60	1206	302	0	47	2.00	4830.00	64.00	8.00	72.00	14496
30	889	711.20	702	144	0	73	4.00	4476.00	49.00	2.00	51.00	11716
31	575	460.00	561	558	0	99	0	2477.00	39.00	2.00	41.00	14570
32	1050	840.00	548	147	0	84	2.00	3371.00	22.00	0.00	22.00	13949
33	607	485.60	433	36	0	93	0	1527.00	19.00	1.00	20.00	14586
34	93	74.40	48	24	0	37	2.00	1213.00	67.00	8.00	75.00	15284

35	93	74.40	49	24	0	37	2.00	1215.00	71.00	13.00	84.00	15081
36	9	7.20	23	71	0	125	0	126.00	67.00	7.00	74.00	5243
37	2	1.60	18	13	0	91	0	51.00	55.00	4.00	59.00	29517
38	57	45.60	90	18	0	42	1.00	755.00	24.00	1.00	25.00	14542
39	58	46.40	90	18	0	41	1.00	756.00	48.00	2.00	50.00	14482
40	195	156.00	126	54	0	59	0	501.00	34.00	0.00	34.00	11294
41	1742	1393.60	949	153	0	154	4.00	5793.00	26.00	1.00	27.00	13357
42	1053	842.40	463	87	0	93	3.00	3566.00	16.00	1.00	17.00	13665
43	194	155.20	125	54	0	59	9.00	4998.00	28.00	1.00	29.00	15873
44	2232	1785.60	1016	307	0	366	0	4790.00	5.00	0.00	5.00	15900
45	313	250.40	96	112	0	155	2.00	1617.00	5.00	0.00	5.00	12569
46	52	41.60	79	67	0	68	1.00	777.00	1.00	1.00	2.00	15834
47	41	32.80	79	67	0	67	1.00	766.00	1.00	0.00	1.00	13021
48	5	4.00	17	23	0	73	1.00	562.00	1.00	0.00	1.00	17603
49	4	3.20	18	24	0	72	1.00	564.00	0.00	0.00	0.00	15210
50	0	0.00	0	0	0	0	0.00	0.00	6.00	3.00	9.00	15106

Table 2: Ground Water samples for creating water surface

Ward Nos.	Water Level 1 (in Meters)	Water Level 2 (in Meters)	Average Water level (in meters)
1	3.40	3.08	3.24
7	2.10	1.90	2.00
12	7.53	7.63	7.58
20	7.00	6.35	6.68
21	7.00	6.35	6.68
23	5.50	4.65	5.08
23	5.00	5.43	5.22
25	4.65	4.80	4.73
26	4.30	4.80	4.55
30	4.90	4.90	4.90
34	4.40	4.40	4.40
36	9.40	9.10	9.25
38	1.55	1.50	1.53
41	22.50	22.50	22.50
42	4.40	4.15	4.28
44	4.45	5.60	5.03
44	3.30	1.92	2.61
45	7.75	8.80	8.28
46	5.75	5.60	5.68
48	5.10	5.80	5.45
50	2.50	2.30	2.40

4.2 Vizagkapattinam 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. Vizagkapattinam railway station is located 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 ship yard is located in the ward No.50. The newly developed and the extension of human settlement are found 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 Coromandal fertilizer factory are located in the area. The entire area is categorized and featured with mainly marshy and open scrub and the mangroves batch is found in the backwater river mouths.

4.3 Malaria mosquito breeding potential surface areas

Mosquito breeding surface areas are calculated and classified into four groups for digital mapping. The mosquito potential breeding surface areas are the (i) ward No.23 is high potential for mosquito breeding and followed by the (ii) ward Nos. 26, 29, 41 and 43 are the next highest potential breeding surface areas and (iii) the ward nos. 18, 21, 22, 24, 25, 27, 30, 33, 32, 42, 44, and 45 are the potentially moderate for mosquito breeding habitats and the remaining (iv) ward Nos. 1-17, 19, 20, 28, 31, 34- 40, 46-50 wards are low potential surface areas for malaria mosquito breeding (Fig.3)

4.4 Ground Water level

Ground water level samples were collected for the monsoon (October) for the mapping the ground water level. Because of the problem of malaria transmission was persisting mainly during the monsoon season. Totally, the 21 number of sample sites was randomly selected for ground water level and 2 samples from sites were collected (Table. 2). GARMIN 12 XL handheld GPS instrument was used for registering the coordinates of the each sample site. The average value of 2 water sample of the each sampling sites were collected for ground water level calculation and which were imported into the ArcView Spatial Analyst and ArcView 3D analyst GIS platform for mapping the ground water surface levels and these point values and which was interpolated for mapping contours of water level and created ground water surface by spatial analysis of inverted distance weighted (IDW) methods using the nearest neighborhood analysis of 12 samples with weighted value of 2 for each sample sites for creating the contour interval of 2metres contours of ground water surface levels of the entire city (Fig.4).

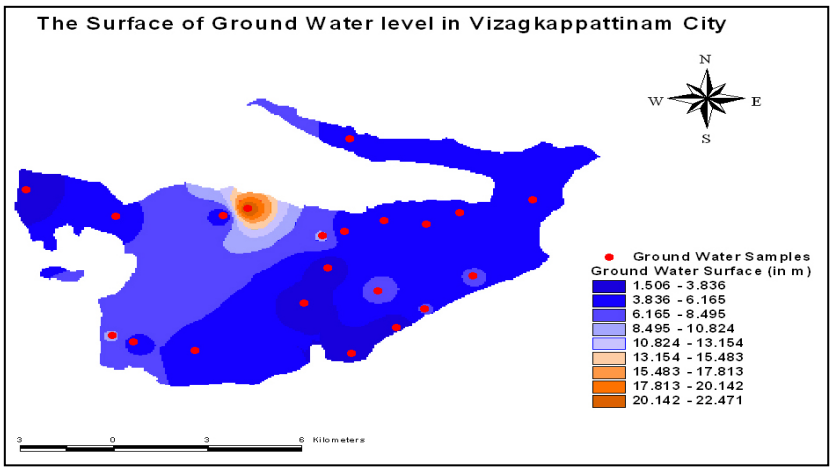

Fig 3: Malaria Vector Mosquito potential breeding surface areas

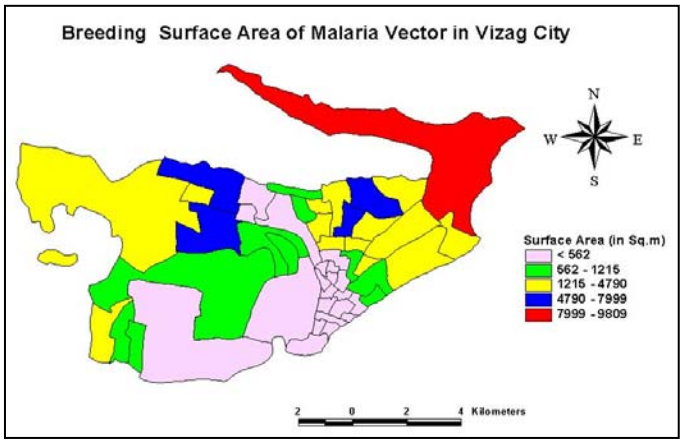

Fig 4: Ground water level and the contours of ground water level (in m)

4.5 Malaria *Plasmodium vivax* and *Plasmodium falciparum* cases in the city

The environmental sanitation in the city corporation and maintains the regularity waste disposal are good. The corporation maintains good records of housing, water supply, environmental sanitation, waste disposal, malaria mosquito entomological data, and malaria cases. However, the severity of malaria endemic in the city is problematic and uncontrolled and the malaria situation in the city is influenced by the complex of many factors. The vizagkapattinam city housing pattern is irregular and congested. The combined influence of mosquito breeding surface areas, waterlogged areas, pools, canals, river and streams, cement tank, over head tank, high ground water surface level, etc., are fueled to the increase of malaria cases (Malaria *Plasmodium vivax* (Fig.5a) and *Plasmodium falciparum* (Fig.5b) cases.

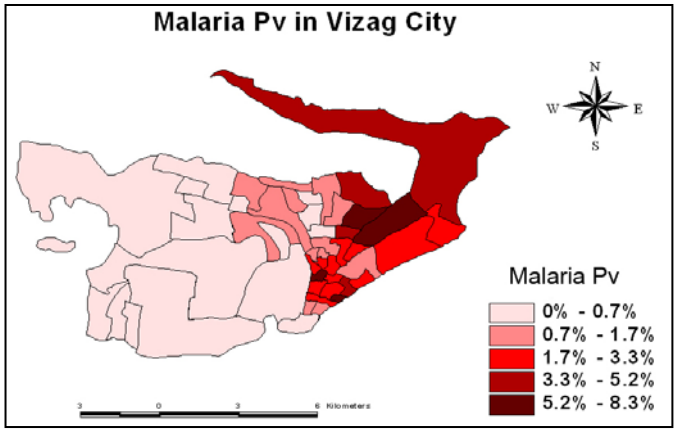

Fig 5a: Malaria *Plasmodium vivax* cases in Vizag city

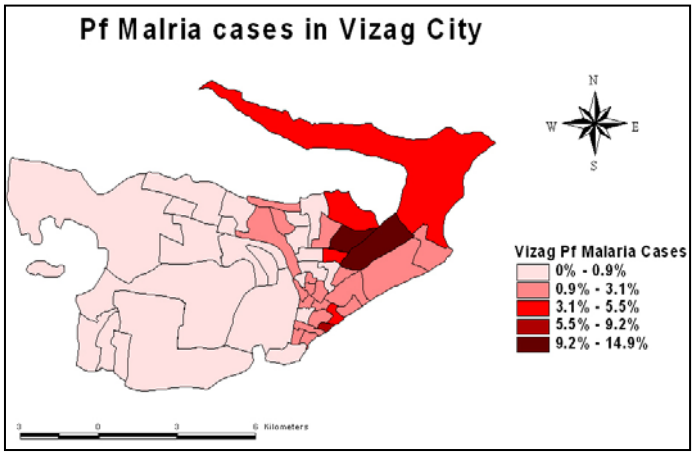

Fig 5b: Malaria *Plasmodium falciparum* cases in Vizag city

4.6 Ward wise Total Malaria Cases

The ward wise total malaria cases of both *Plasmodium vivax* and *Plasmodium faciparum* were mapped. The malaria problem severity shown in the map and the area under the problem of seriousness was clearly addressed through the critical analysis and it was clearly illustrated at a glance. As the result, the prevalence of malaria endemic problem experienced in the ward Nos. 4, 7, 8, 11, 14, 22- 28, and followed by the malaria problems in the ward Nos. 5, 9, 10, 13, 16 - 21, and 35. Malaria moderately problematic areas are ward Nos. 1, 2, 3, 29, 30, 31, 34, 36, 37, 39, 40, and 43. The remaining wards Nos. 6, 12, 15, 32, 33, 38, 41, 42, 44-50 are not affected much malaria transmission (Fig.6).

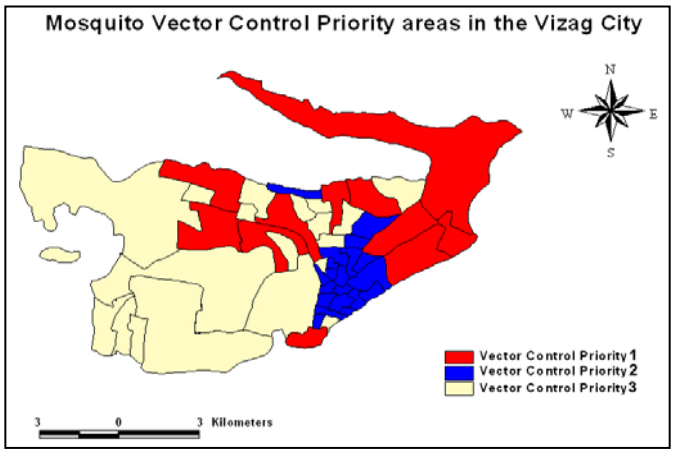

Fig 6: Map showing wards wise Malaria cases in Vizagkapattinam City

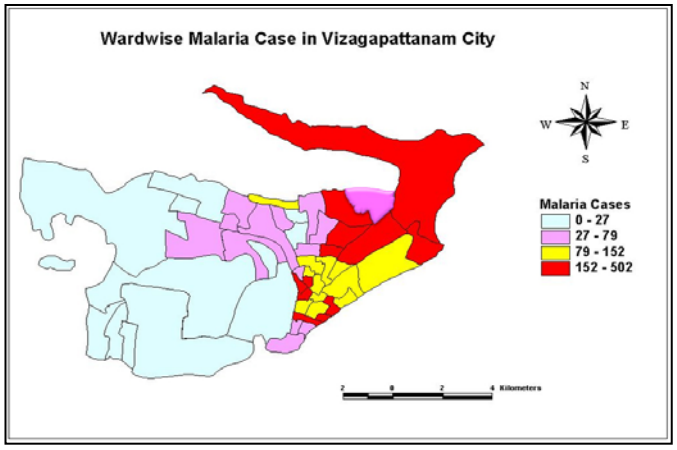

Fig 7: Priority areas / wards for Malaria vector Mosquito control

4.7 Vector Control Priority areas / wards for malaria control

The thematic layers of mosquito breeding surface areas, ground water surface level, and malaria cases was superimposed on the ward base map with 1:25,000 large scales and land use/ land cover classes of satellite image with 5m X5m high spatial resolution for performing the spatial analysis for obtaining the result map of priority areas for vector and disease control, using Arc View spatial analysis and Arc view Image Analyst software. The result obtained from the spatial analysis, three major areas are classified as priorities 1, 2 and 3 for the control operation (Fig.7). Thus, based on the priorities of the areas or the wards have to be chosen for implementing the malaria mosquito control measures with appropriate control strategy.

5. Conclusion

The application of remote sensing, GIS and GPS are useful for detection, identification, delineate and mapping the mosquito potential breeding surface areas and studying the mosquitogenic conditions in the city and giving meaningful spatial solutions and usefulness in the important decision making for implementing the ward wise vector control operation. The land use/ land cover classes of the study area on 1:25,000 scale image derived from a systematic value added hybrid colour composite satellite image processing of the merged product of the IRS PAN and LISS III with of 5m X 5m high spatial resolution is providing reliable, accurate and has significance results for mapping the mosquitoes breeding potential areas which are fueled and supporting for malaria transmission in the city. Remote sensing and GIS based derived map is giving spatial solution map of priority areas 1, 2 and followed by 3 is finding the usefulness for controlling the vector and disease transmission in the city (Fig.7). Based on the results, the following areas are classified into four major categories and which was recommended for control operation for malaria mosquito control measures in the given areas on the basis of priorities of the map result of the present study (i) Coastal region with dense human settlements, (ii) Dense population in the foothill areas, (iii) Marshy areas / Industrial areas with low density population settlements and (iv) semi-urban in the peripherals of the metropolitan.

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