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RESEARCH ARTICLE

A Spatio-temporal mapping of malaria risk zones integrating Annual Parasite Index and Geographic Information System in Vadodara District, Gujarat (India)

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ABSTRACT

Background: Risk maps have proven to be important tools for public health decision-making and priority setting for vector-borne diseases because they assist with the targeting of prevention and control efforts. The spatial information obtained from mapping malaria hazard and risk will provide a guideline for control programs and preparing health facilities based on the requirement of each area. Geographic information system (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. **Aim and Objective:** This study attempts to identify malaria risk zones at macrolevel based on annual parasite index (API). **Materials and Methods:** Spatiotemporal API data (2006–2011) are integrated into GIS and weighted overlay analysis is performed to delineate risk zones in Vadodara district. **Results:** On the basis of API as recorded during 2006–2011 from the villages of the Vadodara district, it was figured out that 50% region of Chhota Udaipur Taluka has recorded continuously very high incidence of malaria and followed by part of Sankheda and then Dabhoi Taluka. **Conclusion:** API has declined, but still a considerable region is more than above the desirable limit of the API and several vulnerable regions are there with low API and there is the prospect of elimination of this disease in this region.

KEY WORDS: Annual Parasite Index; Geographic Information System; Malaria Risk; Spatiotemporal; Weighted Index Overlay Analysis

INTRODUCTION

Malaria risk becomes higher developing countries.[1] A large number of malaria-causing factors including proximity to vector breeding site, inadequate use of control measures, and land use plays a big role. The multiplicity of malaria-causing factors in semi-urban areas, as the main cause of its prevalence is difficult to control at the same time.[2] The increasing trend of environmental change is dramatically changing malaria pattern at the local as well as global scales.[3]

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Gauging the risk of malaria represents a critical step in its management and the investigation of its consequences. The term malariometry is applied to the numerical measure of the risk of malaria in communities.[4] Many approaches have been developed and applied to malariometry, but no single method stands out as universally applicable.

The risk of malaria is highly dependent on interactions between the host, parasite, mosquito vector, and environment, a relationship known as the epidemiologic triad of disease. Changes in any one of these elements may profoundly impact the risk of infection. Measures of the risk of malaria may be broadly classified as either indirect or direct. Indirect measures gauge risk through alternate indications of the risk of infection such as rainfall, altitude, temperature, entomological parameters, spleen rates, antibody titers, or patterns of antimalarial drug use in a community. Direct measures of risk depend on diagnoses of malaria (clinical or microscopic) and their relationship to a variety of denominators representing classes of persons at risk over some unit of time. In general, in the indirect measures, data at hand are used to estimate the risk of malaria. However, in direct estimates of risk, conscious effort to collect data of estimating the risk of malaria is necessary.

The measurement of malaria incidence requires every suspected malaria case to be diagnosed through a comprehensive surveillance system comprising passive case detection (examination of suspected, usually febrile cases presenting routinely to any point of the health service), supplemented by active case detection (examination of fever cases sought through home visits at regular intervals).[5,6]

Although there is a long history of considering the constituent factors of malaria risk and the malaria transmission cycle through the use of mathematical models,[7] and careful evaluation has been made of the comparative usefulness of a variety of metrics for measuring the impact of interventions,[8] national strategic plans often make decisions about targeting interventions by relying on categorizations of annual parasite incidence. Some authors have adopted the use of the annual parasite index (API)[9,10] for mapping malaria risk, which has been expressed by the relation between number of positive blood cases and total population and represented by API. It describes where malaria cases are observed and thus where diagnosis and treatment commodities and services are required. Although API may not be the best representation for transmission risk in such places, it may still be useful for describing the burden of malaria on the health system and may suggest where total incidence is sufficiently low that more intensive case-based surveillance measures may be feasible to implement.[11]

API is studied by Shivakumar *et al.*,[12] in Karnataka, concluded that the prevalence of malaria has been on a declining trend, but some of the malariometric indices have been on a fluctuating trend and stressed on multidisciplinary approach to curb the disease. UP,[13] in Gandhinagar[14] in Jharkhand.[15]

Geographic information system (GIS) technology has increasingly been utilized in public health research, planning, monitoring, and surveillance within many developing countries and low-resource settings. 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.[16] One of the measures to be considered as preventive is to work on the main factors contributing for the development and expansion of the problem. In this regard, GIS and remote sensing can best fit to investigate the root problem both spatially and temporally.

As a result, using GIS and remote sensing as a tool that can grant information within shortest period of time, so that, decision makers get prepared to make better and faster decisions which can reduce the damage and minimize the loss. Geospatial technologies have been used extensively in malaria risk mapping and malaria control throughout the world.[17] The functionalities of GIS can help in developing malaria information system. At the microlevel, in village, malaria cases that can be identified to a specific coordinate and control measures can be easily determined by overlying topological map.[18] He recommended maps showing risk zone map can be used to select sites for control programs that could also help in their structure of parasite control component by defining the catchment area of clinical facility; as well, this information is useful for planning projected resource needs and the distribution/requirement of protectorate clinical facilities. Thus, capability of GIS is especially useful for planning, logistics, and operations of malaria control programme.[19] In the context of forecasting and control by integration of GIS with remote sensing technology, it is possible to develop real-time information system depicting potential flows in disease transmission, enabling the initiation of rapid response strategies.

In the current day circumstances, GIS is finding application in diverse fields including health,[20] and he 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.[19]

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. Hazard/risk maps have proven to be important tools for public health decision-making and priority setting for vector-borne diseases because they assist with the targeting of prevention and control efforts.[21] The spatial information obtained from mapping malaria hazard and risk 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 countries. This tool is useful for management strategy to allocate resources for preparing the needs for control of disease in high-risk areas of disease.

A national strategy for malaria elimination has been envisaged in prompting the development of the National Framework for

Malaria Elimination in India 2016–2030. The main focus of this Framework is to propel India on the path toward malaria elimination in a phased manner. Under this Framework, all states/UTs have been grouped into one of four categories based on their malaria burden. Specific objectives have been established for each of these categories and a mix of interventions will be implemented in each of them. Eliminate malaria nationally and contribute to improved health, quality of life, and alleviation of poverty. In line with the World Health Organization, Global Technical Strategy for Malaria 2016–2030, and the Asia Pacific Leaders Malaria Alliance Malaria Elimination Roadmap, the goals of the National Framework for Malaria Elimination in India 2016–2030 are eliminate malaria (zero indigenous cases) throughout the entire country by 2030 and maintain malaria-free status in areas where malaria transmission has been interrupted and prevent reintroduction of malaria.[22]

Objective

The study is based on API records (2006–2011) integrated into GIS and weighted overlay analysis to delineate malaria risk zones at macrolevel using village-level incidence.

MATERIALS AND METHODS

Study Area

Vadodara district is situated between 21° 49′ and 22° 47′ N latitudes and 72° 50′ and 74° 17′ E longitudes, occupying 7,550 sq km. area. The district has 12 Taluka with total population of 3,641,802. There are 1553 villages and 16 towns. The climate is characterized by hot summer and dryness in non-rainy season May is the hottest month while January is the coldest month. The annual rainfall of the district is 475.2 mm. About 95% of rain received during Southwest monsoon season from June to September [Figure 1].

Methodology

Weighted index overlay analysis is a technique for applying a common measurement scale of values to diverse and dissimilar 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. There is no standard scale for a weighted overlay method.

Epidemiological Data

Annual parasite incidence: The number of malaria cases per 1000 population per year is called the annual parasite incidence or API. The API represents the most broadly applied measure of risk of infection. Many health authorities rely on the API as the core measure of the risk of infection. The statistic is often used as the basis for comparing risk between communities, districts, provinces, and nations. The means of deriving the numerator for the API, "cases of malaria," vary a great deal. Comparisons of risk based on the API demand consideration of the sources and case definitions, for example, clinical diagnosis versus smear-confirmed diagnosis for reported total cases. The API numerator often represents a hybrid of programmed cell death and active surveillance methods and the relative contributions of each impact interpretation of the API. Data for API are collected from Malaria office Vadodara.

$$\begin{array}{c}\text{Annual Parasitic}\\ \text{Incidence}\left(\text{API}\right)\end{array} = \frac{\begin{array}{c}\text{Total no. of positive slides}\\ \text{for parasite in a year}\end{array}}{\text{Total Population}} \times 1000$$

RESULTS

The value of epidemiological indicator suggests that the overall incidence of malaria was very high throughout the

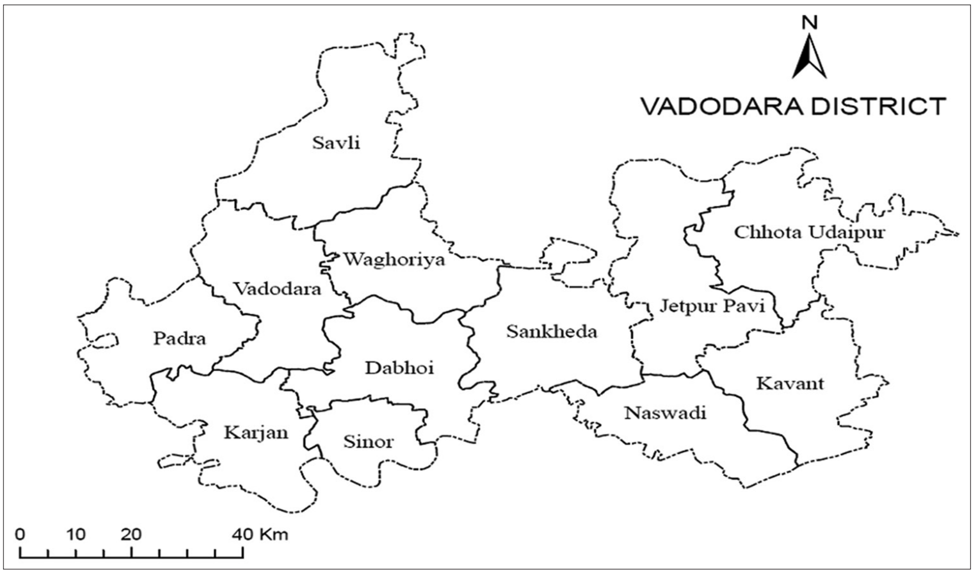

Figure 1: Study area

Table 1: API value aggregated at district level (2006–2011)

Taluka name	API (MAX) 2006	API (AVG) 2006	API (MAX) 2007	API (AVG) 2007	API (MAX) 2008	API (AVG) 2008	API (MAX) 2009	API (AVG) 2009	API (MAX) 2010	API (AVG) 2010	API (MAX) 2011	API (AVG) 2011
Chhota Udaipur	21.46	4.32	12.99	2.11	25.76	1.63	16.44	1.92	15.31	2.12	28.57	3.07
Dabhoi	24.23	3.59	6.67	0.93	6.88	0.37	5.88	0.41	7.71	0.55	3.82	0.39
Jetpur Pavi	31.58	1.84	4.88	0.70	4.76	0.36	2.83	0.19	3.82	0.28	5.08	0.20
Karjan	17.54	1.32	7.14	0.59	3.51	0.17	3.01	0.16	2.42	0.16	2.10	0.14
Kavant	12.43	2.10	8.69	1.16	4.56	0.58	2.98	0.30	12.22	0.87	5.84	0.71
Nasvadi	18.42	3.02	5.60	0.46	5.35	0.28	6.19	0.26	3.19	0.18	5.67	0.21
Padra	16.26	1.73	18.52	0.97	3.61	0.26	2.80	0.29	2.07	0.14	2.01	0.23
Sankheda	18.18	1.19	14.93	0.61	6.92	0.37	12.35	0.26	18.13	0.66	20.92	0.64
Savli	12.80	2.61	19.23	1.29	9.01	0.65	9.01	0.39	7.94	0.44	9.62	0.74
Sinor	7.00	1.16	2.37	0.54	7.00	0.36	2.00	0.18	1.43	0.22	0.97	0.16
Vaghodia	18.76	2.80	3.66	0.71	5.08	0.31	4.46	0.42	10.87	0.76	7.46	1.06
Vadodara rural	31.32	2.71	2.95	0.54	9.04	0.74	4.94	0.48	10.81	1.27	7.52	0.91

Computed from District Malaria Office, Vadodara, annual parasite index, API: Annual parasite index

district which can be owed to the high rainfall and flooding events in the year 2005 and 2006 due to which the water pools providing breeding sites for mosquitoes. As per the data [Table 1]. There are several pockets observed through spatial distribution, namely.

One in the central and southern parts of Chhota Udaipur, northern parts of Naswadi, Dabhoi, and southeastern part of the Vadodara Taluka, and central part of Savli Taluka. The highest API observed was around 32, in Mastupur Gamdi of the village of Vadodara Taluka and Chapargota of Jetpur Pavi. These are tribal areas of district. Apart from these, there are 59 villages in the district which have recorded API >10. The Chhota Udaipur Taluka has the more villages having the higher API followed by Dabhoi, Naswadi, Vadodara, Jetpur Pavi, Waghodia, and Karjan. 611 villages are having API >2.

The condition of year 2007 suggests that there was by the decline indices which can be attributed to intensive malaria control program and efficient a large slow down on the malaria cases.

Eradication measures undertaken *in lieu* of such high number of incidences in earlier years could have resulted into such changes.

But, it was still a matter of concern in the that 8 villages recorded API higher than 10 among which 4 were of Chota Udaipur 2 Sankheda, one each from Savli and Padra Taluka. While 235 villages are having API more than 2.

As observed in the year 2008 only three villages recorded API higher than 10 and only 107 villages are having API >2. This also suggests the effective malaria eradication program at the village level; the incidences appear to be controlled, except isolated villages, wherein the higher incidence may be attributed to migration.

The epidemiological situation of the malaria in the year 2009 seems to be continuously getting better as only four villages have reported API >10 and total 99 villages in scattered pockets of district had API >2. In tribal Chhota Udaipur Taluka, higher API persists in terms of disease burden.

The epidemiological situation of the malaria in the year 2010 seems to be stable as with reference to 2009 in terms of API value. The number of villages has increased from 4 to 13 which have reported API >10 and total 139 villages in scattered pockets of district are having API >2.

The situation in Chhota Udaipur Taluka continues to be the same. In this year, the dominance of cases in the tribal Talukas is still on higher side, and in addition, one village of Waghodia and Vadodara Taluka each records high API.

The epidemiological situation of malaria had shown a slight increase in the incidence of malaria in the district. The highest API observed was around 29 in the Ode village of the Chhota Udaipur with a total of nine villages with >10 API. Among this high incidence, seven villages are mainly in Chhota Udaipur and two are of Sankheda Taluka both tribal Taluka. 164 villages are having API >2, i.e., 45 more villages then as observed in the year 2010.

DISCUSSION

This requires modification in malaria eradication and control programs. Since malaria is a vector borne disease and closely associated to ecological and cultural conditions it becomes relatively difficult to control in the diverse nature wherein the climatic adaptations also continues with the living organism, thus the vector thus a temporal trend helps in identifying the pockets of endemic regions to the malaria.

The malaria risk zones identified by weighted sum overlay method in which all the spatial distributions of API were overlay and the values were summed up, thus higher the value higher will be the resultant API index [Figure 2].

On the basis of API as recorded during 2006–2011 from the villages of Vadodara district, it was figured out that 50% region of Chhota Udaipur Taluka has recorded continuously very high incidence of malaria and followed by the part of Sankheda and then Dabhoi Taluka.

This pattern suggests that during the past 7 years, several outbreaks in villages of district must have occurred, but the higher values of API suggested that region struggles to control the incidence. The disease burden has decreased in comparison to the status in 2006, but still, a considerable region is far above the desirable limit of the API and several vulnerable regions are there with low API and

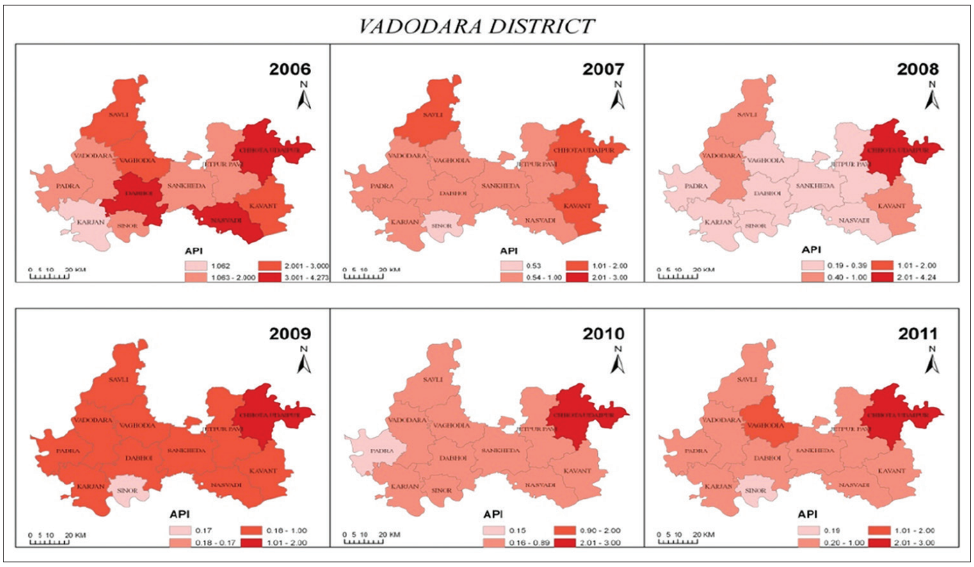

Figure 2: Spatiotemporal distribution of annual parasite index (2006–2011)

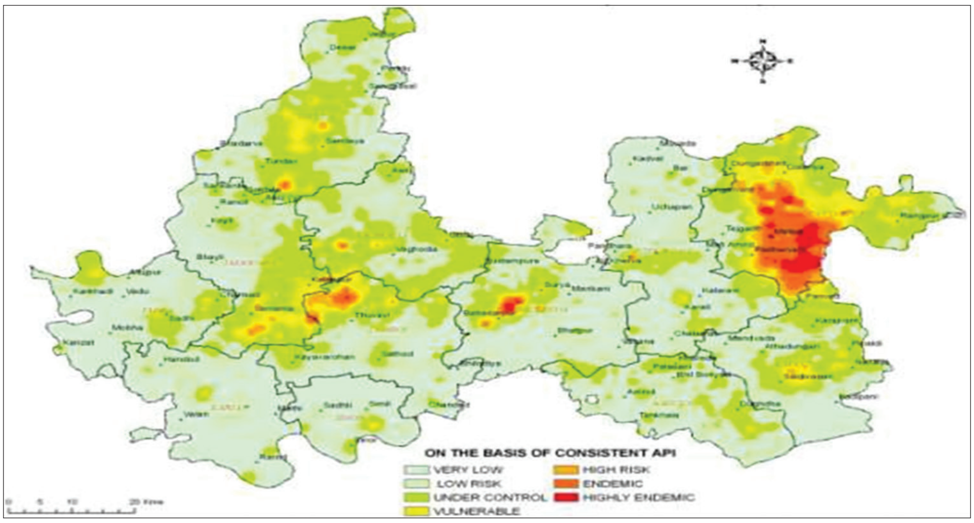

Figure 3: Malaria risk zone based on annual parasite index at village level (2006–2009)

chance of elimination of this disease in this region can be raised.

CONCLUSION

GIS-based malaria incidence mapping supports in risk mapping for analyzing spatiotemporal trends and assists health authorities to understand more about spatial and temporal distribution of the disease in their area. This information can help control programs and for identifying health and health-care facilities based on the requirement of each area. Such maps are essential and contribute to the reliable early warning systems. Health workers generally are unable to identify high or risk areas in the areas they operate so as to tailor interventions and do effective health monitoring. The geographical distribution of any major disease forms an important basis for locating appropriate interventions for its control and a means to monitoring their effectiveness [Figure 3].

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