The development of spatial modeling of risk zones of Malaria epidemic in Mangalore city of Karnataka State using Geo-Information Technologies

Dr Naveenchandra B[*], Shannon Meryl Pinto[**], Dr Usha[**]

[*] Director, Geo-Informatics Research Institute, Vijnan Foundation, Udupi, Karnataka State, India
Email:naveenchandra1307@gmail.com
[**] SRF, Geo-Informatics Research Institute, Vijnan Foundation, Udupi, Karnataka State, India
Email:shannonmerylpinto@gmail.com
*** Lecturer in Physics, Government PU College for Girls, Udupi, Karnataka State, India
Email:iamushanchandra@gmail.com

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Abstract- Malaria is a complex epidemic and one of the most serious vector-borne diseases world-wide. Malaria risk becomes higher in developing countries. A large number of malaria-causing factors including proximity to vector breeding site, inadequate use of control measures, and changes in land use play a big role. Recent trends indicate that there is a considerable increase in the frequency and severity of all epidemics namely Malaria, Chikungunya and Dengue outbreaks with a spread to both urban and rural areas of Karnataka State, India. Malaria is a major health issue in Dakshina Kannada district of Karnataka State, India and considerable numbers of people are affected by it. Malaria is biologically a specific spatial infectious disease and can be studied location based by taking into account the characteristics of malaria vector activities. Since early 1990s, Dakshina Kannada district of Karnataka State has been witnessing a great spurt in construction activities, owing to rapid industrialization, construction of highways, railways, urban housing and other constructions. The objectives of this study were mapping the malaria disease susceptibility area in by using IRS/Landsat 8 imagery, identified the influence of physical environmental factors on the spread of malaria disease, and analysed the spread of malaria disease based on environmental factors using Geo-Information Technologies. The research method used weighted overlay spatial analysis of spatial parameters by IGiS Software and generated hot spot mapping of the epidemic village wise and analysed for 20 years of time series. This study showed that urban areas which are located on the coast are prone to malaria disease.

Index Terms- Geographical Information System (GIS), Global Positioning System (GPS), Malaria, Remote Sensing (RS), Risk Zone Mapping

I. Introduction

Malaria is a disease caused by the Plasmodium parasite which is transmitted by the female Anopheles mosquito. Malaria is a life-threatening health problem that almost happened in every Indian region. Malaria disease problem is not only experienced by Indian, but this endemic disease can cause death and also threaten communities in various parts of the world, particularly in tropical and subtropical countries. Malaria is biologically a specific spatial infectious disease and can be studied location based by taking into account the characteristics of malaria vector activities. That area supports the breeding and living place of malaria mosquitoes due to heavy rainfall etc .These parameters are spatial environmental factors that influence the spread of malaria disease in the study area. Malaria is biologically a specific local infectious disease and can be studied spatially by taking into account the characteristics of malaria vector incidence data in time series. Geographical information systems (GIS) based systematic housing and population survey with aid of GPS is useful for collecting data for the study of factors affecting it and its vector distribution. The role of geo-information technologies is an important tool for formulating control activities, assessing changes in transmission in different environmental setup over time and determining resources to control prevalence, particularly in areas of high risk of disease transmission. Therefore, the present study has been designed for mapping the occurrences of disease epidemics and to study the environmental aspects all epidemics. Therefore, the present study has been designed for mapping the occurrences of disease epidemics and to study the environmental aspects all epidemics. The thematic parameters that can be extracted through Landsat 8 imagery for identification of malaria epidemic transmission, i.e. land use, soil texture, vegetation density with overall mapping accuracy of vegetation density, land use, and soil texture are 84.2%, 87.7%, and 83.7%, while other parameters resulted from spatial analysis of non-remote sensing data,

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i.e. temperature, rainfall, slope, altitude, and distance to river. Mangalore is one of the endemic urban areas of malaria which is geographically a coastal area dominated by water-flooded land use. The study area is Mangaluru city, the revenue headquarters of Dakshina Kannada district of Karnataka state. In the last twenty years, as a part of urbanization in the area due to which substantial number of constructional activities and also migration of man power from other parts of Karnataka state migrating to Mangaluru city. This resulted in the spread and high incidences of malaria in Mangaluru city and surrounding areas. Malaria is a major health issue in Dakshina Kannada district of Karnataka State and maximum numbers of people are affected as compared with other parts of the state. Many approaches have been developed and applied to control Malaria, but no single method comes out for identifying the environmental aspects for this epidemic.

The present study has been designed for GIS thematic mapping of occurrence of epidemics, to study the environmental aspects of all epidemics. Application of satellite images and GIS software was potentially useful for stratification of transmission of risky areas for the epidemic management of the study area. GIS and Remote Sensing (RS) are novel technologies that have evolved as a frontrunner in the study of the epidemiology of all diseases. Mapping malaria cases can help health authorities to understand more about spatial distribution of the disease in their area as well as its temporal occurrence. The risk maps have proven to be important tools for public health decision-making for vector-borne diseases as it provides with the targeting of prevention and control efforts. The spatial thematic maps obtained from GIS Software towards malaria hazard and risk will provide a guideline for control programs and preparing health facilities for utility planning. This tool is useful for management strategy to allocate resources for preparing the needs for control of disease in high-risk areas of disease.

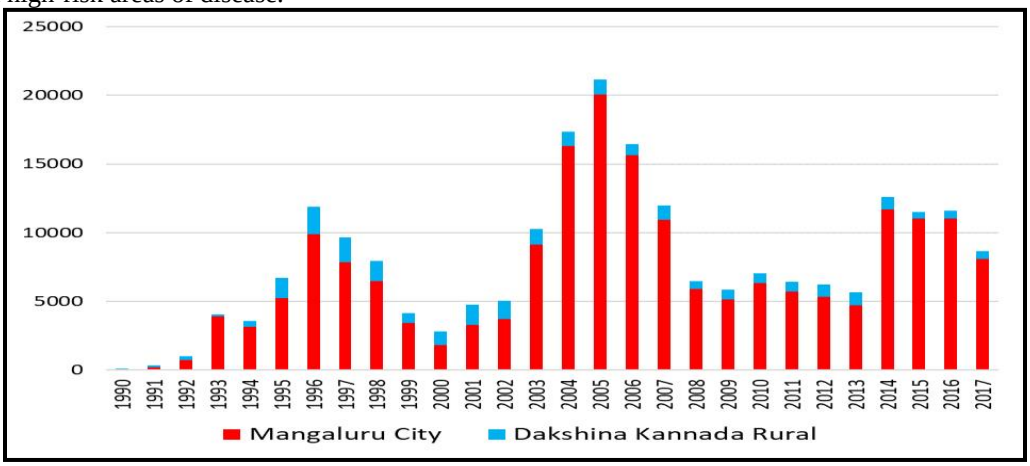

Figure 1: The comparison of incidence of Malaria epidemic in Mangalore City with Dakhina Kannada District inferring city alone affected 90% with other rural areas for 27 years

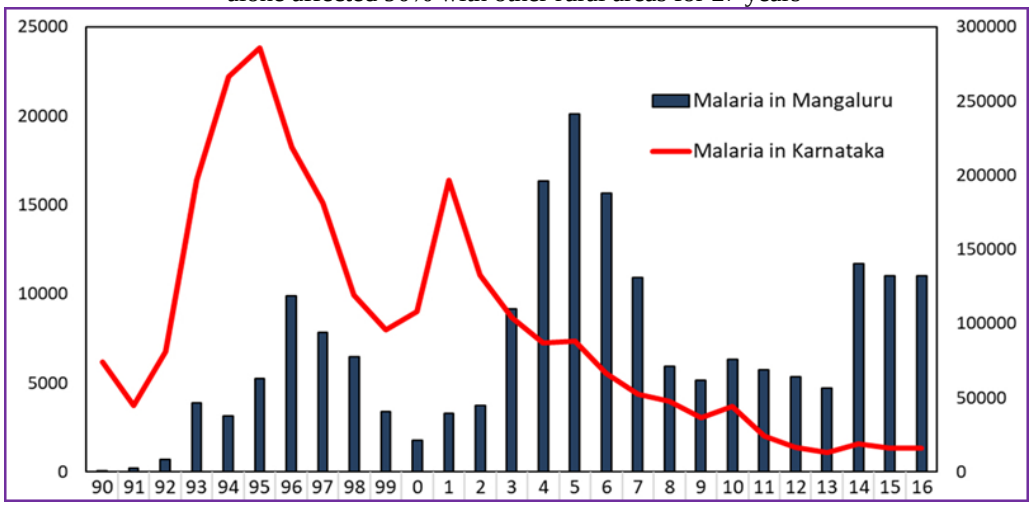

Figure 2: Shows the comparison of incidence of Malaria epidemic in Mangalore City with Karnataka State inferring city alone affected more in 26 years

During 1980s, when Malaria was prevalent in the region, most of the cases occurred in the rural areas of Dakshina Kannada district. Since 1990, with the urbanisation boom, the infection has remained mostly localised to Mangaluru city, with almost 80-90% of the cases reported from the district belonging to the city limits as compared with rural areas of the district (Figure No 1). Whereas the incidence of Malaria is showing a downward trend in Karnataka state, it is continued to increase in Mangaluru city during 1990 to 2016 (Figure No.2).

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II. MATERIALS AND METHODS

2.1 Study area: The study area consists of the coastal region of the DK district in Karnataka state in India, lies between 12°45' N to 13°7'30" N latitude and 74°45' E to 75° E longitude. The location map of the study area is shown in Fig.1.2. As per the 2001 census, the total population of the taluk was 882856 with 68.08 % of the population living in urban areas [4]. The density of population in the taluk is 1048 persons per Sq.km. This geographic region bordered by the Arabian Sea on its West, by the thick forested area on its east is rich with natural resources. The availability of favourable natural habitats and increasing artificial water collections due to construction related activities has rendered this region more susceptible to malaria [5]. The city of Mangalore has experienced a spurt in industrialization and construction activities since 1990. The incidence of malaria in this region has been increasing over the same time period.

2.2 Study period: Change detection of the land cover types assessed for the years 2000, 2010 and 20021. The malaria incidences in the region for the period 1990 to 2021 were obtained from the National Vector Borne Diseases Control Program division of the State Public Health Department of Karnataka. Remote sensing (RS) data for the region were obtained as Landsat TM images for the years 2000 (dated 14th April and 20th December 2000), 2010 (dated 23rd April and 27th January 2010) and 2021 from the U.S. Geological Survey data repository.

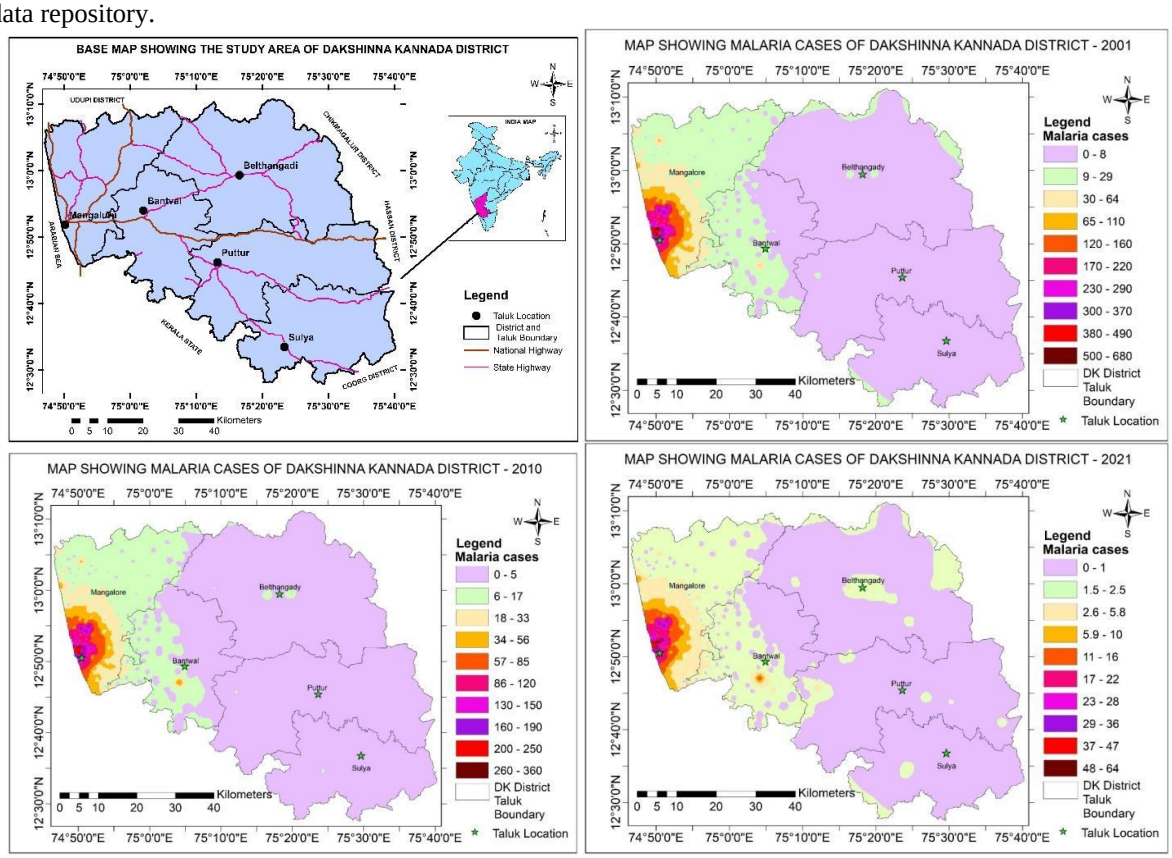

Figure 3 shows the location map and malaria incidence map in Dakshina Kannada District for the year 2001, 2010 and 2021

2.3 Topography and climate

The average annual rainfall in the study area is 3955 mm of which 87% is received during South-West monsoon (June to September). The climate is tropical with high humidity and the temperatures vary between 17 and 37 degrees Centigrade. The topography of the study area is undulating with dense vegetation. Lateritic soil overlies granitic gneisses and friable sandstones. Alluvial deposits occur along the river courses. The beaches are composed of sand deposits.

2.4 Geology and soils

The rocks in the study area are classified as recent ansubrecen deposits and laterite formations. They include alluvial formations, clays, red and dark clay soils and laterite like or lateroid formations. Laterite like formations covers a fairly large area along the coast and little totheinteriors. These rocks are of considera blethickness and they probably represent the alterations of the underlying rocks by process of laterisation and the ferruginous character at the surface is characteristic of such formations.

2.5 methodologies

Knowledge of both land-use and land cover is very important criteria for socio-economic planning of the area. The land use relates to human activities like residential, institutional, commercial and recreational etc. whereas the land cover term relates to the various types of features present on the surface of the earth [9]. Viewing the Earth surface from space is now crucial to the understanding of the influence of man's activities on over time series. In remote sensing techniques, data from earth sensing satellites has become vital in mapping the earth's features and infrastructures, managing natural resources and studying environmental changeMulti resolution

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data acquired at regular time s1eries have been useful in mapping and monitoring the changes in land cover types. Digital image processing techniques have been used for preparation of land use/ land cover maps from the multi-date, multi-sensor satellite data [7]. IGiS image processing software and its GIS analysis capabilities such as vector module have been used for the preparation of land use/ land cover maps and to detect the change pattern.

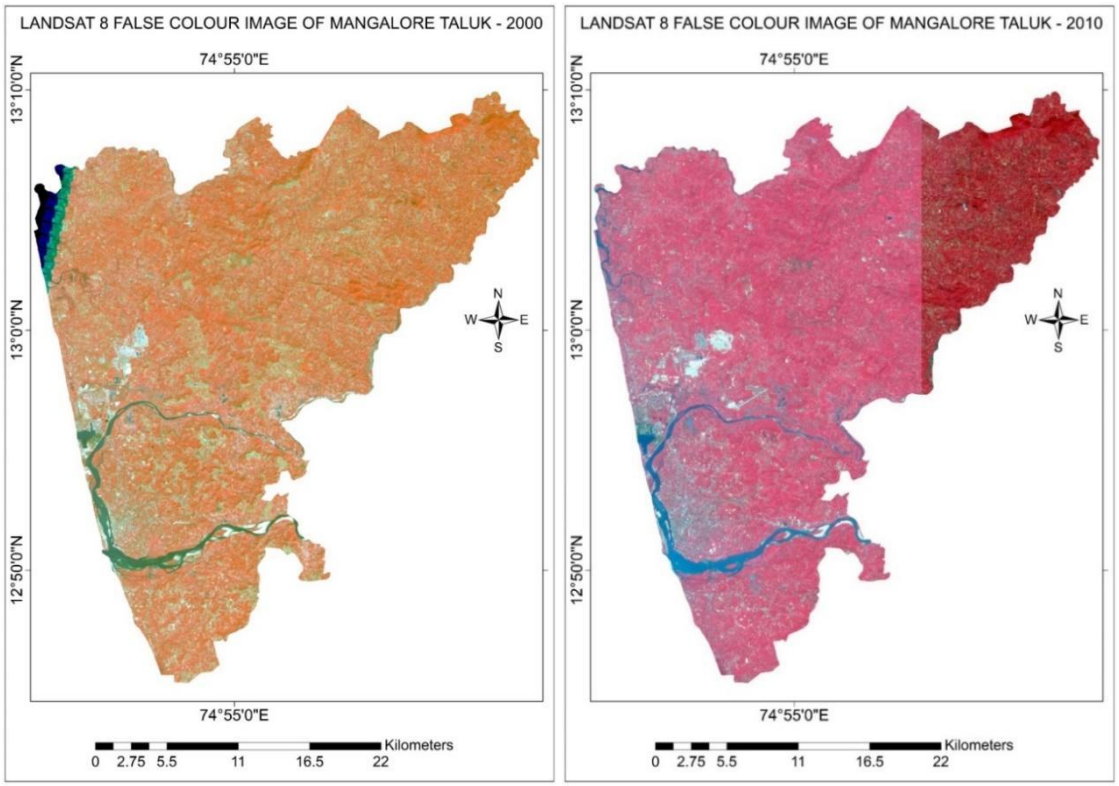

Figure 4 shows the LANDSAT IMAGERIES OF MANGALORE TALUK FOR 2000 AND 2010

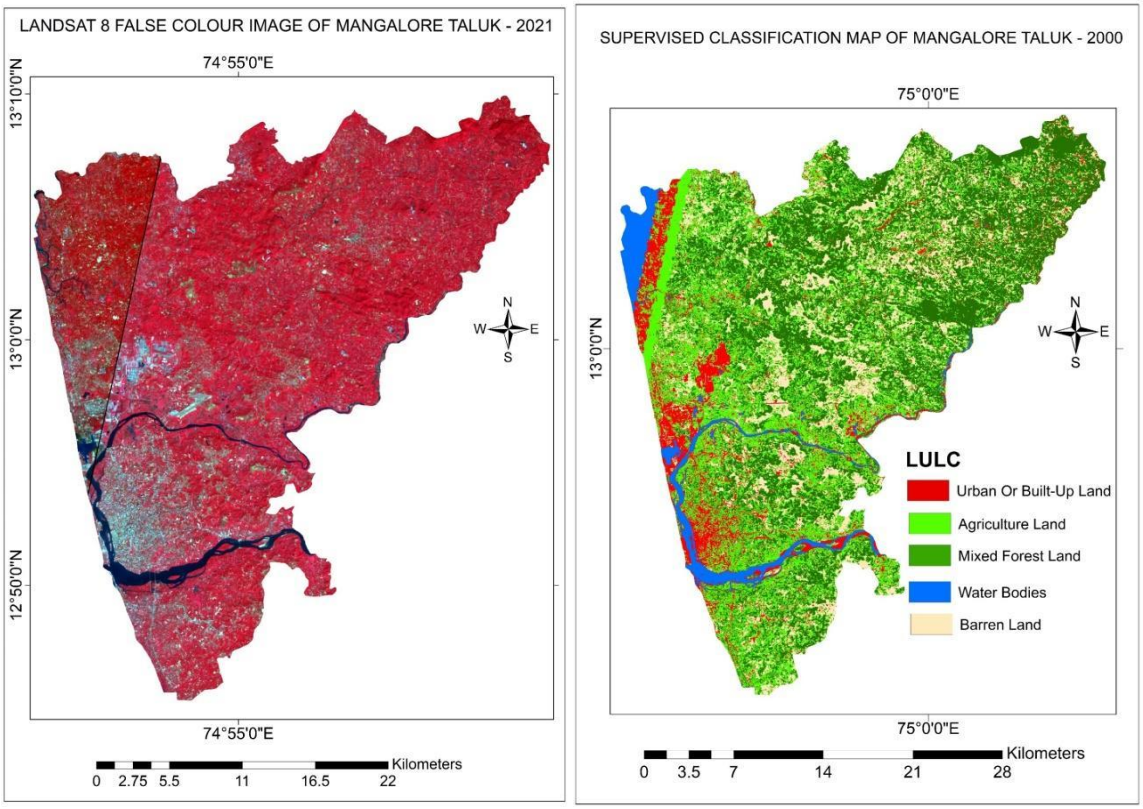

Figure 5 shows the LANDSAT IMAGERIES OF MANGALORE TALUK FOR 2021 and LU/LC map

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The base map was registered using 33 well-distributed ground control points (GCPs). The second order polynomial transformation with nearest neighborhood resampling technique has been adopted. Process of image to map registration was then adopted for the registration of satellite imagery and boundary map of Managalore taluk. Vector module has been used for on screen digitization and to obtain the boundary of the study area. Using this as raster mask, Landsat-7 and 8 imageries of the study area have been extracted. After the registration of digital images, the training sets for each land-use/land-cover class are collected for both imageries. Extensive field visits have been undertaken for collecting the ground truth information. The various land-use/land-cover classes identified include built-up land, cultivated land, coconut plantation, arecnut plantation, fallow land, casuarinas trees, open scrub, marshy vegetation, barren land without scrub, sand and water body. The multispectral classification was carried out using supervised classification techniques with maximum likelihood classifier. The overall accuracy of the classification was finally obtained through the computation of confusion matrix.

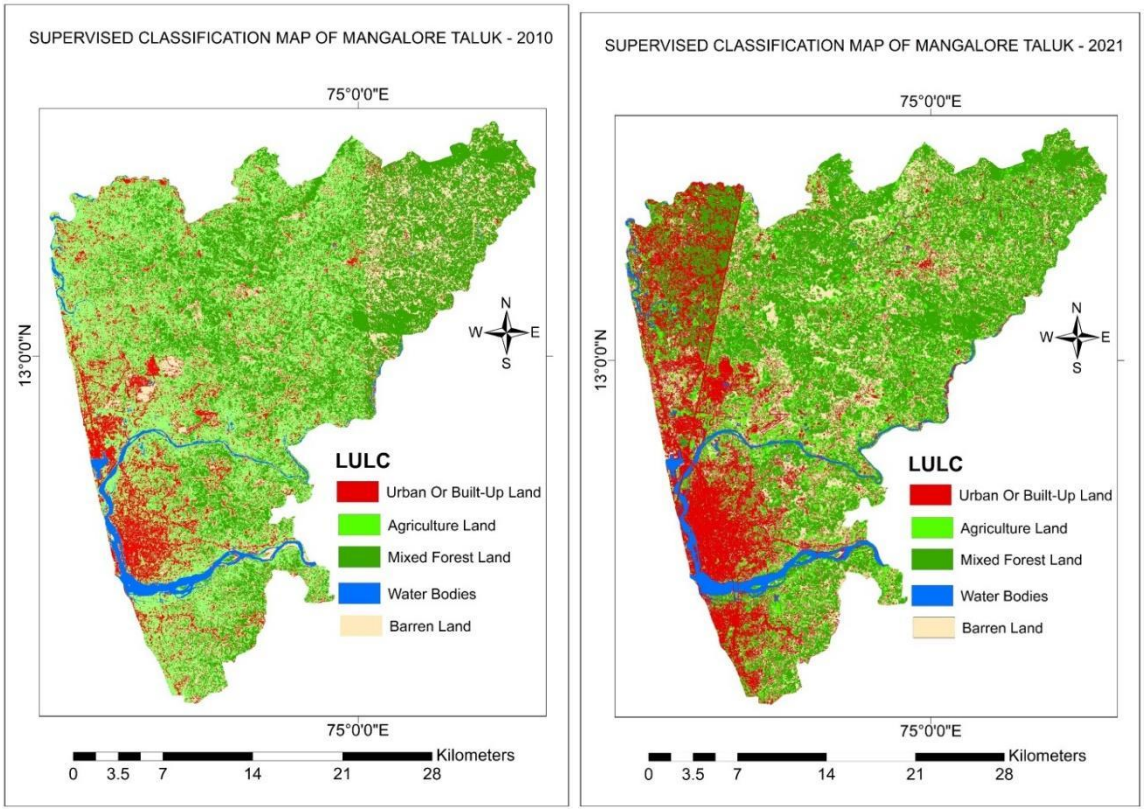

Figure 6 shows the LU/LC thematic map derived from LANDSAT IMAGERIES FOR 2010 AND 2021

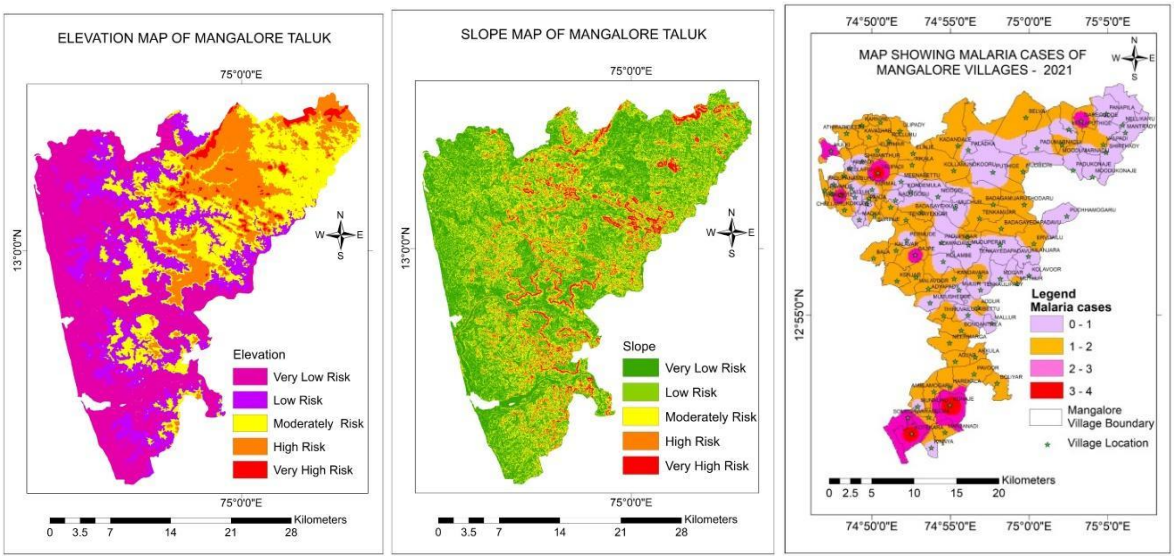

Figure 7 shows the Elevation, Slope and thematic map showing malaria cases in 2021

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III.

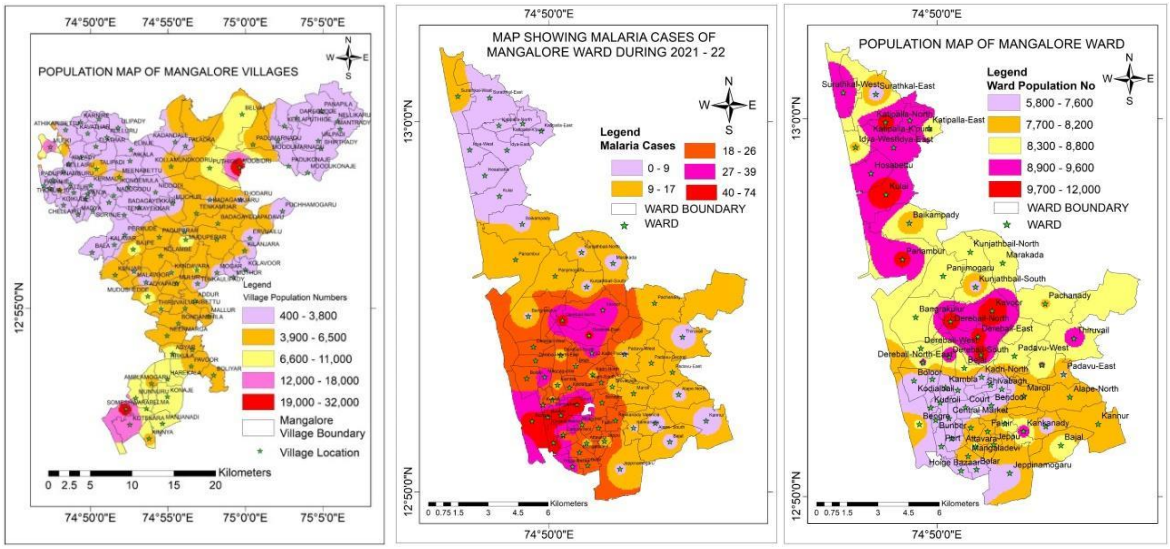

Figure 8 shows the Population in study area village wise and TMC ward wise with malaria incidence in 2021

2.6 Risk Zone mapping using Weighted overlay analysis:

Weighted overlay analysis is a GIS extension technique for applying a common measurement scale of values to diverse and distingue inputs to create an integrated analysis. The effectiveness of this method is that the individual thematic layers and their classes are assigned weightages on the basis of their relative contribution toward the output and generated risk zone mapping using spatial statistical analyst tool exist in IGiS software environment for action plan and decision making. The Risk thematic maps have proved to be important tools for public health decision-making and priority setting for vector-borne diseases as they assist with the targeting of prevention and control efforts. The spatial data obtained from mapping malaria hazard and risk will provide a guideline for control programs and preparing health facilities based on the requirement of the study area. Geographic information system (GIS) has been continuously used for the analysis of spatial health-related data. This has resulted in opportunities for better understanding of spatial variation of diseases and the correlations with environmental factors. Providing accurate malaria risk maps can effectively guide the allocation of malaria resources and interventions.

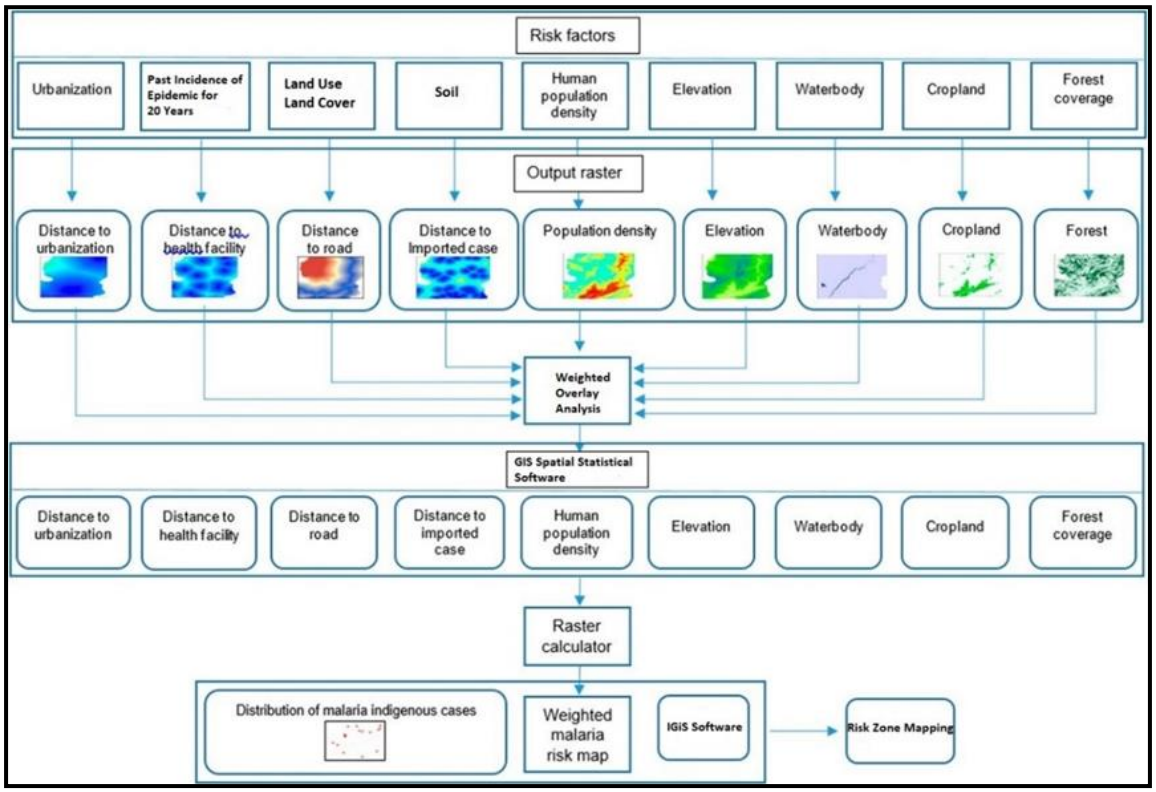

FIGURE 9: Summary of malaria risk analysis process in IGIS Software Environment.

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I.

Geo-Information Technologies have been used extensively in any epidemic risk zone mapping and malaria control throughout the world. The functionalities of GIS can help in developing spatial Health Information system. In village level or ward wise, malaria cases that can be identified to a specific coordinate and control measures can be easily determined by overlying risk zone thematic map. Thus, capability of Geo-Informatics Techniques is especially useful for planning, logistics, and operations of malaria control programme. In the current day circumstances,

Factors	Weight	Class	Rank	Susceptibility
Slope	15	0-4%	5	Very High
		4-12%	4	High
		12-22%	3	Moderate
		22-37%	2	Low
		37-109%	1	Very Low
Elevation	15	1776-1850	5	Very High
		1850-1945	4	High
		1945-2045	3	Moderate
		2045-2155	2	Low
		2155-2465	1	Very Low
Distance from Breading Sites	5	0-1km	5	Very High
		1-2km	4	High
		2-3km	3	Moderate
		3km-4m	2	Low
		> 4km	1	Very Low
Population Density	10	510	5	Very High
		365	4	High
		190	3	Moderate
		50	2	Low
		15	1	Very Low
Past Incidence Index of 20 years	25	0-1km	1	Very Low
		1-2km	2	Low
		2-3km	3	Moderate
		3km-4m	4	High
		> 4km	5	Very High
Land Use Land Cover (Urbanisation, Water body, Crop land, Forest coverage)	20	Bare Land	1	Very Low
		Forest/Built-up	2	Low
		Grazing Land	3	Moderate
		Crop Land	4	High
		Water	5	Very High
Soil	10	Liptosols	1	Very Low
		Nitosols	2	Low
		Vertisols	4	Moderate
		Luvisols	5	Very High

Table 1 shows the weight and rank for the environmental aspects to develop spatial modeling

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III. RESULTS AND DISCUSSIONS

GIS is finding application in diverse fields including health, and the put forward that in any disease control programme, there are several factors involved, namely estimation of disease burden, monitoring of disease trend, identification of risk factors, planning, allocation of resources, and implementation, and a common line involved in all these activities is "geography" GIS due to its inherent ability to manage both spatial and non-spatial information provides an excellent framework for disease monitoring and control. Mapping malaria cases can help health authorities to understand more about spatial distribution of the disease in their area as well as its temporal occurrence. GIS has been continuously used for the analysis of spatial health-related data.

This study looking at the changes in important land cover types in this region between the years 2000 and 2021 shows that there was an increase in the urban land cover by 42%, with a reduction in the mountainous terrain by 14.7% and vegetation by 38.7% correspondingly. A 4.5% reduction in the level of thick vegetation (NDVI>0.2) was noted in the region, which could be as a result of increased urbanization. The fresh water and stagnant water collections increased by 31% in 3 years and are essential for mosquito breeding and transmission of the disease. Some of these artificial water collections are due to construction related activities and collections after rainfall in places like disused vehicle tires, tree holes, used coconut shells, open water tanks, open wells etc. which are associated with human activities. The absolute numbers of malaria cases in the region had also increased between the study period and the incidence of malaria increased five-fold. An increase in the urban land cover, water collection and a rise in malaria burden are noted in Mangalore between 2000 and 2021. The breeding habits of the mosquitoes vary between species are dependent on other environmental factors like amount of rainfall, temperature, humidity, elevation of the terrain etc. According to the result of the findings, large area of the study area is located on high and very high-risk area for malaria. This research confirmed the method used was capable to integrate all the spatial data of malaria hazard due to environmental factors and the components of malaria risk factors in a GIS environment. The Weighted Overlay analysis in GIS environment was shown to be useful for delineating areas at different rating in terms of malaria hazard and malaria risk.

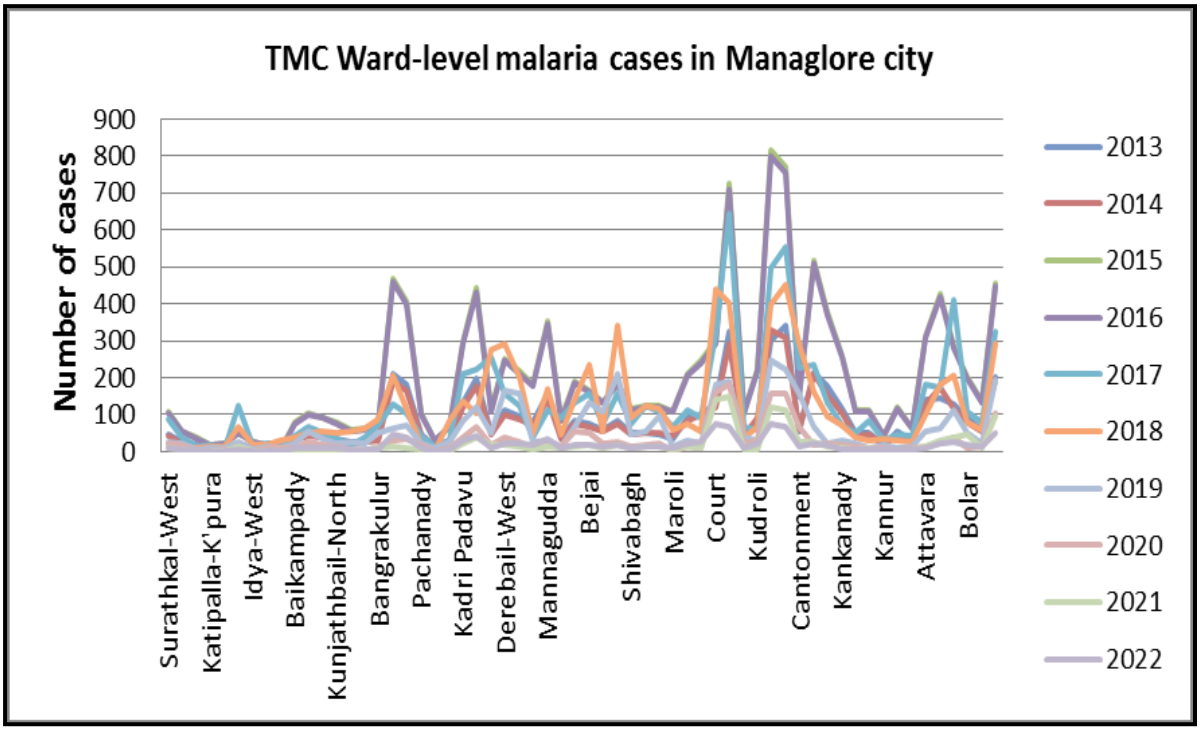

Figure 10 shows the malaria incidence cases in Mangalore TMC ward wise from 2013 to 2022

Regression analyses are statistical techniques that allow for the modelling, examining, and exploring of spatial relationships, to better understand the factors behind observed spatial patterns and hotspots, and to predict outcomes based on that understanding[13]. The application of spatial statistical methods to geolocational health data research has enabled complex scenarios of the malaria disease to be visualized through the creation of spatial maps within the IGiS Software environment. The study of the spatial variation between disease incidence cases and associated environmental factors with the GIS software has greatly improved the understanding of these factors. Malaria has been reported to be associated with environmental and climatic factors such as rainfall, humidity, temperature and understanding the behavior of these factors in space with the application of regression statistics [13] will further improve on timely control measures and resource allocations. The generated regression maps suggest that for administrators to archive the targets for malaria control to minimize by 2030 thereby to carry out future investigations in areas where the environmental variables showed strong spatial associations with malaria hotspot cases

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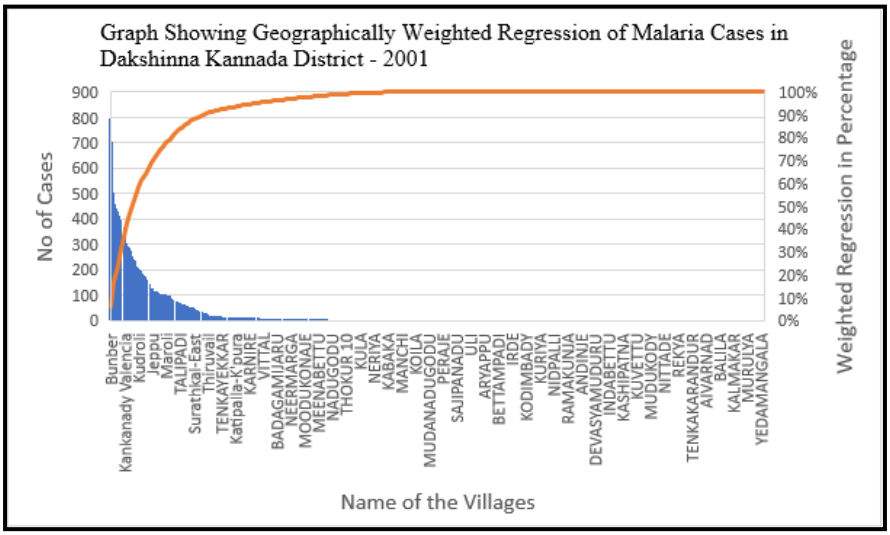

Figure 11 shows the weighted regression of Malaria cases of study area in 2021

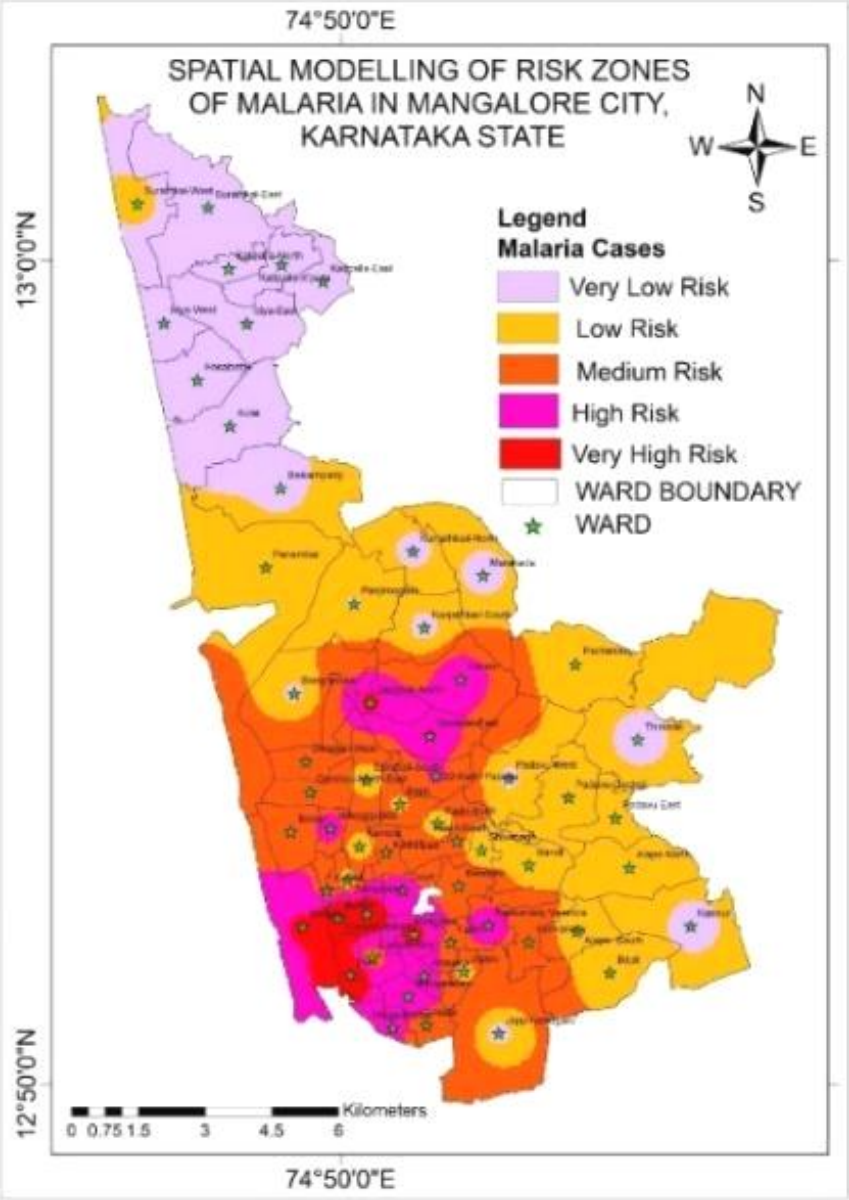

FIGURE 12: Developed Spatial modelling of Malaria risk zone mapping of Mangalore City ward wise

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IV. CONCLUSIONS

From the spatial database model developed using Geo-Information Technologies for the Malaria incidence in Mangalore TMC for the year 2001, it is observed that highest cases are observed in Kadri South ward, Derebail East, Derebail west, Bengre ward, Central market, Bunder area, Port area and Milagres ward of Hampankatta area as compared to other town municipality wards. Geographical information systems (GIS) based systematic housing and population survey with aid of GPS is useful for collecting data for the study of factors affecting it and its vector distribution. The role played by Geographical Information System (GIS) and Remote Sensing in malaria risk mapping is enormous. GIS techniques serve as an important platform for preparing, mapping and modelling various variables related to malaria epidemic. Remote Sensing also plays an important role by providing environmental information such as timely satellite image, DEM and LULC data of the study area. Thus, the research has shown that GIS and remote sensing is important to create operational maps which could help the concerned bodies to identify hazard and risk areas for disease management. Zonation based Risk maps are fundamental for estimating the scale of the epidemic risks, and hence the geographical areas identified as hotspot are needed to combat malaria. They provide benchmarks for assessing the process of control and indicate which geographic areas should be prioritized in the ward or villages.

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AUTHORS

First Author – Dr Naveenchandra B,; PhD; M.S.; M.Sc.; PGDOM; Director, Geo-Informatics Research Institute, Vijnan Foundation, Udupi; Karnataka State, India; 576101; naveenchandra1307@gmail.com; 09449818550
Second Author – Ms. Shannon Meryl Pinto; M.Sc.; PGDCA (Geo-Informatics); Senior Research Fellow; Geo-Informatics Research Institute, Vijnan Foundation, Udupi; Karnataka State, India; shannonmerylpinto@gmail.com; 09686920100
Third Author –Dr Usha, Phd; M.Sc.; Lecturer in Physics, Government PU College for Girls, Udupi; Karnataka State, iamushanchandra@gmail.com; 09482580122

Correspondence Author – Dr Naveenchandra B, naveenb@vijnanfoundation.org; +91-8088815094

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