Tracking the malaria culprit

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Be it anopheline population dynamics, vector distribution, surveillance system to identify high risk periods and locations or malaria information system, GIS is an ideal tool in the monitor and control of malaria. This apart, GIS provides valuable information regarding distribution and interaction of disease risk factors, morbidity and mortality patterns and health resources allocation.

As a tool for analysis and decision making, GIS and remote sensing opened a new horizon for monitor and control of diseases. Information on landuse, water bodies, vegetation, forest cover and others can be used as data sets in GIS for mapping of disease receptivity and identification of risk factors. GIS offers new and expanding opportunities to look into disease epidemiology. Even when used minimally, these systems allow a spatial perception on the disease.

Malaria mapping across the world

Since 1987, Ames Research Centre at NASA has been conducting survey studies on the relationship of the important vector of malaria, namely, Anopheles albimanus to environmental variables associated with the regional landscape elements in southern Chiapas, Mexico (Rejmankova et al., 1992; Rodriguez et al., 1993). The studies revealed that flooded pastures and transitional swamps are two important land elements for providing larval habitats during the wet season. After flooding, these become potential vector breeding sites putting mosquito density at the peak. Satellite data were digitally processed to generate the map of landscape elements. GIS analysis was used to determine the proportion of mapped landscape elements surrounding villages where An. albimanus densities had been estimated. Stepwise discriminant analysis and stepwise linear regression revealed that transitional swamp and unmanaged pasture were the most important landscape elements in relation to vector abundance, the same as revealed by ground surveys. Also the villages with high and low vector abundance were distinguished with an overall accuracy of 90%.

In Pacific coastal plain of Chiapas, Mexico, GIS was also applied to track the dynamics of anopheline mosquito population (Pop et al., 1993). Landsat satellite thematic map (TM) imagery were analysed both for dry and wet seasons. A hierarchical approach was used to link the type of larval habitat and land cover units and make predictions for potential for low, medium and high anopheline production. GIS techniques were used to predict differences in anopheline production in villages. In California, rice fields producing high and low anopheline population could be identified with 90% accuracy nearly two months before peak larval season (Wood et al., 1991, 1992). Using GIS capabilities, buffer zones were created around the rice fields. The landuse/land cover within the buffer zones and in the surrounding areas in low and high anopheline producing rice fields was found to be quite different. Preliminary results also helped in the development of a sophisticated anopheline population dynamics model. In California, about 100 to 240 kha land is under rice cultivation, and therefore any conventional larval
survey is logistically impossible. The study reaffirms the need to develop such new technology for vector surveillance.

In Israel, between 1980 and 1990, there were more than 2,000 imported malaria cases, 87% of them being immigrants from Ethiopia. In spite of record rains in 1991-1992 following several years of drought, there was no local transmission. The GIS based surveillance system was used to correlate localised outbreak to specific breeding sites to target cost effective control measures (Kitron et al., 1992). Using GIS, distance between breeding sites positive for potential anopheline malaria vectors and population centre positive for imported malaria case was estimated. Since the five malaria vectors of the region have different flight ranges, the vector contributing most in transmission of malaria was identified. And breeding sites within the threshold level with location of migration centres were targeted for enhanced surveillance and intensive vector control activities. Such GIS based surveillance system is useful for identifying high risk periods or locations and increase the efficiency with the limited resources available.

Malaria information system (MIS) was used to prepare maps to identify malarious areas in KwaZulu/Natal province in South Africa. The parasite resistance, cross border population movement and agricultural development were identified as three main reasons to explain the rising trend of malaria. These maps were also useful in analysing other health situations.

While an epidemiologist working on malaria can otherwise bring out similar conclusions, GIS based analysis provides more accurate description of the land mass and its characteristics, seasonality, and the location and size of populations (Savigny and Wijeyaratne, 1955). A study was conducted in Kataragama in a highly endemic region of southern Sri Lanka. GIS based study brought out that malaria cases were clustered in particular households; and association of malaria risk is mainly linked to proximity of the house to the forest edge and source of water. Madeleine et al., 1999 showed a significant association between age-related malaria infection in Gambian children and environmental greenness. GIS has been used to plan malaria control programme in South Africa by Booman et al., 2000.

Indian experience

India ranks second in terms of occurrence of malaria in the world. Spatial malaria trend in India reveals varying levels of endemicity; most of the regions in the country have unstable malaria except north eastern region. In 1976, there was a countrywide resurgence contributing 6.45 million cases of malaria (NMEP, 1977). In 1977, to contain malaria, Government of India implemented the modified plan of operation. In early 80s, malaria cases got stabilised to about 2 million but later an increasing trend is being observed and presently about 2-3 million cases are being reported annually. More alarming is the increase of killer malaria, viz. *the falciparum malaria* which constitutes 30-40% of the total malaria cases. WHO's Revised Malaria Control Strategy laid emphasis on selective and sustainable integrated control measures. These are situation specific and need a detailed knowledge of local area (WHO, 1993). In spite of several survey reports, large areas still remain unexplored (Rao, 1984; Nagpal and Sharma, 1995). The terrain system has undergone radical ecological change due to the developmental activities resulting in change in disease and vector dynamics. There is a need for continuous monitoring vis-à-vis ecological changes for control measures to be effective. Traditional survey techniques are time consuming and labour intensive and these in no way cope up with environmental changes. Recently, in India, Malaria Research Centre has conducted studies using GIS for

![Thematic Maps and Integration](image_url)

**Figure 1:** a) Thematic maps of Nadiad taluk, Kheda district, Gujarat used in the study.

b) Overlaying and integration of thematic maps and comparison with API
decision support in malaria control which are described in the following paragraphs. Much like the abilities of lab systems to make clinicians aware of ‘panic values’, GIS will provide the same ‘early warnings’ to suggest that the clinicians investigate environmental ‘place’ factors that could be contributing to patients’ symptoms as well as in helping patients make life changing decisions that could impact their health in a more direct way.

i) Mapping malaria receptivity in rural areas and identifying risk factors

Nadiad taluk in Gujarat, comprising of 100 villages and that witnesses unstable malaria and periodic epidemics, was selected for the study. Parameters such as water table, water quality, hydro-geomorphology, soil type, relief, irrigation channels, etc., were selected, using topo sheets and satellite imageries and thematic maps of these parameters were prepared. Each map was divided into 2-3 categories of low, medium and high and weights were assigned according to favourable conditions for vector breeding. These maps were sequentially overlaid and integrated. The composite map resulted in 13 contours (Figure 1). Preparation of maps, analysis and integration was done using ARC/INFO 7.1 GIS software.

Contour 1-12 falling in non-irrigated tract exhibited 95% matching with the average of five years of Annual Parasite Incidence (API, number of cases per thousand of population per year) of malaria, i.e. the ground realities. Contour 13, an irrigated area did not show an obvious matching with occurrence of disease in that period, but the ground verification resulted in complete reconciliation of cause and effect relationship in explaining malaria epidemiology in the region.

The study revealed that the parameters for high malaria in villages of Nadiad were - high water table, specific soil type, irrigation and water quality (Srivastava et al., 1999). The technique for mapping any disease receptivity is very useful and can be used for appropriate control measures.

ii) Malaria information management system for urban areas

Urban malaria control is based upon recurrent anti-larval measures at all breeding sites and malaria treatment through passive case detection. For efficient planning, implementation and evaluation of urban malaria control, an attempt has been made to develop an information management system based on GIS (Srivastava et al., 2001a). The system was developed in collaboration with State Health Authority, Tamil Nadu, using Arc/Info GIS software and the analysis was done using ArcView 3.1. This was implemented in Dindigul Municipality on World GIS day in 1999. Dindigul is the district headquarters having a population of about 0.2 million. The town had 8 municipal divisions and 48 wards (Figure 2).

Each ward and the street of the Dindigul town was digitised and assigned a code. Ward-wise and street-wise attribute information on 33 parameters which consisted of ward area, population, number of slums, slum population, street name, number of houses in each street, breeding sources, e.g., wells, overhead tanks, tap-pits, ponds and street-wise/ward-wise malaria profile was attached using GIS software.

Some of the basic functionalities of the system developed are given below:

a) Instant information retrieval:

Since the attribute information is attached to wards and streets, a click of the mouse on the respective geographic unit retrieves the information attached.

b) Zoom:

Any geographic unit can be selected and zoomed in, and from a macro unit one can reach at the micro level unit. For example, if a ward is selected and zoomed in, one can reach the streets and from the streets to the houses. Even house-wise information such as name of the house owner, number of family members, their age and sex, malaria history, drug resistance status, etc., can be attached.

c) Overlaying attributes:

Every breeding site such as wells, over head tanks, outside storage tanks, inside storage tanks, tap pits,
etc., were mapped. Overlaying and integration of maps of each breeding site can estimate breeding potential in an area.

d) Situation analysis:
It is also possible to study malaria dynamics both in space and time. One can identify the wards/streets where mosquito vector/larval population or malaria incidence has increased. By overlaying the breeding sources, it is possible to identify specific problematic breeding site to implement situation specific control measures.

As soon as new data is entered or old data is updated, revised maps are dynamically generated and the GIS is capable of identifying the trouble spots.

Once the basic infrastructure is ready, it is easy to convert it to surveillance system for any other disease, viz., filaria, dengue or Dengue Haemorrhagic Fever (DHF). One needs to replace malaria data by other disease data and add a few disease determinants.

iii) Mapping of distribution of malaria vectors and other Indian anophelines
Out of the total 58 species of Indian anophelines, six are major vectors of malaria, viz., An. culicifacies, An. fluviatilis, An. stephensi, An. dirus, An. minimus and An. sundaicus in different ecological settings. A GIS based technique has been evolved to map Indian anophelines including malaria vectors (Srivastava et al., 1998, 2001b, 2004a). An example of An. minimus, a forest fringe species, is given here.

An. minimus - a species of forest fringe areas
Along the foothills of Himalayas, from Uttar Pradesh to northeast India, An. minimus has been the most important vector of malaria. Ecological parameters viz., forest cover, rainfall, altitude, soil type and temperature mainly govern the distribution of the mosquito species. Thematic maps on these parameters published by the National Thematic Mapping Organisation (NATMO), Govt. of India on 1:6,000,000 scale were digitised. Digitisation, overlaying and analysis were done using Arc/Info and Arc/view GIS software.

Each reported distribution location was mapped on thematic maps to decipher the ecological value at that point. A matrix was formed to represent favourable set of values for species existence. A mathematical model was developed to extract the range of each parameter and integration. The resultant map after integration of favourable areas in thematic maps using GIS predicted the areas favourable for An minimus (Figure 3). The results were validated by reported distribution and carrying out precision field surveys in four states namely, Uttaranchal, West Bengal, Assam and Meghalaya at nine locations, and amazingly, An. minimus could be collected from all the locations.

In Banbasa of Champavat district of Uttaranchal, after 1950s, the species was reported to have disappeared, while in Dhubri of Assam state, it was not reported in earlier entomological surveys. But in both the places An. minimus was encountered. Besides validation of GIS prediction, reappearance of An. minimus at Banbasa and first reporting from Dhubri were established. GIS predicted precisely the location in these districts to conduct entomological surveys where the species could be found.

Activities could be limited to the favourable areas for cost effective control of the disease.

The technique developed to prepare map distribution of Indian Anophelines can be used to delineate the areas favourable for any species of flora and fauna, which is very useful for precision surveys. The technique is fast and can be easily duplicated in other parts of the country/world. For any disease, once the vector distribution is known, species specific control measures can be formulated in cost-effective manner.

For an effective vector borne disease control, RS can help in quick data generation and GIS can provide valuable information regarding distribution and interaction of disease risk factors, morbidity and mortality patterns and health resources allocation.

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References


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