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Diagnostic Features of Malaria Transmission in Nadiad Using Remote Sensing and GIS

M.S. Malhotra and Aruna Srivastava

Introduction

Nadiad taluka of Kheda district, Gujarat, is situated in western India. Epidemiological investigations demonstrate that malaria is endemic in the state. Kheda district showed the highest incidence of malaria in Gujarat state, with Nadiad taluka consistently being the most affected area. Occasional deaths have occurred due to falciparum malaria, although the area is constantly sprayed with residual insecticides. In 1981, a serious epidemic of P. falciparum malaria resulted in the deaths of 31 people in one village alone (Sharma et al. 1986).

An. culicifacies is the main vector of rural malaria. It breeds in stagnant water in fallow fields, rice fields, irrigation channels, field channels, and seepage water collection sites. During the monsoon season, high humidity favours malaria transmission, as the longevity of An. culicifacies increases.

A feasibility study using a geographical information system (GIS) was initiated in April 1993 to identify the specific factors responsible for high receptivity and vulnerability to malaria in Nadiad taluka. The aims of this study were to:

- Map the various geomorphological, physical, and climatic characteristics of the region;
- Develop a georeferenced database related to malaria; and
- Identify relevant factors having a direct or indirect bearing on malaria transmission in Nadiad taluka.

Materials and Methods

The economy of Nadiad taluka has been based predominantly on agriculture since 1966 (Chowdhary et al. 1983). The average annual precipitation is about 800mm, all of which falls during a rainy season of 35 days (Ashok and Nathan 1983).

Since stagnation of water for long periods of time is likely to create mosquitogenic conditions, the following factors related to water stagnation were

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taken into consideration: soil type, water table, irrigation, surface water bodies, topography, climate, drainage, and hydrogeomorphology.

Topological sheets at a scale of 1:250,000, showing topography and terrain of Nadiad, were obtained from the Survey of India, Dehradun. These sheets were incorporated with satellite imageries, and a composite map of Nadiad was drawn showing important physical features of the region, such as slope, forest/vegetation, rivers, streams, reservoirs, other water bodies, human settlements, roads, and so on. This map was used to extract the relevant features and specific characters of the region.

Findings

Soil Types

Data and maps on types of soil existing in Nadiad were obtained from the appropriate authorities. Soil zones were marked on the maps, which were then digitized. Four main types of soil are present throughout Nadiad taluka.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Number of Villages</th>
<th>Water Retention Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankhi Series</td>
<td>38</td>
<td>Medium</td>
</tr>
<tr>
<td>Drained, noncalcareous, fine loamy and mixed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratanpur Series</td>
<td>52</td>
<td>High</td>
</tr>
<tr>
<td>Noncalcareous, fine clay, mixed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matar Series</td>
<td>0</td>
<td>Low</td>
</tr>
<tr>
<td>Well drained, slightly saline, alkaline type, sandy loam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chaklasi Series</td>
<td>11</td>
<td>Low</td>
</tr>
<tr>
<td>Well drained, non-calcareous, course, loamy and mixed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Soil Types and Characteristics in Nadiad Taluka
In southwestern Nadiad, Ankhi and Ratanpur series of soil were encountered. These soils are comprised of loam and fine clay and are non-calcareous. As this area of Nadiad is located within an extensive irrigation zone that has a network of canals and drains, water stagnation is common. A small region in southern Nadiad is characterized by the Matar soil series. The Chaklasi soil series is also found in small area in the south, as well as in northern Nadiad.

**Water Table**

Subsoil water is an important factor for the creation of stagnant water pools. Shallow ground water can result in stagnant, humid marshy areas, which encourage mosquito breeding and survival.

Subsoil water has become shallower in several areas of the Nadiad region through the development of irrigation systems. In 1958, the year in which irrigation canals were first introduced into the area, no water tables existed above 1.5m from the surface during premonsoon. With the installation of the irrigation systems, the water table began rising, and by 1981, 475ha of land had water tables located at less than 1.5m from the surface. Similarly, the area with water tables located from 1.5 to 3.0m below the surface increased from 2,643ha in 1958, to 9,360ha in 1981. Other water table depths are shown in Table 2.

| Depth of water table from ground surface (m) | Area Covered | | | |
| --- | --- | --- | --- |
| | ha | 1958 | ha | 1981 |
| | % of total | % of total | |
| < 1.5 | - | - | 475 | 0.2 |
| 1.5 – 3.0 | 2643 | 0.9 | 9360 | 3.2 |
| 3.0 – 6.0 | 18058 | 6.1 | 83338 | 28.3 |
| 6.0 – 9.0 | 15277 | 5.2 | 33500 | 11.4 |
| > 9.0 | 257882 | 87.8 | 167207 | 56.9 |
| Total | 293860 | 100 | 293880 | 100 |
Topography
The Nadiad region is characterized by a generally flat topography, restricted natural drainage soils, and a semi-arid climate. The area slopes north-east to south-west, with an average gradient of about 1-1.600m towards the Gulf of Cambay. There are, however, a few isolated local high spots and ridges. Without the existence of an efficient water drainage systems, each of the factors mentioned above can lead to the creation of stagnant water pools, which, in turn, encourage the breeding and survival of mosquitoes.

Hydrogeomorphology
Two categories of geomorphology may be found in Nadiad. Flood plains are found near the shores of the Shedi river and its tributaries. This land feature has developed relatively recently, and its moisture content is very high. Alluvial plains exist throughout the rest of the Nadiad region. The moisture content of the Alluvial plains is relatively lower than that found in the flood plains.

Irrigation, Drainage, and Surface Water Bodies
The Mahi river is one of the major river systems in western India. In 1978, a reservoir was constructed on this river for irrigation. The command area of this irrigation system includes the southern half of Nadiad taluka. The abundance of water in irrigated areas is due to seepage, silting, and stagnation, creating innumerable breeding sites for mosquitoes. A thematic map showing details of the irrigation system was prepared and digitized.

Tank irrigation was one of the earliest systems of irrigation to be used in the Nadiad region. Irrigation tanks and ponds, when used together with canal irrigation, act as storage reservoirs. Excess irrigation water is diverted to these tanks, for use when canal sources become scarce.

Every village in the Nadiad region has at least one pond from which water is gathered. These ponds receive both rain and canal water. In an attempt to fight famine in the Nadiad area, the village ponds were deepened. While this has created a year-round supply of pond water, it has also created a high local humidity level conducive to heavy vector breeding. The information on pond location was extracted from topological sheets and remote sensing composite maps.

Climate
Climatic features such as rainfall, humidity, and temperature have a direct influence on the propagation of mosquitoes and their survival. These data were plotted to study the relationship between climate and malaria transmission.
Results and Conclusions

ARC/INFO was used to overlay eight maps, producing a composite map of soil type, water tables, topology,hydrogeomorphology, irrigation, drainage and surface water bodies, and climate. The resulting georeferenced data analysis divided Nadiad into four water-holding areas.

When this map was superimposed onto a map showing high, low, and average API (number of malaria cases per 1,000 population per year) of 5 years at the local level, however, the resulting picture is difficult to explain: high API villages do not show any visible correlation to the water holding capacity of the four areas of the composite map.

This result demonstrates that to establish determinants of malaria in Nadiad, it is necessary to analyze other data in addition to that generated by a study of water holding capacity. Additional parameters that could be examined include population movement, labour settlement, intervillage migration, rice cultivation, creation of borrow-pits that supports the breeding of An. culicifacies, the outreach of health services, and so on.

It was established that malaria was more prevalent in areas with high water tables, the presence of surface water, and canal irrigation systems, than in riverine villages. The former areas are more conducive to the breeding of An. culicifacies. Analysis of climatic data has demonstrated that during years in which the relative humidity (RH) was above 60%, malaria transmission was high, while during years when the RH was below 60%, transmission rates were low. Humidity is, therefore, seen as an important conditioning factor for vector presence, as it governs longevity and, therefore, the reproduction rate of An. culicifacies.

It may be noted that the Kheda district in Gujarat does not have a regular malaria transmission pattern. Ground water stagnation is more pronounced where the water table is shallow. In years with favourable climatic conditions, such as high rainfall levels and high humidity, malaria transmission increases within the nonimmune population, creating epidemic situations.

Because of population movement, migration, and poor surveillance, it is difficult to analyze the data at a micro or village level. GIS should, therefore, be applied to macrolevel analysis to:

• Bring out broadly the conditions conducive for vector breeding and malaria transmission, and
• Suggest integrated control methods that are both cost effective and sustainable.
References

