

Chapter 14

Spatial Analysis and Mapping of Malaria Risk in Dehradun City India: A Geospatial Technology-Based Decision-Making Tool for Planning and Management



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Abstract Land-use change emerged as one of the most rational component to the global environmental change, potentially has significant consequences on human health in relation to mosquito-borne blood diseases like malaria. Land-use change can influence mosquito habitat, and therefore the distribution and abundance of vectors and land use mediates human–mosquito interactions, including biting rate. Based

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on a conceptual model linking the landscape, human, animal and mosquitoes, this study focuses on the impacts of changes in land use on malaria in Dehradun city of India. Health center wise data on malaria and land-use change data were prepared. Results of the different components of the study were integrated in the geographic information system (GIS) environment and linking land use to disease. The impacts of a number of possible scenarios for land-use changes in the region were delineated and also a risk map of the study area was prepared. Results indicated that land-use changes have a detectable impact on malaria. This impact varies according to the land use land cover (LULC) condition as well as the socio-economic condition but can be counteracted by the adoption of preventive measures.

Keywords Malaria risk · Land use land cover · GIS · Spatial analysis

14.1 Introduction

Malaria is one of the most widespread diseases affecting humans and it remains endemic in many parts of the world (Baeza et al. 2017). From the ancient history of man malaria has infected humans and may have been a human pathogen for the entire history of mankind. Tolle (2009) determines that malaria as a global concern and the World Health Organization (WHO) has estimated that about 40% of the world's population, mostly those living in the developing and underdeveloped countries are at high risk of malaria. Of these 2.5 billion people are at risk, more than 500 million become severely ill every year and more than 1 million die due to the effect of malaria. Malaria is a serious disease especially in Asia and Africa, where one in every five (20%) childhood death is due to the effects of this mosquito-borne infectious disease caused by parasitic single-celled microorganisms belonging to the Plasmodium group. On an average, an Indian child receives between 1.6 and 5.4 episodes of malaria fever each year and at every day five children dies from malaria. The vast majority of cases occur in children under the age of 5 years and pregnant women are also quite vulnerable (Kumar et al. 2007).

Since, the birth rule in India malaria has varied entomological, epidemiological, socio-economical and ecological determinants and thus remains a major public health problem. The interactive outcome of these disease determinants leads to various combinations of transmission risk factors at local and focal levels. The 1980s two million reported cases increased during the 90s both in terms of morbidity and mortality. In the last 5 years, about 40 epidemics including 1400 malaria deaths have been reported from nine states within the country (Srivastava et al. 2003). The urban centres in India are more prone to malaria as compared to rural India. Some of the reasons might be inadequate surveillance, poor reporting, and a time lag in reporting

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to decision makers and lack of georeferenced information to pin-point the trouble spots for a timely preventive action.

Geospatial technology is being widely used for identification, characterization, monitoring, surveillance, and managing of breeding habitats and mapping of malaria risk around the many parts of the world (Ahmad et al. 2018). Remote sensing imageries were used for identification and characterization of the habitats that produced potential *Anopheles* vector mosquitoes in the Republic of Korea (Sithiprasasna et al. 2005). Integrated use of remote sensing and GIS has been successfully demonstrated in many studies related to the mapping of malaria risk in different parts of Africa (Kleinschmidt et al. 2001). Malaria is a serious public health problem in Southeast Asian countries including India. After the implementation of Modified Plan of Operation (MPO) in 1976 in India, malaria incidence came down to 2–3 million from 7.5 million recorded cases. However, malaria continued to be an endemic in certain pockets particularly in the tribal regions. The emergence and wide-spread drug-resistance in malaria parasites in India initiated using cost-effective and reliable alternative method for the vector control (Dongus et al. 2007). Public funds for health services in India have been largely focused on medical services, and public health services have been neglected. This is reflected in the virtual absence of modern public health regulations, and of systematic planning and delivery of public health services. Various organizational issues also hinder the rational deployment of personnel and funds for disease control (Khaleghian and Gupta 2005).

Geographic information science (GI Science) and attendant technologies in remote sensing, geographic information systems (GIS), and spatial statistics can be used for the surveillance and control of disease vectors in general, and specifically mosquitoes in VBD (Pam et al. 2017). Geographic information systems (GIS), production of global environmental digital datasets, meteorological and remote sensing data collection and analysis at near real-time, development of methodologies, models and tools for data standardization, collection, spatialization, analysis and dissemination, networking and information sharing, development of integrated information management systems. Some experience has also been gained in the use of thematic digital datasets for spatial modeling of vector-borne diseases (Kazansky et al. 2016).

GIS-based malaria cases mapping can help health authorities to understand more about the spatial distribution of the disease in their area as well as its temporal occurrence. The provided information will provide a guideline for control programs and preparing health facilities based on the requirement of each area. GIS has been continuously used for the analysis of spatial health related data. It can be a useful tool for analyzing the spread of diseases in both developed and developing (Kazansky et al. 2016). This tool can also be useful for management strategy to allocate resources for preparing the needs for control of disease in high risk areas of disease. GIS also enable us to generate revised maps as soon as new data are available. In India, GIS-based malaria mapping as a decision support system to control malaria-a case study has also been made in the Koraput district in Orissa, where the problem is more severe due to minimal transport facilities and inadequate healthcare facilities. In rural India, due to lack of facilities people visit a hospital only if the illness is highly prolonged and if there is no response to the primary line of treatment (Daash et al. 2009).

During the rainy season, piedmont zone of the Indian Himalaya is highly prone to waterlogging. There are innumerable streams which flow into the river Ganga and Yamuna, the main river of Uttarakhand (Sidhu 2016; Jasrotia et al. 2018). The dense forest provides shelter and humidity for mosquitoes breeding which might cause an increase in vector density. As the population density is low and the breeding sites are very extensive, the ratio of the breeding sites to man is very high. Breeding sites are covered with dense aquatic vegetation which further makes it difficult to employ any control agent. Patches of swamps and seepages exist all along the streams and tributaries.

There are many factors which affect the spread of malaria in Dehradun city, India. Some of the major factors are anthropogenic, geo-climatic, socio-economic factors and way of living. It is essential to understand such factors that cause increase in the vector densities, and hence the transmission of diseases to prevent the emergence and resurgence of more diseases, as well as to serve as basis for effective control (Yadav et al. 2013). Dehradun has a good healthcare system which helps people from every socioeconomic class to get affordable treatment. Moreover, the cases are well documented and are updated in the form of spatial format by the responsible state agency.

14.2 Study Area

Dehradun city is situated in the newly formed state of Uttarakhand. It is one of the oldest cities in India. The city of Dehradun is situated in the south central part of Uttarakhand State located at an altitude of 640 m, lies at 30° 19' N and 78° 20' E covering a total area of 38.04 km² (Fig. 14.1). The site where the city is located slopes gently from north to south and southwest and is heavily dissected by a number of seasonal streams and nullahs. The drainage of the city is borne by the rivers Bindal and Rispana. Dehradun enjoys a salubrious climate due to its Dun location in the hilly part of the state. Temperature during the summer season ranges between 36 °C and 16.7 °C whereas, winter months are quite colder with the maximum and minimum temperatures ranges between 23.4 °C and 5.2 °C respectively (Matta 2014). During the monsoon season (June to September) Dehradun experiences most of the annual rainfall of about 2000 mm.

14.2.1 Soil Characteristics

The soil type which includes manly texture, organic matter content its infiltration capacity and permeability, greatly affects the soil loss and run-off. Fine texture soils are more susceptible to erosion than coarse texture soils, since rainwater enters in and passes through a dense clay much more slowly than through a porous sand or gravelly soil (Fischer et al. 2015). In the present study area, the alluvial soils at Vasad

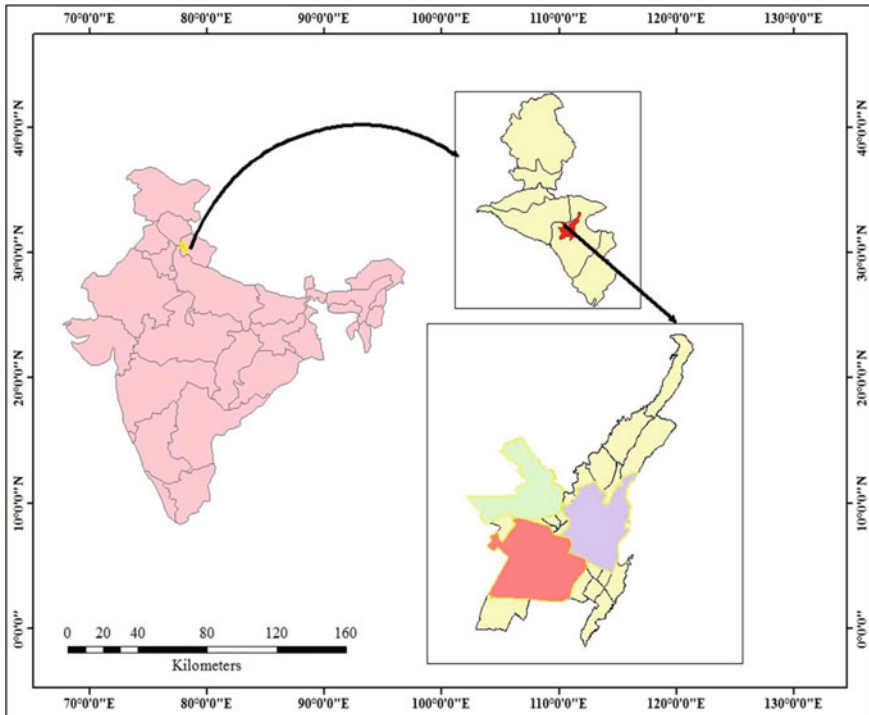


Fig. 14.1 Location map of the study area (Source Landsat-8, OLI)

and Dehradun have a very high rate of run-off; the black soils have an intermediate rate of run-off, but still the rate of run-off is high. The soil left in loose and pulverized condition is particularly liable to erosion through sheet-wash and gullyng (Gupta and Panigrahy 2008).

14.2.2 Ground Cover and Land Use

When rain falls on a surface covered by a thick mantle of plants, its velocity and erosive power, reduces and most of the water either quickly percolates through the soil or moves over the surface with non-erosive velocity (Fischer et al. 2015). Areas not protected with a thick cover of plants are unable to absorb water effectively, because the dashing rains shatter the soil surface, the fine soil particles go into suspension and the thick mixture of water and soil quickly fills and closes the tiny interstices in the soil, reducing infiltration and consequently increasing run-off and soil loss.

14.2.3 Settlement Structure and Urban Form

The settlement structure of Dehradun depicts morphological expansion over a colonial structure. The eastern Rajpur canal was the most important feature in Dehradun during the British period that had served the needs of water for drinking and agricultural purposes (Parkash 2014). The central part consists of the old city, i.e., the colonial vestiges, and private residential areas. The prestigious educational and research institutions are situated outside the core city. The western side houses the Cantonment area, Oil and Natural Gas Corporation, Forest Research Institute, and Wadia Institute of Himalayan Geology. The eastern part of the city is largely residential. The southern part of the city is designated as an industrial area (Kumar and Thapa 2015).

14.2.4 Demographic Aspects

As a part of the past heritage, concentration of national and regional level institutions, and economic activities, availability of infrastructure, and the emergence of Dehradun as the state capital on November 2000, would further invite the influx of population from the rest of the valley as well as from outside (Parkash 2014). This would further increase the growth rate in addition to the natural increase of population within the city itself. Favourable climate, good regional linkages by rail and road, and feasibility of spatial expansion of Dehradun city would be therefore instrumental for further migration. However whether the city would support this population expansion on a sustainable basis also calls for a detailed insight into the socio-economic characteristics of population that in turn decides the quality of population as well as certain aspects of urban planning and urban environment.

14.2.5 Socio-Economic Function of Dehradun City

Cities come into existence due to the functions they perform as central places. A harmonious integration of functions and activities can lead to a healthy and orderly development of the city. The major town functions of Dehradun can be grouped under: Administrative: Dehradun is the capital of the newly formed state of Uttarakhand. Educational and Institutional: The city besides being the seat for prestigious educational institutions, and other technical institutes, are also famous for national level institutes as already stated. Commercial: Dehradun is the largest service centre within the hilly region of Uttaranchal. It meets the trade and commerce requirements of its region. With the expansion of national level institutes and offices, and the expansion of the cantonment area, the commercial activity had gained momentum. Industrial: Establishment of industries based mainly on limestone and forests have attracted

ancillary industrial units and other industries. Development of industries is likely to play a vital role in building a sound economic base of the city. Tourism: Dehradun is endowed with immense potentialities for tourism industry besides being gateway to Mussoorie, the Queen of Hill stations. There are a number of tourist places and recreation spots within a short distance of the city that can be developed adequately. Defence: Dehradun is the headquarters of Indian Military Academy. A number of other defence establishments also are in Dehradun. The defence function has played a vital role in shaping the development and economy of the town (Suthar and Singh 2015).

14.3 Methodology

The Landsat 7 (ETM+Pan merged 15 m) data is used to prepare the spatial distribution map aided with ancillary data. The malaria data was collected from the Integrated Disease Surveillance Programme, National Centre for Diseases Control (IDSP 2013). Data consisted the entries from 15 health center of Dehradun city. The city witnessed highest cases of malaria (349) in 2015. Health center named Shri Mahant Indresh (SMI) reported highest number 61 Plasmodium falciparum (Pf) of malaria cases, while 23(pf) cases were reported in SPD Bhagat Singh colony. Lowest number of cases: 1(Pf), were reported by Synergy Institute of Medical Sciences. ArcGIS 10.0 software suit was used for mapping spatial distribution of malaria incidence at the micro level with the help of GPS survey. A 2 km buffer was created along each health location. Further, the wards falling in the buffer zone were divided into categories of high malaria incidence ward, moderate malaria incidence ward and low malaria incidence ward depending upon the number of malaria cases. Digitization of different data layers pertaining to the study area, rivers, water bodies, Income group population, location of health centres, Ward maps, etc. were carried out using Google earth explorer. Different attributes of the layers were added to the database for further analysis. The detailed methodology adopted in the present study is shown in the Fig. 14.2. The LULC for three area respectively high malaria cases, medium malaria cases and low malaria cases was prepared to find the spatial distribution of malaria in the Dehradun city. Supervised classification is done to prepare LULC map for different area in Dehradun municipal area. Various classes considered are built-up, vegetation, agriculture, and vacant land. The supervised classification approach was used to determine various the land cover types present in the scene. To do this, representative training sites of known land use land cover types are used to compile a numerical interpretation key that describes the spectral attributes for each type of interest the location and distribution of malaria vectors will be analysed through thematic presentation and mapping. To remove the bias and error field verifications for the training data has been done.

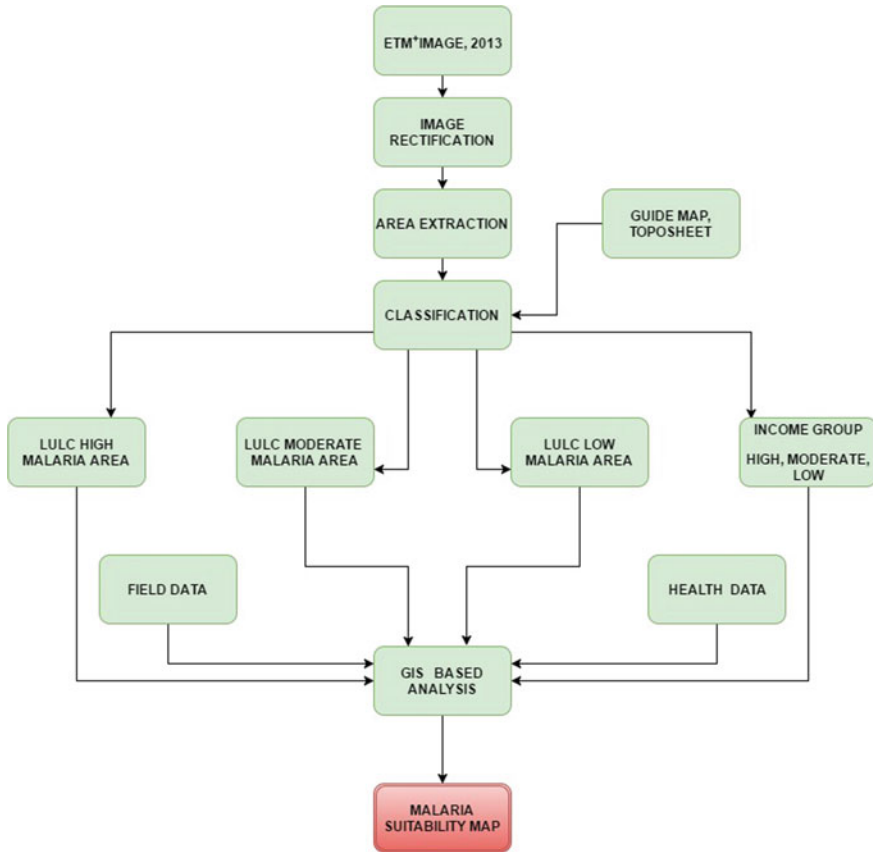


Fig. 14.2 Methodology adopted in the study

14.4 Results and Discussions

The section presents the results of the carried out analysis.

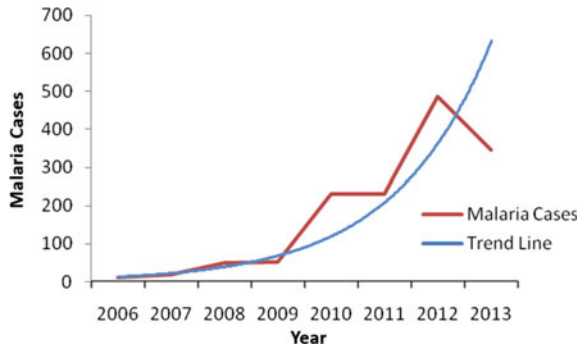
14.4.1 Temporal Distribution of Malaria Incidence

Temporal distribution of malaria incidence is considered, where 8 years (2006–13) data are taken from chief medical office, Dehradun. In 2013 total malaria examined case was 108521 (B/S exam) with total positive cases 346 persons (44Pf). During rainy season, the city is prone to water logging in the low lying area. There are innumerable streams which flow into the River Yamuna, the important river of Uttarakhand. The dense forest within the city provides shelter and humidity for mosquitoes

Table 14.1 Malaria cases in the Dehradun city (2006–2013) (*Source* National Centre for Diseases Control (IDSP 2013) Dehradun)

Year	2006	2007	2008	2009	2010	2011	2012	2013
Malaria cases	11	19	49	53	232	230	487	346

Fig. 14.3 Showing trend line of malaria growth from (2006–2013) (*Source* National Centre for Diseases Control (IDSP 2013) Dehradun)

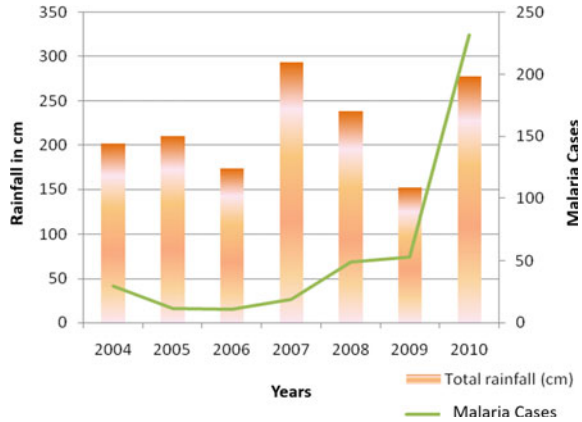


breeding which may cause increase of vector density. The trend line shows gradually increasing malaria rate in 2009 but it increases exponentially after 2010 and get doubled in the 2014 (Table 14.1 and Fig. 14.3). This is a matter concern, thus, must be addressed by the decision makers.

14.4.2 Malaria and Rainfall Relationship

Rainfall data was collected from the year 2004 onwards from Indian meteorological department (IMD) website (www.imd.gov.in), which gives a picture about the rainfall pattern in the district. From the data yearly irregularities in the rainfall is evident. The average monthly variation of the rainfall shows that the rainfall is more prominent in the region from the month of June to September. Rainfall affects anopheles mosquitoes breeding site, a malaria vector, typically breeds in small water sources. In Dehradun city a relationship between rainfall and malaria incident in per year is shown in the graph below. The Correlation between rainfall and malaria is show a moderate positive relationship (r^2) = 0.42 (Fig. 14.4). Climatic factor like rainfall is not a single factor for malaria survival. Other factors like geographical and the socio-economic conditions also play an important role like LULC of a particular area. To understand this we analysed the LULC of the study areas with the malaria cases in the next section.

Fig. 14.4 Relationship between rainfall and malaria cases (*Source* National Centre for Diseases Control (IDSP 2013) Dehradun)



14.4.3 Land Use Land Covers Distribution

The spatial and temporal changes in the distribution of malaria and land use land cover changes (Table 14.2 and Fig. 14.5a–c) can influence malaria transmission intensity (Wagner 2017). The association between land cover type and occurrence of malaria is statistically significant (Himeidan et al. 2013). In high intensity area water is 2%, agriculture 12%, vegetation 18% and built-up 62% and river Bindal is flows almost vertically to the study area. In the moderate intensity area water level is similar (2%), but the vegetation area is 13% and a high built-up percentage (77%) is present which is higher than the high intensity area.

One of the important observations is high malaria incidence frequency prone area consist 11.74% of agricultural land of the total area which makes this area a high-risk malaria zone. Further analysis shows a positive correlation between high malaria cases and the forest cover. The correlation between each class is calculated and positive relationship between the land use/land cover and malaria has been found. Figure 14.6a shows the relationship graph of vegetation percentage with malaria cases

Table 14.2 LULC percentage of the study area (Hectare: ha) (*Source* Landsat-8, OLI)

Land use/Land cover classes	High malaria incidence area		Moderate malaria incidence area		Low malaria incidence area	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Water bodies	31.58	47.63	27.18	40.99	7.54	11.37
Agriculture land	166.86	11.74	0	0	0	0
Forest cover	254.99	47.89	140.10	26.31	137.25	25.78
Vacant land	81.52	35.30	83.91	36.34	65.45	28.35
Built-up	879.18	36.50	842.85	34.99	686.23	28.49

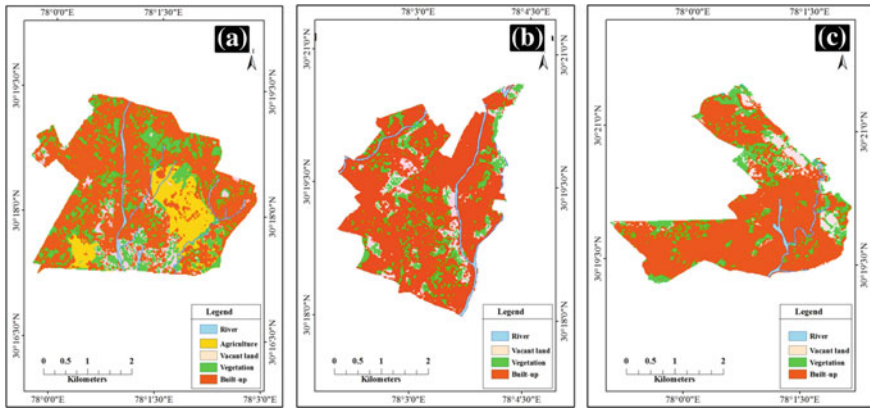


Fig. 14.5 a–c Land use land cover map of high malaria incidence area (a), medium malaria incidence area (b) and low malaria Incidence area (c) (Source Landsat-8, OLI)

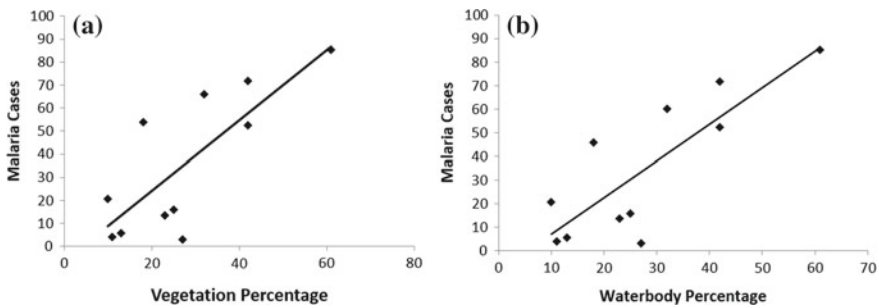


Fig. 14.6 a–b Relationship of malaria cases with vegetation area percentage (a), (b) Relationship of malaria cases with Waterbody area percentage (Source Landsat-8, OLI)

($r^2 = 0.6172$), and Fig. 14.6b shows the malaria case relationship with water body percentage ($r^2 = 0.6758$).

14.4.4 Socio-Economic Condition and Malaria

Socioeconomic, socio-cultural and behaviour patterns of the community plays an important role in disease transmission. To study the socio-economic conditions of the people the income group map for all the three areas have been prepared from Google earth and field verifications have been done to validate the datasets (Fig. 14.7a–c). We found that high income group (HIG) area is less vulnerable to malaria occurrences as compared to the low income group. Further, medium income group area is also found to be vulnerable to the malaria occurrence risks. The percentage of HIG people is

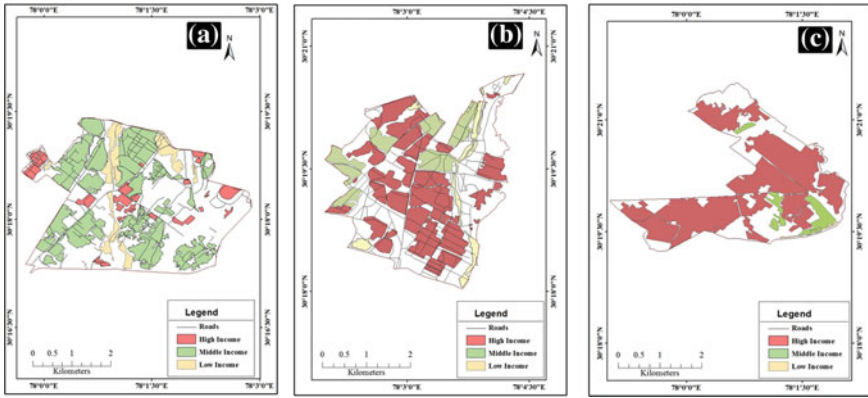


Fig. 14.7 a–c Income map of high malaria incidence area (a), Income map of medium malaria incidence area (b) and Income map of low malaria incidence area (c) (Source Field Survey)

low in high malaria incidence area but it is high in moderate and low area. The high malaria incidence area is predominant by the LIG group of people and vice versa.

14.5 GIS-Based Malaria Risk Analysis

Hazard is the probability of the occurrence of mosquitoes infective with malaria in a certain area. It was approached by assessing the suitability of environmental condition for malaria transmission based on environmental and physical factors. After preparing all the factor parameters compatible to risk analysis, estimating weights for risk parameters was defined. To illustrate, the malaria risk map health, hygienic condition, rainfall, land use land cover and income of the household were used to decipher the malaria risk map (Fig. 14.8).

14.6 Conclusion

GIS now days emerge as one of the most significant tool in the spatial analysis and demonstrates tremendous capabilities of the technology available to epidemiologists and researchers. Integration of GIS with remote sensing data helped us a lot in identification surveillance of breeding habitats and mapping of malaria risk areas in the study area. The global positioning system data in a GIS assisted format helped us in generating base map, mapping breeding habitats and analysis of areas of high disease prevalence. The GIS-based malaria incidence mapping assisted in risk mapping for analyzing past as well as present trends of malaria. Such kinds of

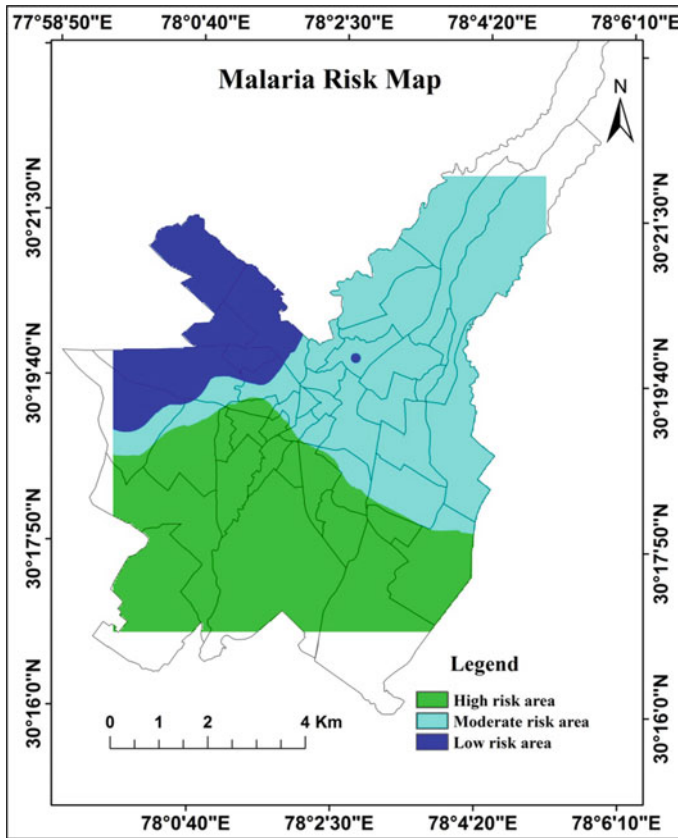


Fig. 14.8 Malaria risk map of the study area (Source National Centre for Diseases Control (IDSP 2013) Dehradun)

mappings have been extensively used in preparing maps of global malaria risk distribution in space and time. Spatial analyses using geo-processing tools have assisted in establishing relationship between malaria incidence and other potentially related factors. GIS mapping helped determine distribution of malaria vector mosquitoes along with monitoring and evaluation of malaria control activities in various countries. Three zones were identified for the malaria risks in the study area. It is found in the study area that less hygienic condition, poor health and economic standard are the major factor contributing the malaria in the study area. The areas which are delineated as high-risk area are low income area, poor hygienic condition are the major contributing factor to the high-risk malaria zone.

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