Chapter 10
Application of Geospatial Technique in Analysis of Malaria Prevalence in an Endemic Area of Ranchi, India

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Abstract The fatality and endemic nature of malaria is one of the prime causes of mortality and morbidity in the Tribal states of India. Despite many advanced control measures, India contributes up to 1000 deaths per year. This present study was conducted to determine the impact of topographic factors, socio-economic status, and climatic conditions on malaria prevalence in Ranchi district of Jharkhand state. The Landsat-derived indices including NDVI and NDWI have been used along with the Primary Health Care center's data to spatially assess the malaria incidences. Malaria hotspots have been identified by using the criteria developed by the NVBDCP, Ministry of Health and Family Welfare, India, based on Slide Positive Rate (SPR), Annual Parasite Incidence (API), and Annual Blood Examination Rate (ABER). The Bundu and Sonahatu blocks have been identified as the vulnerable areas for malaria, where topographical variation and socio-economic factors played an important role to aggravate the malaria incidences along with climatic factors. The year 2005 was found to be worst affected observing 17 deaths. Elevation range of 200–400 m was found as favorable for malaria occurrences. Rainfall and average maximum temperature were found to be positively correlated with API in monsoon months, whereas relative humidity was found to be positively correlated with SPR. This work illustrates the efficacy of geomatics to assess the spatio-temporal relationship among malaria host, agent, and environmental factors.

Keywords Malaria · Socio-economic · NDVI · NDWI · Jharkhand · Landsat

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10.1   Introduction

In the twenty-first century, the mosquito-borne malaria is an endemic throughout the tropical and subtropical regions of the world. Malaria results in enormous socio-economic deprivations and is a major cause of the grim scenario of poverty in India as well as in many developing countries (Dhiman, 2009; Gallup & Sachs, 2001; Sarkar et al., 2019). In addition to extermination of people, malaria creates a substantial economic burden globally, especially for poor people living in remote areas of the world (Amegah et al., 2013; Enayati & Hemingway, 2010; Rai et al., 2014; Sachs & Malaney, 2002; Sharma, 2003; Worrall et al., 2005). In the north-eastern India people reside under deprived health environmental conditions, which enhances the possibility to get affected by the malarial transmission (Dev et al., 2003). Several researchers have mentioned that there is a high incidence of malaria disease in the northeastern states of India (Dhiman et al., 2010; Nath et al., 2013; Rabha et al., 2011; Yadav et al., 2012). The World Health Organization (referred as "WHO" hereafter) reveals that malaria caused 584 thousand deaths throughout the world in the year 2013 (WHO, 2014). WHO reports indicate that approximately 300 million cases of acute malaria cases have been recorded every year. Despite the high level of control measures, this disease of antiquity remains prevalent.

A vector-borne disease (VBD) such as malaria generates an unacceptable and terrible health burden on developing nations (Ceccato et al., 2005; Ratmanov et al., 2013; Mutheneni et al., 2014). In Southeast Asia, India has the highest malaria burden (61%), followed by Myanmar and Indonesia (World Malaria Report, Fact Sheet, 2012). However, malaria is not homogenous in its distribution and has a major regional burden variation. Malaria is the major health problem faced by the tribal states of India including Assam (Yadav et al., 2014), Orissa (Daash et al., 2009), Jharkhand (Saxena et al., 2014), Madhya Pradesh (Bharti et al., 2020), and north-western Rajasthan (Kochar et al., 1997). The tribal population of India contributes nearly about 30% of total malaria cases with more than 60% of *Plasmodium falciparum*, and 50% deaths owing to malaria (Srivastava et al., 2009). National Vector Borne Disease Control Programme (NVBDCP) India indicated that the low socio-economic development, difficult terrains, and less developed infrastructure are the major attributes responsible for the malaria eruption in the country. The malaria control measures and efforts initiated in India have been presented in Fig. 10.1.

In the 1940s, DDT was introduced to control malaria epidemic in India. Malaria pervasiveness remained low in India throughout the 1960s and then experienced a slight revival in the 1970s (Cutler et al., 2010). Malaria prevalence or its vector proliferation is primly attributed to anthropogenic activities, immigration behavior, and performance of control measures in an endemic area. In the state of Jharkhand, studies conducted by the National Institute of Malaria Research (NIMR), India, indicated that *An. fluviatilis* has been found dichlorodiphenyl trichloroethylene (DDT) resistant/tolerant, whereas *An. culicifacies* shows resistant nature for DDT and malathion and the secondary vector *An. annularis* was found resistant to DDT, susceptible to deltamethrin, and tolerant to malathion. Jharkhand is one of the states
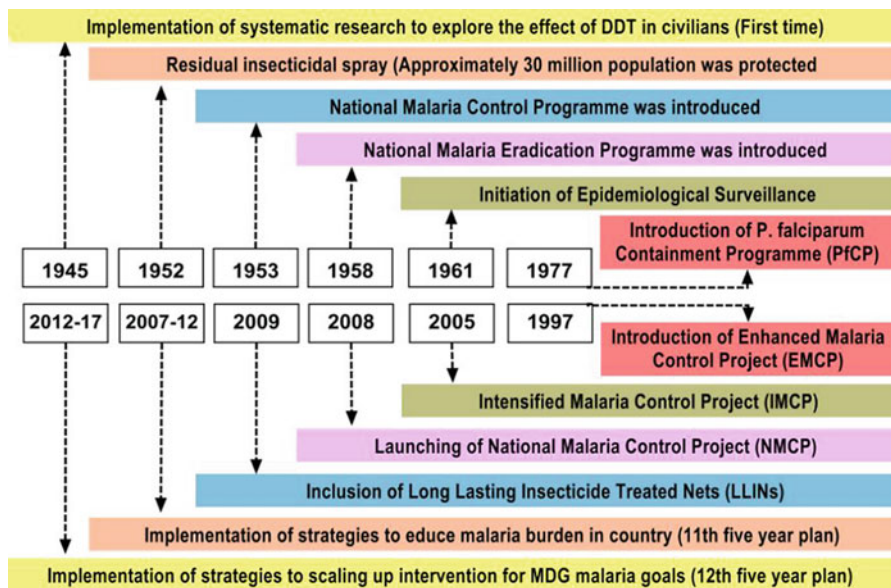
Fig. 10.1 Historical and a new future prospect related particularly to the malaria disease in India from the year 1945 to 2017

of India where regions with Annual Parasite Incidence (i.e., a malariomatric index to express malaria cases per thousand population) (API) >5 can be seen. *Anopheles fluviatilis*, *Anopheles culicifacies*, and *Anopheles annularis* are some of the malaria vectors which are more prevalent in the Ranchi district of Jharkhand, India (Saxena et al., 2012).

Multitudinous research work has been conducted in the tribal states of India (such as Haryana, Gujarat, Assam, Jharkhand, etc.) to identify the malarial hotspots (Bharti et al., 2020; Saxena et al., 2014; Srivastava et al., 1999; Srivastava et al., 2009; Yadav et al., 2014;). Sonitpur district in Assam (Nath et al., 2012, 2013), Gwalior city, Koraput district of Orissa (Daash et al., 2009), and Udalguri district in Assam (Yadav et al., 2012) are some of the studied regions of India. In order to explore malaria vector transmissions, the ecological and entomological studies have been performed very well (Ahmad et al., 2011; Smith et al., 2013); spatial modeling of vector-borne diseases (Machault et al., 2011) and effectiveness of the malaria control measures (Karema et al., 2012) are some of the important researches in the field of malaria preventions.

Globally immense progressions have been made in the direction of malaria eradication. Despite of the advance and fast intensification of malaria control measures, geographically half of the world remains at risk of contracting this disease (Gething et al., 2011). In this view the Geographical Information System (GIS) played an important role in better understanding of spatial distribution of malaria burden (Craig et al., 1999; Omumbo et al., 2004; Saxena et al., 2014). GIS provides

better visualization of malaria prevalence (e.g., Kleinschmidt et al., 2000), relationship with other potential malaria factors (Hu et al., 1998; Hightower et al., 1998; Saxena et al., 2014), malaria risk mapping (Clements et al., 2006; Kirk et al., 2015; Snow et al., 1999), development of malaria surveillance index (Cohen et al., 2010), and malaria ecotoping (Kaewwaen & Bhumiratana, 2015). The Malaria Information Systems (MIS) which is a PC-based purpose-designed system was developed to collect the accurate data for effective decision-making in the malarious provinces of South Africa (Carrin et al., 2002). Louis Jr. et al. (2005) presented the issues confronting Roll Back Malaria with the influential Italian drive to eliminate malaria disease between the mid-twentieth centuries. A detailed research has been conducted to study the altering epidemiology about malaria by means of interpretations of political, ecological, and social changes in local population over 40 years in the Cascades region of southwestern Burkina Faso (Giles-Vernick et al., 2011). Oloukoi et al. (2014) conducted a study to examine the observed and predicted trends of related health risk due to climatic variability and mitigation strategies at the household level in Nigeria.

Presently, GIS has been widely used to assess the malaria transmission risk, control measures, and identification of malaria hotspots and to develop geospatial attributes for anti-malarial plants (Srivastava et al., 2004; Qayum et al., 2014, 2015). The surveillance of malaria vectors, outbreak investigations, and potential environmental factors and socio-economic variable can be mapped using a GIS frame. Global malaria risk distribution maps have been prepared using GIS that helps to combat with any calamity in any region of the world. It has been stated that malaria shows a positive correlation with proximity to wetland areas (Van der Hoek et al., 2003; Zhou et al., 2012). In the year 2004, Hay et al. (2004) presented a single global malaria risk distribution map using overlay operations in GIS.

The real burden of malaria in India is still not known, and this jeopardizes the desirable outcomes despite extensive planning and resource allocation for malaria eradication. The present work is an effort to identify the areas of malarial transmission risk in Ranchi based on defined risk categories related to the various climatic, topographic, and ecological indicators in a GIS environment. The study attempts to address suspected underreporting of malaria cases in the neglected region where the ecological malaria suitability is high, while case detection is low. The generated ecology-based geospatial malaria risk model should help the identification of hotspots and contribute to judicious planning and management of the malaria situation in all potentially endemic areas, which is of particular importance in the elimination phase. Knowledge of malaria and socio-economic upliftment are key factors in adopting the appropriate intervention strategies. Keeping in mind that there are many risk factors that influence vulnerability to malaria including proper knowledge about malaria transmission and prevention, demography, and socio-economic status of different population groups, the present study was undertaken to identify factors predisposing to malaria in highly endemic areas in Ranchi district. This work represents a GIS-based assessment of environmental and socio-economic drivers which facilitates to the malaria combating agencies for targeting the vector control measures in the Jharkhand state of India. Identification of malaria hotspot in this

plateau region at the block and village level has been also attempted with the help of ancillary survey data. The findings will help to understand the patterns of malaria epidemiology in district Ranchi and would present an understanding how the malarial parasite is circulating constantly and which area requires more effective control measures to combat it.

10.2   Study Area

Ranchi, the capital of Jharkhand state, is situated in the southern part of Chotanagpur plateau, India, consisting an area of 7698 km^2 with a population of around 29,14,253. Ranchi district has 14 administrative blocks with an average literacy rate of 87.68%, and 13% of the total population contributes as below the age of 6 years. This district is the 46th largest city in India with geographical extent from 23°05' N and 84°52′ E to 23°24' N and 85°54′ E and 23°43' N and 84°58′ E to 23°23' N and 85°22′ E. The average elevation of the study area is 650 m and western region having a relatively higher elevation compared to eastern part. Ranchi has a rolling topography with approximately 159.14 ha of dense tropical forest. This area mainly lies in humid sub-tropical climate zone "Cfa," but unique topographical settings and dense forest provide a pleasant climate to this region. The "Subarnarekha" River and tributaries of "South Koel" are the life-lines for Ranchi region. In the summer temperature varies from 20 to 40 °C, whereas winter experiences a range of temperature from 1 to 25 °C. This region receives 80% of the total precipitation during monsoon, and the average annual rainfall of the district recorded as 56.34 inches. The state of Jharkhand is malaria endemic and attributed approximately 7% of the total cases of malaria disease in India. Apart from that, the district of Ranchi has been identified as a malaria vulnerable district in India. *Anopheles culicifacies*, *An. annularis*, and *An. fluviatilis* have been identified as the major vectors of malaria in Jharkhand state (Saxena et al., 2012). The "Bundu" PHC of the Ranchi district has been identified as the most malaria-affected area (Saxena et al., 2014). The lowlands of the district Ranchi have been found to be suitable for paddy cultivation, whereas the uplands provide conditions for orchards and cultivation of pulse, millet, and vegetables. The study area is shown in Fig. 10.2.

10.3   Methodological Framework

This section describes the collection of spatial and non-spatial data, details of study design, and image pre-processing steps undertaken to generate the spatio-temporal analysis of malaria prevalence in Ranchi district: first, the temporal design decided for identification of malaria prevalent regions; second, input satellite images have been described along with elevation data information; third, the strategy for ancillary data collection, discussions about criteria for finding malaria hotspot, and related

Fig. 10.2 Geographical location of the study area

calculations have been presented; and fourth, the thematic layer generation pertaining to the malaria hotspot surveillance in the Ranchi district. Lastly, vegetation condition assessment and Water Indexing have been performed to explore the environmental influences in malaria aggravation in the study area.

Study Design (Temporal) Strategy

The present study has been carried out for the year 2000–2010. Remote sensing and GIS have been used in the identification of malaria-affected regions in Ranchi district. The study has been designed as dividing the total study years into four different time periods (subgroups), i.e., T1-Study of Malaria Epidemic (SME) (2000–2002); T2-SME (2003–2005); T3-SME (2006–2008); and T4-SME (2008–2010).

Satellite Images, Elevation, and Ancillary Data Information

In GIS modeling framework a collection of well-defined secondary database is required to describe the relationship among various spatial and non-spatial attributes. In this view, malaria incidence data has been collected from the State Malaria Office, Ranchi, Jharkhand, for the given time periods. The Primary Health Centre (PHC) and Health Sub Centre (HSC) wise annual statistics regarding malaria disease data has been obtained for the year 2000–2010. In the present work Landsat TM image of November 2005 has been used. The satellite image which has been used in analysis was converted to the reflectance units. The Survey of India Toposheet of 1:50,000 and 1:250,000 scales has been considered for the base map generation. Elevation information has been extracted by using ASTER Digital elevation model data. Rainfall, temperature, and humidity records have been utilized to explore the relationship between occurrence of malaria incidences and environmental influence, especially pertaining to the climate convenience of malaria disease. The present work basically aimed to explore the influence of socio-demographic and environmental characteristics over the malaria incidences in Ranchi district. In this connection block wise demographical data (i.e., status of families below poverty line (BPL), district literacy rate, and population density) was taken into consideration.

## Malaria Hotspots Identification Criteria

An ample number of malaria indicators have been defined by the World Health Organization. The main problem is to select the appropriate "Core Indicators" that can provide an accurate information about targeted population by a specific vector-borne disease. In the present study, criteria developed by the NVBDCP, Ministry of Health and Family Welfare, India, have been used to identify the highly malaria-prone areas in Ranchi region. The criteria are as follows:

1. Number of deaths owing to the malaria disease (based on clinical diagnosis or microscopic confirmation).
2. Annual Parasite Incidence (API) must be 5 or >5 during the last 3 years.
3. Annual Blood Examination Rate (ABER) must be 10% or higher during any of the years from the last 3 years.
4. Malaria case reports contribute to the proportion of *P. falciparum* as 30% or higher, provided the SPR = 3% or higher during any of the years from the last 3 years.

Calculation of Core Indicators

The prime objective of surveillance is to identify alteration in trend or distribution in malaria diseases. It is the basis of vector-borne disease control measure strategy. There are several indicators for malaria surveillance which have been proposed, i.e., Annual Falciparum Incidence (AFI), Annual Malaria Incidence (AMI), Malaria Death Rate (MDR), Crude Death Rate (CDR), and Under-Five Mortality. In spite of that some standard principal indicators have also been documented for malaria surveillance, i.e., Annual Blood Examination Rate (ABER), Annual Parasite Incidence (API), and Slide Positivity Rate (SPR). The Slide Falciparum Rate (SFR) and Plasmodium Falciparum (PF%) are two other decisive indicators for the malaria disease assessment. From the aforementioned indicators selectively ABER, API, SPR, and PF% presented in Fig. 10.3 have been calculated as follows:

Annual Blood Examination Rate (ABER)—ABER gives the total number of blood smears examined for Malaria Parasites per 100 populations in a year and expressed as % of population. The operational efficiency of the control measures can be optimized by using ABER. The status about accurate Annual Parasite Incidence
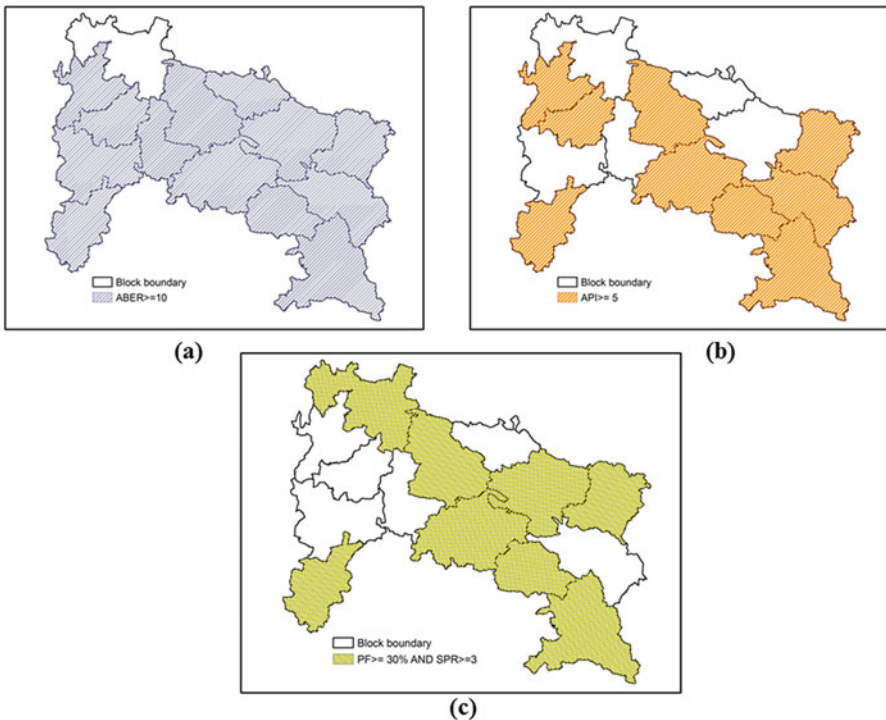
Fig. 10.3 Maps of core indicators for malaria surveillance in Ranchi during T4-SME generated using hotspot criteria: (**a**) ABER ≥ 10 in any of the last 3 years; (**b**) API ≥ 5 in any of the last 3 years; (**c**) PF % > 30 in any of last three years and SPR ≥ 3

(API) fundamentally depends upon the ABER. It has been calculated by Eq. (10.1) as given below

$$ABER = (Number\ of\ Slides\ Examined/Population) \times 100 \qquad (10.1)$$

Annual Parasite Incidence (API)—API defines total number of blood smears positive for malaria parasite (MP) per 1000 population in a given year for a given area. It depends on the adequacy of case detection mechanism of ABER. API has been calculated by using Eq. (10.2) as given below:

$$API = (Total\ Positive/Total\ Population) \times 1000 \qquad (10.2)$$

Slide Positive Rate (SPR)—SPR expresses the total number of blood slides found positive for malaria parasite per 100 number of blood slides examined. It is more reliable than API even for areas where ABER fluctuates by year to year and has been calculated by using Eq. (10.3)

$$SPR = \frac{No.\ of\ Blood\ Smears\ found\ Positive\ for\ Malaria\ Parasite}{Total\ Blood\ Silde\ Examination} \times 100 \quad (10.3)$$

Plasmodium Falciparum Percentage (PF%)—It is the total number of blood smears found positive for P. falciparum per 100 number of blood smears positive for malaria parasite. PF% facilitates the relative proportion of *P. falciparum* infection and trends in relation to the total case load. It has been calculated by Eq. (10.4)

$$PF\% = \frac{Total\ No.\ of\ Blood\ Smears\ Positive\ for\ P.falciparum}{Total\ No.\ of\ Blood\ Smears\ Positive\ for\ Malaria\ Parasite} \times 100 \quad (10.4)$$

Development of Thematic Layers

A GIS-based framework facilitates the overlay operations that can be very useful to interpret the relationship among the malaria surveillance indices. Thematic layers developed by using ArcGIS software provide the indispensable information about the malaria-affected region over the temporal as well as spatial scale. Based on certain pre-defined criteria (Sect. 3.3), a series of thematic maps have been generated.

Socio-Environmental Condition Assessment

This study aimed to explore the influence of environmental and socio-economic factors on malaria prevalence in the Ranchi region. In this view, it was necessary to assess the regional vegetation and water resources condition of the area under investigation. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) have been developed to assess the regional environment. Further, BPL data and census 2001 and 2011 demographic data were collected to analyze % BPL population, % literacy, and population density in the study area.

10.4   Results and Discussion

Statistical Analysis

During the total time-period considered, the PF% was found highest (62.11%) in the year 2003; interestingly no death has been reported in this year. In year 2005, 17 deaths were reported despite the low PF% (43%) as compared to PF% in 2003 (Table 10.1). An increasing trend in API (from 1.03 to 4.73) has been observed during 2003–2009, whereas the PF% values have been found to be decreased from 60.11% to 30.15% in the years of 2003–2006, respectively (Fig. 10.4a, b).

A block wise malaria incidence trend has also been analyzed from year 2000 to 2010. It was observed that the Bundu, Lapung, and Silli were the most malaria-affected administration blocks of Ranchi district in the years 2008, 2001, and 2009, respectively (Fig. 10.5a, b). It has also been found that most of the malaria cases occurred in the month of August and September due to continuous rainfall credited to the Monsoons. Owing to the regular precipitation the local waterbodies and water channels receive plenty of water that supports the mosquito breeding events. From the detailed examination of the spatial distribution of malaria surveillance

Table 10.1 Malaria case situation of district Ranchi during 2000–2010

| Year	ABER	API	SPR	SFR	PF%
2000	2.51	2.38	9.50	4.89	51.49
2001	1.97	2.26	11.49	5.83	50.75
2002	1.58	1.92	12.20	6.60	54.10
2003	0.90	1.03	11.36	7.06	62.11
2004	2.31	1.69	7.31	3.01	41.20
2005	7.92	3.27	4.13	1.77	42.77
2006	2.96	2.42	8.17	2.46	30.15
2007	3.25	3.39	10.43	4.26	40.83
2008	5.93	4.66	7.85	3.95	50.33
2009	9.77	4.73	4.85	2.44	50.28
2010	9.72	2.76	2.84	1.16	40.88
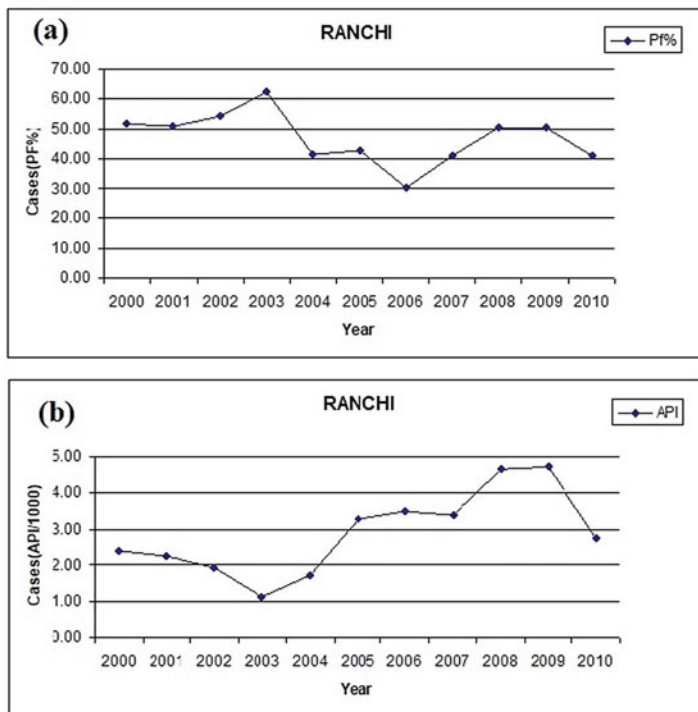
Fig. 10.4 (**a**) Yearly variation in *Plasmodium falciparum* (PF%) during the years from 2000 to 2010; (**b**) yearly variation in Annual Parasite Incidence (API) during the years from 2000 to 2010

parameters over the Ranchi district, the administrative block Bundu has been identified as the most malaria-affected region in the district.

Identification of Malaria Hotspot Region

As the identification of malaria hotspot regions was the prime objective for the present study, malaria-affected blocks of Ranchi district have been identified using thematic layers generated in GIS environment based on the criteria defined in Sect. 3.3. It has been observed that the Bundu block was the most frequently affected by malaria during the study periods (Fig. 10.6a–f). Most of the malaria hotspots have been observed in the southeast and northeastern region of the Ranchi district. At the level of HSCs from the year 2005 to 2007, Bundu and Sonahatu blocks have been identified as the most vulnerable area for malaria (Fig. 10.6f). A detailed investigation revealed that a total of 68 villages from Bundu and 40 villages from Sonahatu block have been under serious impacts of malaria incidences.
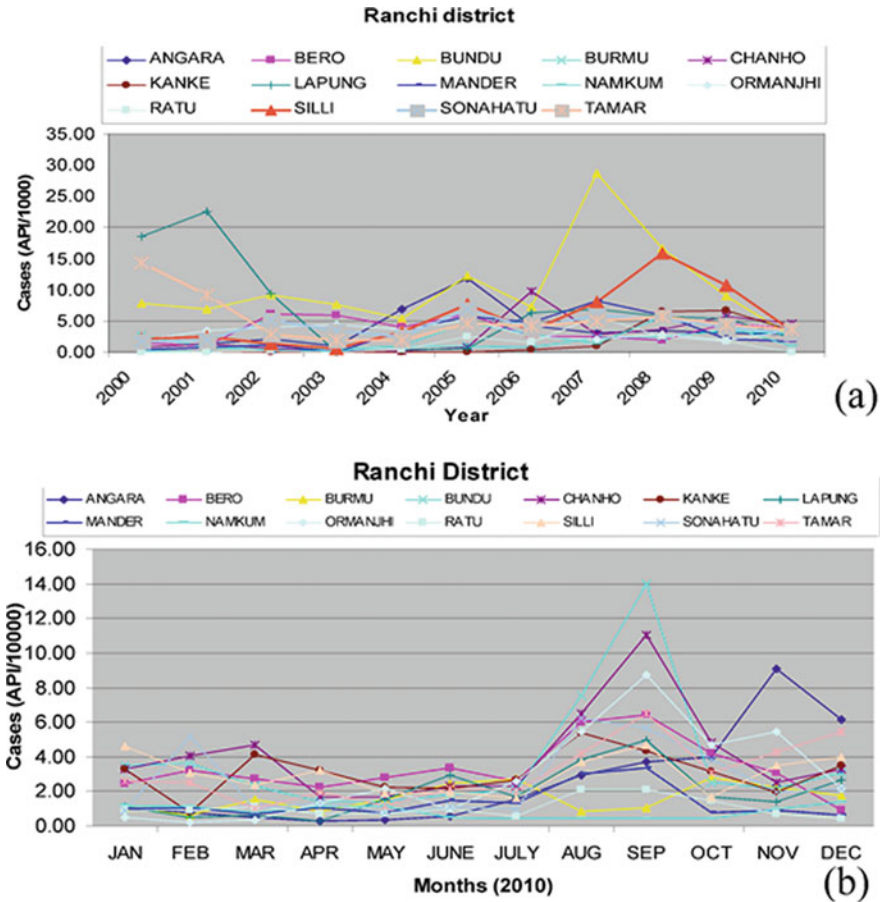
Fig. 10.5 (**a**) Block wise yearly variation in malaria incidences of Ranchi district during the years from 2000 to 2010; (**b**) block wise monthly variation in malaria incidences of Ranchi district during the year 2010

Analysis of Factors Responsible for Malaria Incidence

Topography and Malaria

Topography is one of the decisive parameters for occurrence of malaria incidences in plateau region. During summer season malaria vectors have shown a tendency of shifting their habitats from lower to higher elevations. Figure 10.7a, b depicts that areas having elevation up to 400 meters in Ranchi district are highly prone to malaria disease due to availability of favorable conditions for breeding of the malaria parasites, i.e., temperature, vegetation cover, and humidity. Lower elevated areas are closely related to the streams/swamps and forest that develop a positive impact for suitability of malaria vector and their growth as water is not washed away when it
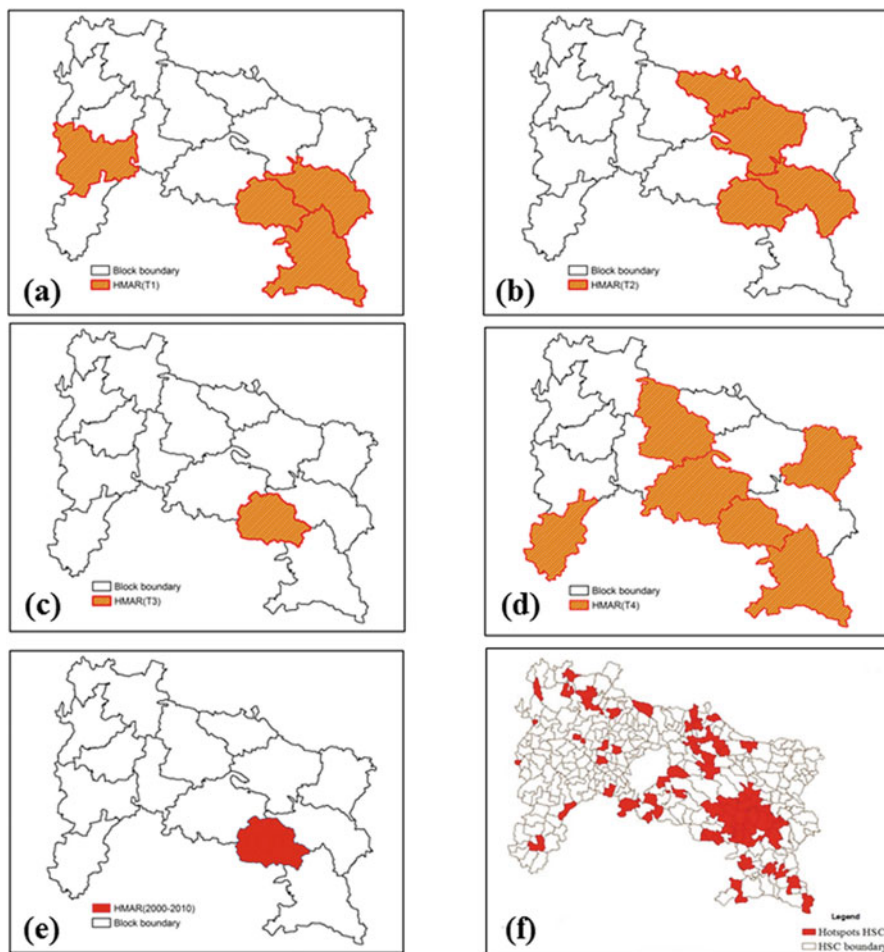
Fig. 10.6 (**a–e**) Highly affected regions by malarial disease in the district of Ranchi from 2000 to 2010; (**f**) highly affected regions by the malarial disease at the Health Sub-Centre level in Ranchi district during 2005–2007

rains as in the mountainous areas. At higher elevations temperature decreases which decreases the rate of parasite reproduction; therefore areas having higher elevation are less prone to malaria in the study area. The vulnerability of malaria incidences with respect to altitude variation at the HSC level has been presented in Fig. 10.7a. The Bundu block (300–600 m) has shown favorable habitat conditions for the malaria vector in this region.
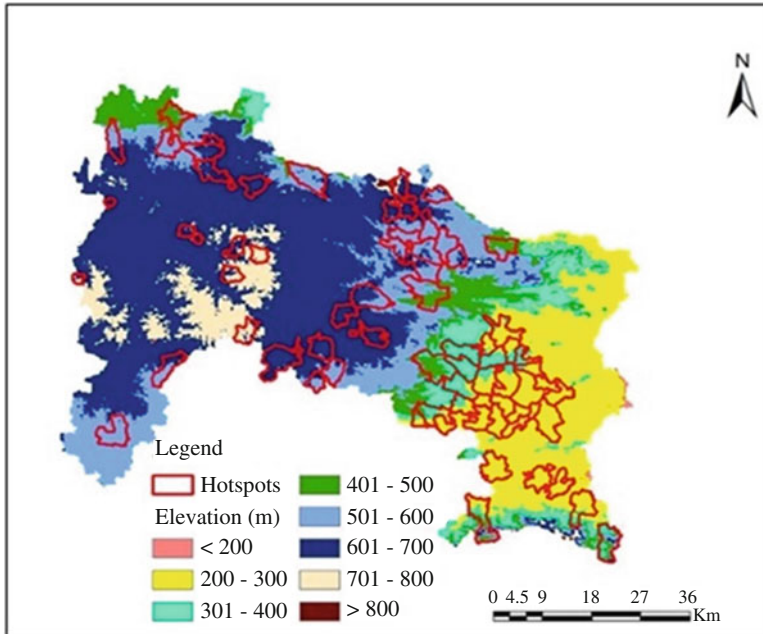
Fig. 10.7 (**a–b**) Altitudinal variation and locations of the malaria hotspots in the study area
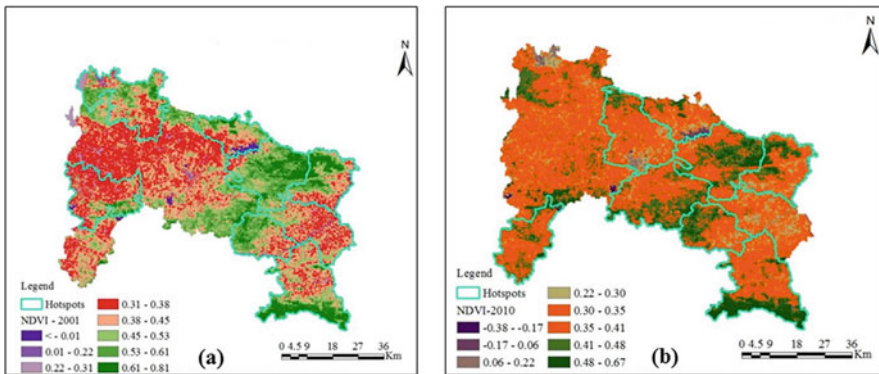

Fig. 10.8 (**a–b**) NDVI map and locations of the malaria hotspots in the Ranchi district

Vegetation and Malaria

The NDVI, as a measure of photosynthesis, can be used as a proxy for suitability of mosquito development. In the present study, areas with having NDVI values from 0.3 to 0.5 shows a high suitability or malaria prevalence in this area (Fig. 10.8a, b). The cropland habitats coupled with its humid conditions support rapid multiplication of malaria vectors. The Bundu block identified under NDVI ranges of 0.3–0.6 during

Fig. 10.9 Normalized difference vegetation map of Bundu block with HSC level hotspots
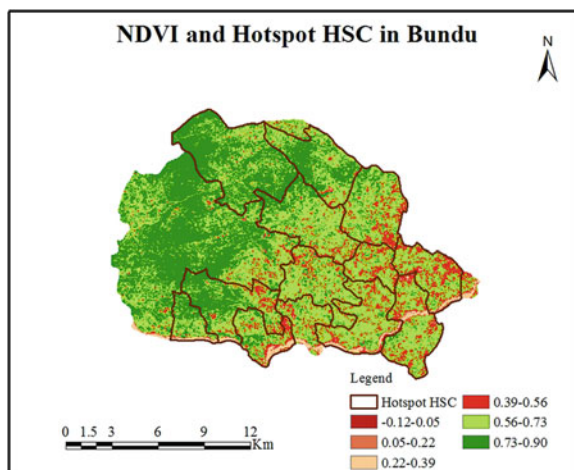
2000–2010 has been found favorable for malaria vector breeding as most of the areas of the block were under paddy cultivation and with occurrence of grasslands (Fig. 10.9). Form the vegetation map it has been observed that Bundu block is highly prone to malaria incidences.

Water Bodies and Malaria

The waterlogged area is one of the major factors for providing favorable conditions for breeding of the malaria parasite and may include riverbeds, oases, drainages, and other man-made water sites. It provides a perfectly suitable site for mosquitoes to lay their eggs. In the present work it has been observed that Ranchi district shows a frequent presence of water bodies. NDWI values of 0.1–0.8 have been observed during study period which acts as a favorable habitat for malaria vectors (Fig. 10.10a, b). The Bundu, Tamar, and Angara blocks have high NDWI values as compared to other blocks and are most vulnerable to malaria disease.

Meteorological Factors and Malaria

Different meteorological parameters such as rainfall, temperature, and humidity with API values have been determined for Ranchi district for the years of 2000–2010. The interaction between temperature and rainfall was found highly responsible for the seasonal characteristic of malaria transmission in this area. Among the several environmental factors, rainfall was found to be well correlated with malaria incidences (Fig. 10.11a). The relative humid condition was associated with increased vector longevity and greater frequency of feeding. The relationship between the aforementioned meteorological parameters and the occurrence of malaria incidences
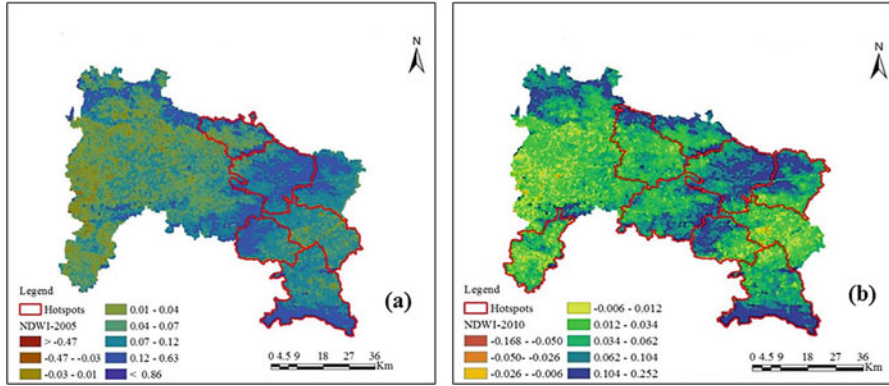
Fig. 10.10 (**a–b**) The NDWI map and locations of the malaria hotspots in the Ranchi district
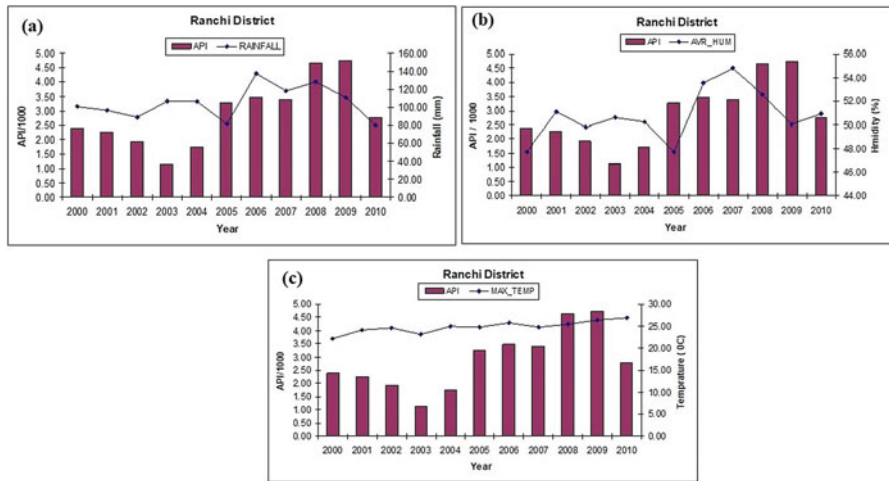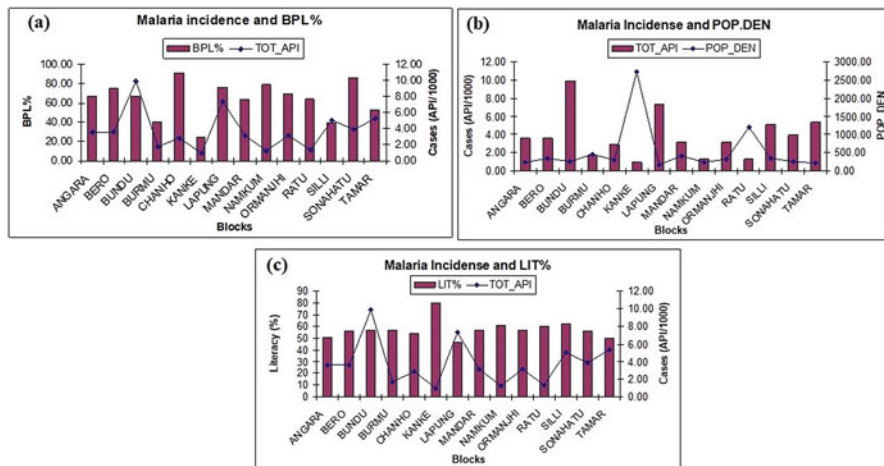

Fig. 10.11 (**a**) Relationship between the rainfall and API; (**b**) relationship between the relative humidity and API in Ranchi; (**c**) relationship between the temperature and API in Ranchi

has been shown in Fig. 10.11a–c. After detailed investigation it was found that there exists a strong correlation between API and rainfall for the year of 2005, 2008, 2009, and 2010. The API and humidity were also found highly correlated for the same time period.

Socio-Economic Factors and Malaria

The average API and different socio-economic data of different blocks of Ranchi district have been investigated. It has been observed that most of the administrative blocks show a positive relationship in between API and %BPL status data, whereas a

Fig. 10.12 (**a**) Relationship between the BPL% (Year-2010) and API; (**b**) relationship between the population density (Census-2011) and API; (**c**) relationship between percentage literacy (Census-2011) and API

poor relationship was found in case of blocks named Chanho, Namkum, and Ratu (Fig. 10.12a). In Bundu block, the %BPL during the year 2010 was >60%, and it was found that the total API was also very high (10 per 1000 population approx.). It is worth mentioning that in Kanke block, the value of API per 1000 population was very low with respect to the block population density along with low value of %BPL (Fig. 10.12a, b). Kanke block's population has not been much triggered by the malaria incidence owing to the high literacy percentage instead of its population density (Fig. 10.12c). It implies that education is one of the very important factors that can change the current malaria status in the country. The possible reasons behind the vulnerability and highly frequent malaria incidences in the Bundu block have been found as a combined impact of comparatively lower literacy rate and socio-economic condition of the block.

Role of GIS in the Management of Malaria

GIS has been used in many studies as a powerful tool for monitoring public health in various geographical locations (Clarke et al., 1996; Hay et al., 2009; Tanser & Le Sueur, 2002). Use of climate data, topographical data, medical reports, and questionaries can be processed using a GIS package to generate information for any epidemic. The information may include hotspot zonation and locating Public Health Centre/hospitals. GIS can be used in rapid estimation of the spatial distribution of malaria prevalence and incidence, medical facilities, and disseminating data to the concerned authorities. The community-based data generated using GIS is valuable as

an operational tool for planning actions against the malaria risk. GIS coupled with other technologies such as the Internet and broadcast networks can be used to create a spatial database to constrain the limits of malaria transmission. These databases can be assembled and analyzed by a team of geographers, statisticians, epidemiologists, biologists, and public health specialists. Furthermore, the information can be made available to public via mediums like mobile apps, radios, TV sets, and newspapers.

10.5 Conclusion

GIS is a powerful tool that can assist in the control of environmental diseases where spatial analysis is essential to focus scarce resources, improve the efficacy of control, and decrease the burden of disease. In the present study malaria prevalence in the Ranchi district has been investigated. The impact of environmental factors and socio-economic conditions on malaria incidences has been investigated. Based on criteria defined by ICMR India, malaria hotspot mapping has been performed. The Bundu administrative block has been found as the most affected area by malaria parasite in this region during the last decade (2000–2010). The monsoon period and post-monsoon time have a great possibility to aggravate the malarial situation in this region. As malaria control measures studies rely mainly on ground-based surveys, the present work would facilitate as baseline research for the ongoing malaria eradication program in India. It could be helpful to achieve the malaria elimination target in India by the year 2022. The present work reveals that the environmental settings and socio-economic factors along with the availability of disease control measures can have a decisive impact on malaria eradication program. This study, although limited to a particular area, can serve as a model for a larger area to highlight malaria hotspots and to monitor the pace of control programs, which is not otherwise feasible. GIS-based models can be used, even at village or cluster level, to pin point the malaria hotspots, and information can be updated and retrieved easily. The methodology has the potential to be applied to other diseases and areas of health that will benefit from being able to display and analyze spatial relationships based on accurate and reliable data. Using the extrapolation technique for current malaria incidence as well as in the past, and the hotspot identification used in this study, malaria occurrence could be predicted in the future, and policy makers could be advised accordingly for effective and optimal distribution of governmental aid for malaria control. The conclusion is that modeling such as this can help determine spatio-temporal prediction and mapping of malaria incidence to aid in the design and administration of appropriate interventions. The study does not suggest any specific control measure, but emphasizes the need to concentrate malaria surveillance and monitoring programs in these malaria hotspots. More studies should be carried out, such as on bed net usage, the relationship between household presence of trees and malaria, and others. The map generated can be further linked with the vector density, vector breeding sites, physio-chemical factors, socio-economic status, and available health resources to provide excellent framework for disease management.

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