3

Epidemiology

3.1 Remote Sensing and Geographic Information Systems

3.1.1 Regional Level Mapping of Malaria Vectors using RS and GIS in North-eastern States in India to Develop Strategic Plan for Malaria Control

We analysed the IRS-IDLISS-III satellite image datasets of two districts of Assam, Sonitpur and Nagaon. Unsupervised image classification of the images taking 100 cluster classes was done, and finally a base layer with four classes, i.e. land use/land cover (LULC) classes of semi-evergreen; moist deciduous; shrubs and grassland; and non-forest area were generated (Fig. 3.1.1). Water bodies, tea gardens and settlements were extracted out from FCC images of each district, and were mosaiced with the base layer for final LULC map generation. Area under different classes was calculated. Sonitpur is mainly occupied by moist deciduous forests followed by tea gardens, shrubs and grassland. Semi-evergreen forests were found to occupy very less area.

"Significant correlation was observed between presence of tea garden and annual parasite index"

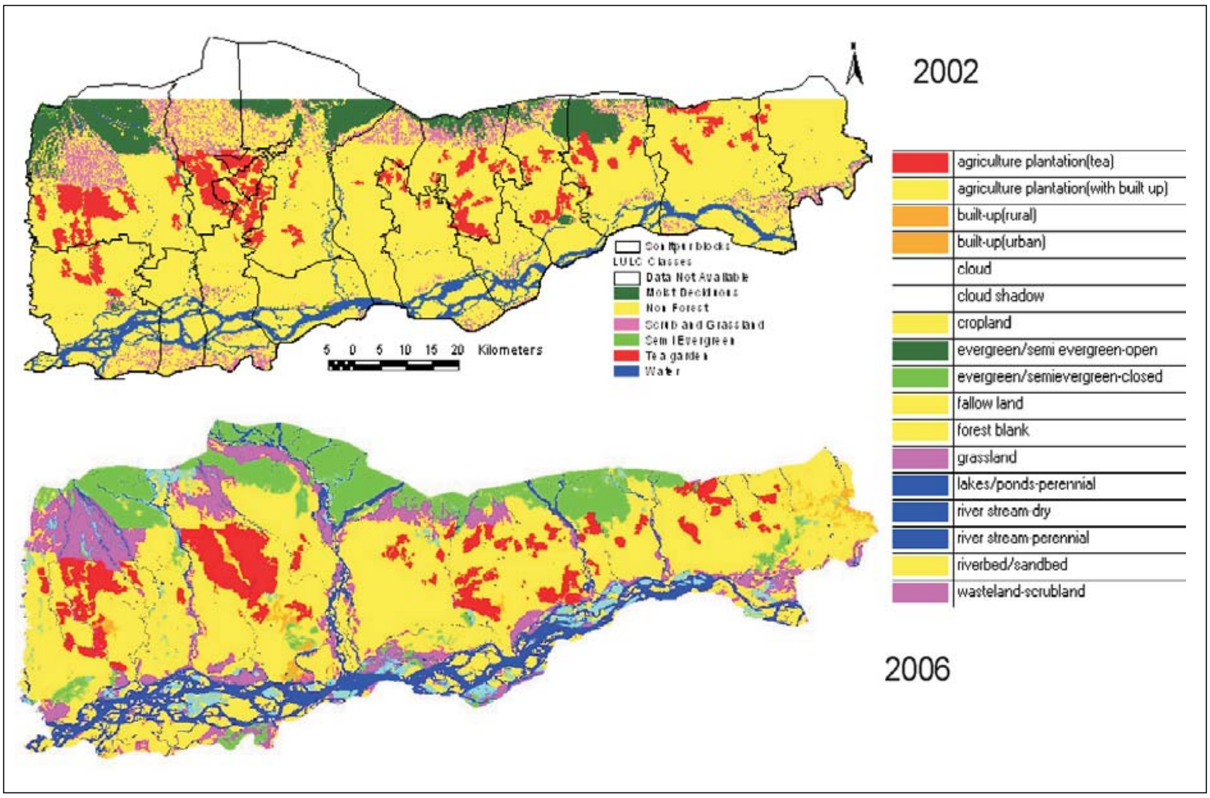

Fig. 3.1.1: Classified land use/land cover images of Sonitpur district, Assam

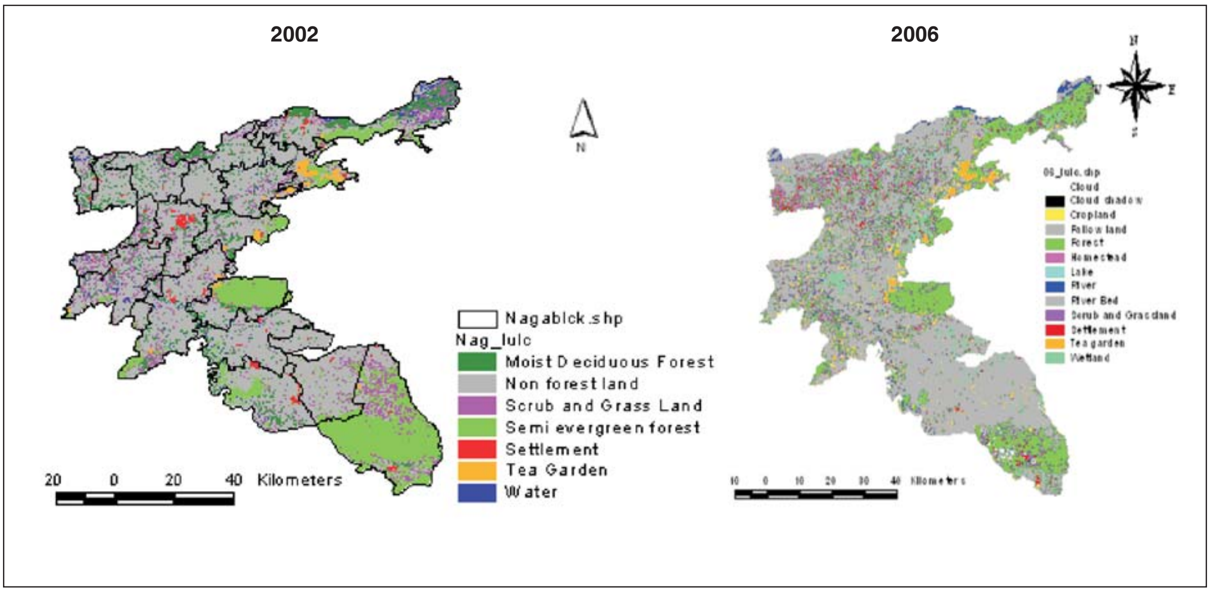

Fig. 3.1.2: Classified land use/land cover images of Nagaon, Assam

In Nagaon, area under different classes, as estimated by satellite images of the year 2002 and 2006 was compared. It was found that nearly 6% area was deforested and there was an increase in the area under tea gardens and settlements (Fig. 3.1.2).

"The presence of An. minimus in bordering areas was predicted using GIS"

Field surveys were carried out using Gramin Handheld GPS instrument for ground truth data (Fig. 3.1. 3). Daily survey track route and way points were recorded along with the landuse/land cover information. Track points and way points were overlaid on the classified satellite image for validation of land use/land cover classes and the errors were rectified accordingly. Parasitological and entomological data were also collected during the surveys.

Fig. 3.1.3: Field surveys in Nagaon, Assam

Malaria data for the two districts were obtained from District Malaria Office and PHCs, various epidemiological indices, such as API, SPR, SFR, etc. mapped for GIS were analysed. A significant correlation was found between the presence of tea gardens and API. The study is in progress.

3.1.2 Micro Level Mapping of Malaria Vectors using GIS in Bordering Districts of Assam and Arunachal Pradesh in India to assist Malaria Control

Digital datasets of IRS-1D LISS-III satellite image of 2002, provided by DRL, Tezpur, were used in this study. Unsupervised image classification was done, a base layer with four LULC classes of semi-evergreen; moist deciduous; scrubs and grassland and non-forest area was generated (Fig 3.1.4). Water bodies and tea gardens extracted out from the satellite images were mosaic with the base layer for final LULC map generation. Land classification

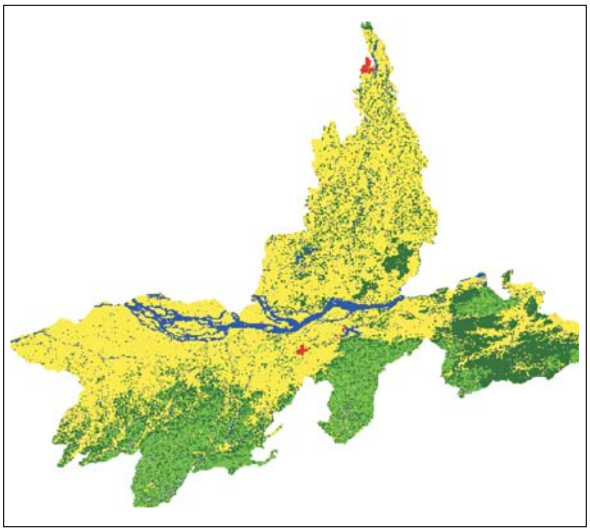

Fig 3.1.4: Classified image of Kamrup, Assam

shows about 7.5% area, having moist deciduous forest and tea garden; semi-evergreen forest is found to be the least.

Field Survey

The survey was carried out between April and May 2007 in District Sonitpur, Assam. Due to rains, heavy breeding was observed in the road side pits. The team carried out the entomological (hand catch, night collection) and parasitological (active blood smear) data collection (Fig. 3.1.5). During hand catch, malaria vector mosquitoes, viz. *An. culicifacies*, *An. fluviatilis* and *An. annularis* were found along with *Aedes* mosquitoes. The temperature recorded was between 22.8 and 32.7°C, and humidity ranged between 65 and 75%. Seven PHCs were surveyed in May 2007, out of seven PHCs as per records highest malaria and deaths were observed in North Jammu-guri followed by Charali, no death was recorded in Bihaguri and Balipara. Highest *Pf*% about 70 was observed in Dhekiajuli followed by Behili PHC. About 588 mosquitoes were collected and among them 75 (13%) were gravid and 158 (26.5%) were semi-gravid. Out of 106 slides collected, five were found positive out of which four were *Pf*.

3.1.3 Application of GIS to Map Distribution of Malaria Vectors and to Develop Disease Surveillance System in Jodhpur Cantonment Area

The study was conducted in Gandhinagar Cantonment area in Gujarat (Fig. 3.1.6). Adult mosquitoes and larvae were collected from Sectors 1–5 and civil area (Sector 6). Highest indoor per man hour density was observed in

Fig. 3.1.6: Gujarat state showing the study site

Fig. 3.1 5: Entomological and epidemiological surveys in Sonitpur, Assam

Sector 4, followed by Sectors 1 and 5. No anopheline mosquito was found in Sectors 2 and 3. *Culex* per man hour density was highest in Sector 1, followed by Sector 4. *Culex* mosquitoes were collected from all the sectors. In outdoor collections, no anopheline mosquito was collected. A few number of *Culex* was also collected. Larval density was found highest in Sector 4, followed by in Sector 5.

GIS Model for Gandhinagar

Entomological data, viz. adult indoor and outdoor density of *Anopheles* and *Culex*, and larval density was attached to the sectors on the digitized maps of Gandhinagar. A click at these sectors retrieves information related to that particular sector (Figs. 3.1.7 to 3.1.9). Greatest advantage on GIS model is that once the basic infrastructure is ready, any information can be updated or attached to the maps for quick retrieval and fast dissemination, and decision support in malaria control.

"The GIS model can be attached to maps can be useful for quick retrieval and fast dissemination & decision support in malaria control"

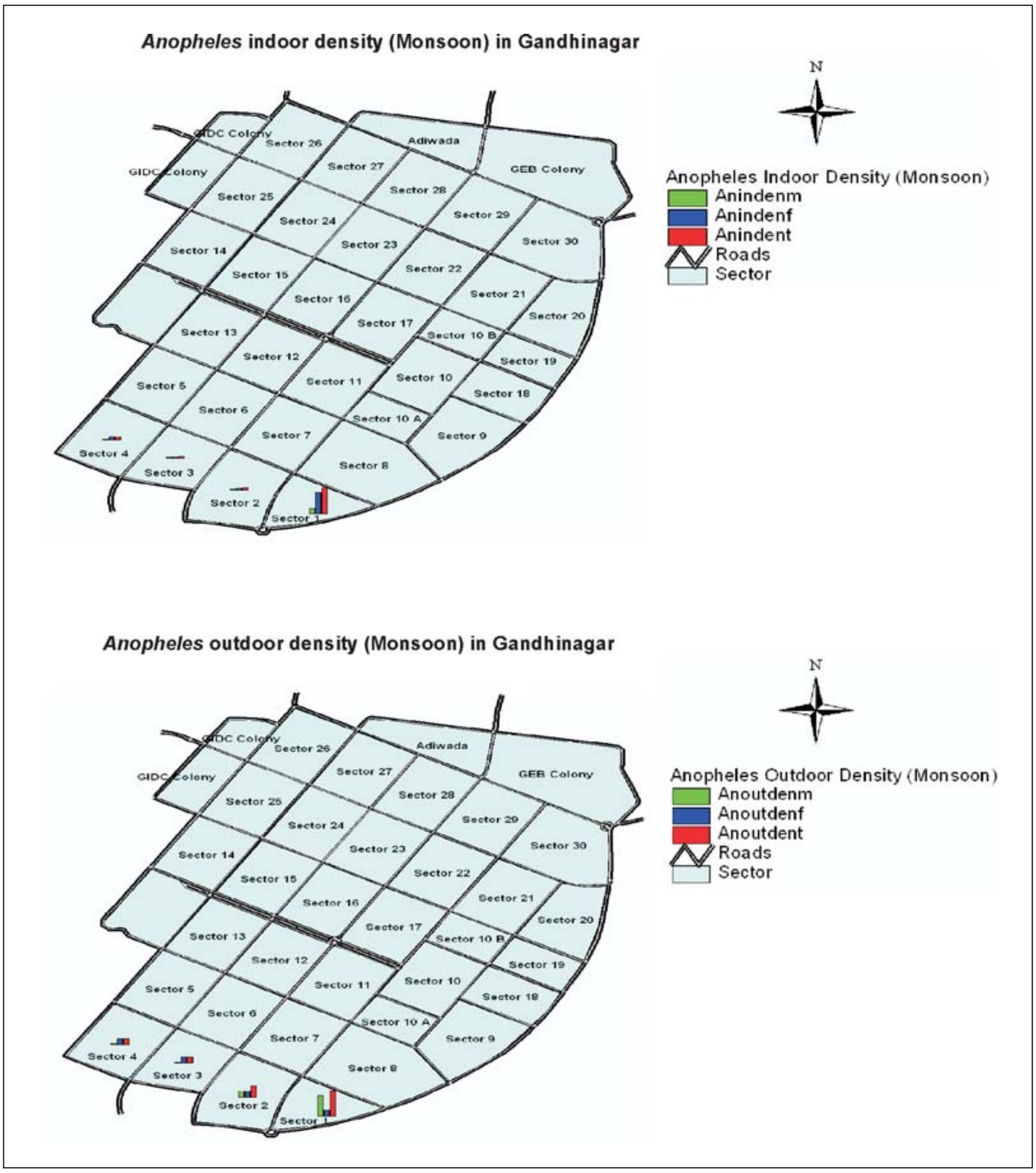

Fig. 3.1.7: Density of *Anopheles* mosquitoes in indoor and outdoor in Gandhinagar (2007)

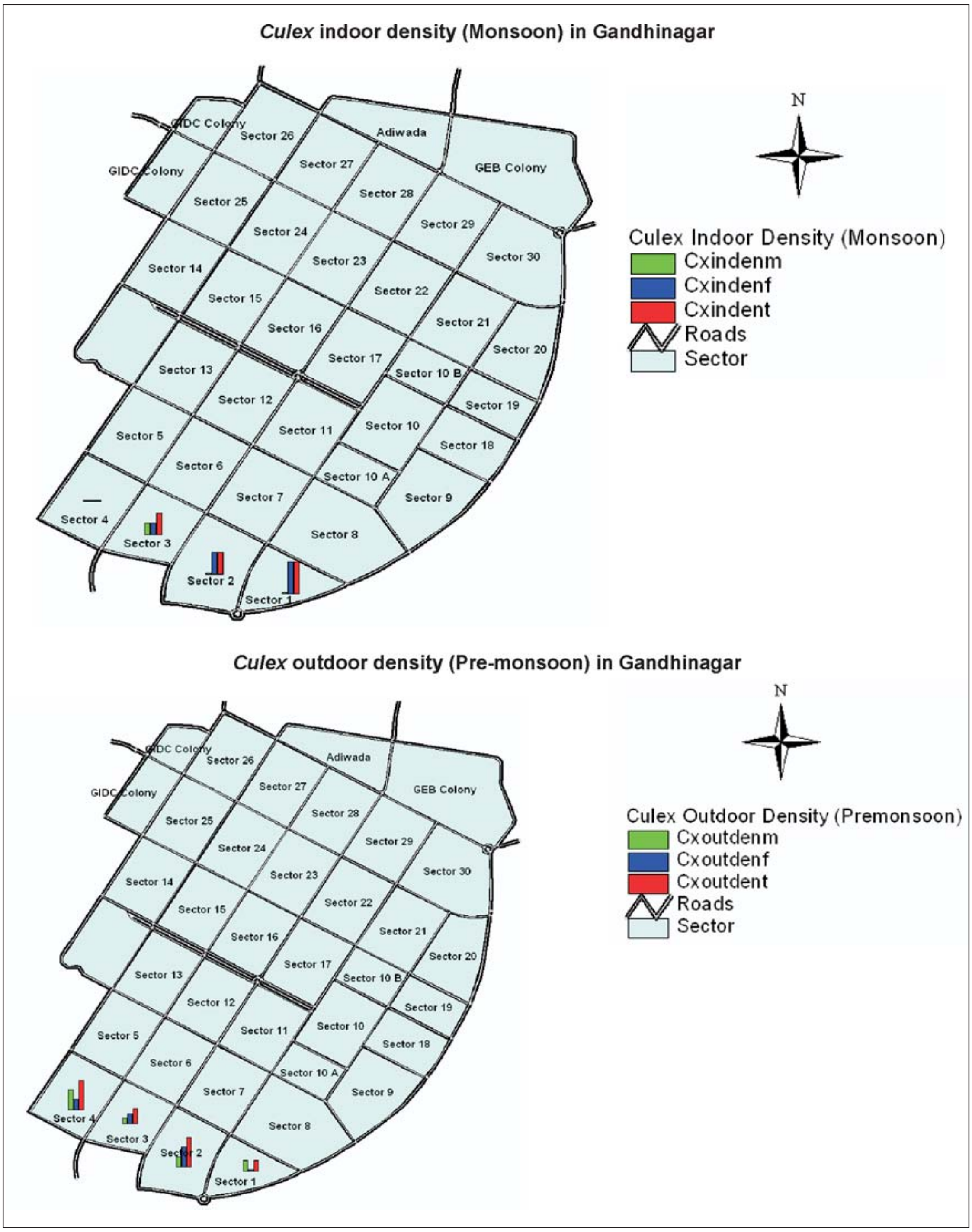

Fig. 3.1.8: Density of *Culex* mosquitoes in indoor and outdoor habitats in Gandhinagar (2007)

3.1.4 Retrospective Study on Chikungunya Outbreak in India

A retrospective study on chikungunya outbreak in India was initiated during 2007 in five states, viz. Delhi, Madhya Pradesh, Orissa, Maharashtra and Kerala (Fig. 3.1.10). Seven questionnaires, namely household survey-Q1A; information of all household members -Q1B; knowledge, attitude, belief, practice regarding chikungunya fever prevention & control -Q1C; patient inventory-Q1D; mortality in household-Q1E; health facility survey-Q2; and stakeholder interview-Q3 were filled up from urban and rural areas of each state except Delhi from where only urban areas were taken (Fig. 3.1.11).

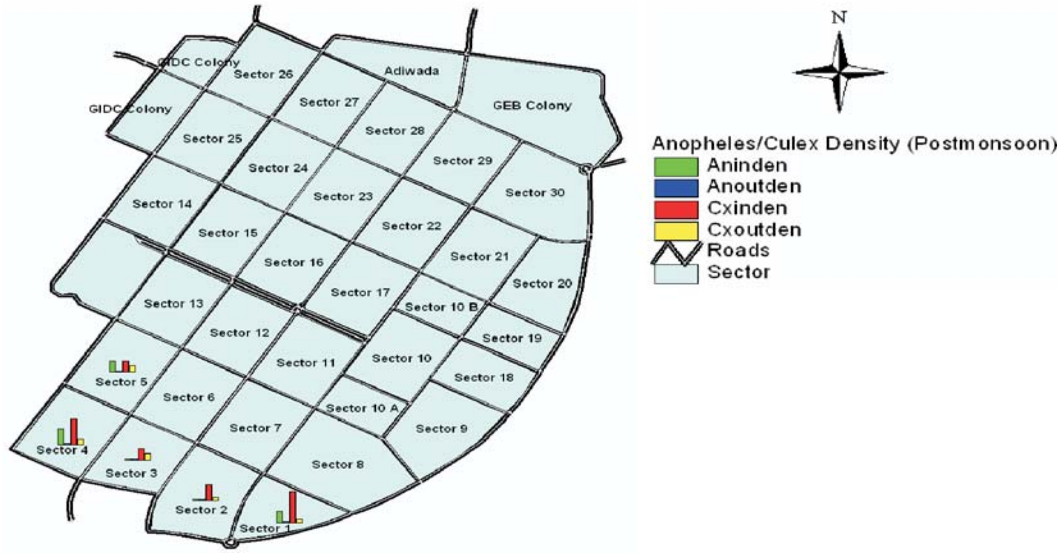

Fig. 3.1.9: *Anopheles* and *Culex* post-monsoon density in Gandhinagar (2007)

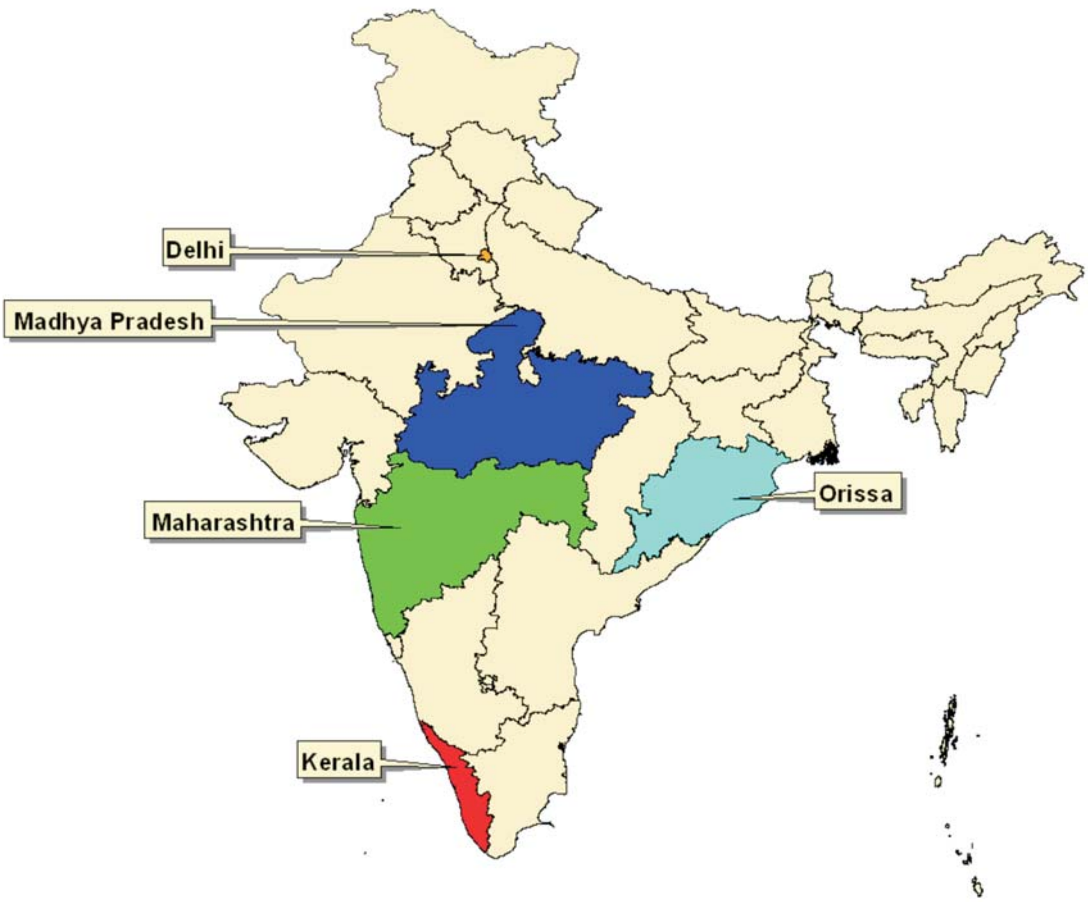

Fig. 3.1.10: Study sites selected for the retrospective study on chikungunya outbreak in India

Fig. 3.1.11: Filling up of the questionnaire

The highest incidence districts identified were: Sundargarh in Orissa, Latur in Maharashtra, Betul in M.P., Alappuzha in Kerala, MGF Zone and Dilshad colony in New Delhi. The lowest incidence districts identified were Ganjam in Orissa, Ratnagiri in Maharashtra, Katni in M.P., Kannur in Kerala and Sadar Paharganj, Najafgarh zone and Dwarka in New Delhi. Thus, a total of five states, 10 districts, 20 sub-centres, 20 urban wards and 2000 households each from urban and rural areas were covered. All filled up questionnaires from different states were analysed at NIMR.

"Orissa appeared to be the most ignorant state as regards the knowledge, attitude, belief and practices for chikungunya fever prevention & control"

Orissa appeared as the most ignorant state as far as knowledge, attitude, belief and practices for chikungunya fever prevention and control was concerned. Loss of man days/school absenteeism per attack was mostly recorded as 5–10 days and the symptoms were mainly recorded as fever, headache and bodyache. Many patients told the duration of treatment as 5–10 days and the expenditure on treatment and food was mostly ≤Rs. 500 and ≤Rs. 250. Besides, the study revealed that the facilities for chikungunya case management did not exist in any of the surveyed hospitals of Orissa.

Maharashtra appeared as the second most ignorant state regarding knowledge, attitude, belief and practice for chikungunya fever prevention and control. The average loss of man days/school absenteeism was more than 15 days. Symptoms were mainly recorded as fever and bodyache, and most of the patients took treatment for more than 15 days. In some families of Maharashtra, many members suffered from the disease simultaneously and on an average the expenditure on treatment was high. Chikungunya case management facility was provided by all the health facilities surveyed during this study.

In Madhya Pradesh, most of the houses were *Kuchcha* type especially in rural areas (Fig. 3.1.12). In some high incidence areas, air coolers were found. General sanitary conditions around most of the urban houses of the highest incidence area were found good. Water storage containers mostly used were cement tanks, metal tanks, overhead tanks and buckets (Fig. 3.1.13). Re-

Fig. 3.1.12: *Kuchcha* houses in Madhya Pradesh

Fig. 3.1.13: Breeding sources in Madhya Pradesh

garding other water collection in the houses/surroundings, mostly water for animals and pet bowls figured out. As far as emptying/drying of all water containers was concerned; some residents said that they did on weekly basis while others said that they did once in a while. Loss of man days/school absenteeism was mostly recorded as 5–10 days. Symptoms were mainly recorded as fever and arthralgia. The duration of treatment recorded was >15 days in most of the cases. Treatment expenditure was mostly ≤Rs. 500 and expenditure on food was ≤Rs. 250. Majority of the patients in Madhya Pradesh didn't receive any information of treatment from local hospital and private agencies/doctors. Chikungunya case management facility was provided by all the health facilities surveyed in Madhya Pradesh.

In Delhi, most of the houses were *Pucca* types and had air coolers. General sanitary conditions around most of the houses were found good. Water storage period in some areas was for 3–6 and >6 days. The key containers in Delhi were overhead tanks, underground tanks, ground level tanks and buckets (Fig. 3.1.14). In the highest incidence areas, emptying/drying of water containers was mostly done on weekly basis. Migration has been featured out as a major problem in Delhi. Loss of man days/school absenteeism was mostly recorded as 1–5 days in the highest incidence areas. Symptoms mostly recorded were fever and headache. Duration of treatment in the highest incidence urban area was 1–5 days. Treatment expenditure was mostly ≤Rs. 500 and on food ≤Rs. 250. Chikungunya case management facility was not provided in the MCD Hospital surveyed during the study.

In the urban areas of the highest incidence district of Kerala, more people were found residing in *Kuchcha* houses. In the urban areas of the highest incidence district, very few

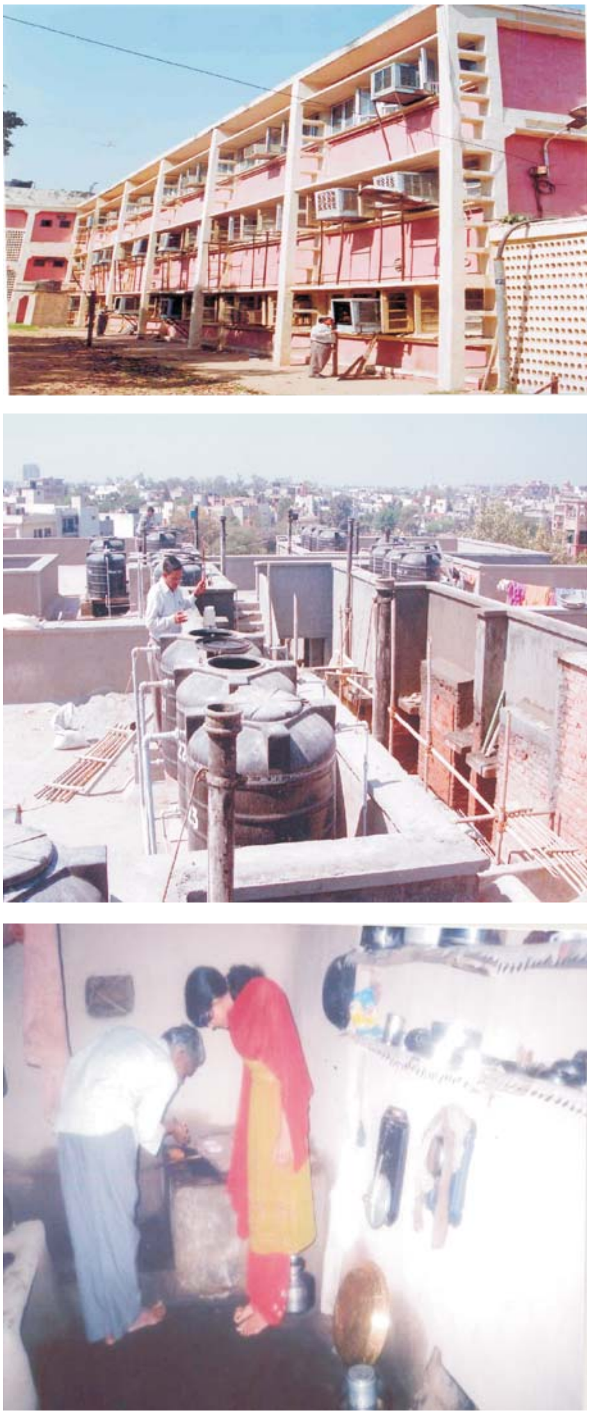

Fig. 3.1.14: Mosquito breeding sources in Delhi

Fig. 3.1.15: Water collections supporting mosquito breeding in Kerala

households had air coolers, but in the low incidence urban areas under the lowest incidence district, all the houses had air coolers. Water storage containers mostly used were: overhead tanks, plastic drums and buckets. Regarding other water collection in the houses/surroundings were mostly troughs for drinking and coconut shells figured out (Fig. 3.1.15). Most of the respondents from Kerala knew answers to the questions related to knowledge, attitude, belief and practice for Chikungunya fever prevention and control. Loss of man days/ school absenteeism was mostly recorded as >15 days. Symptoms were mainly recorded as fever and bodyache. Duration of treatment in the highest incidence urban area was >15 days; while in rural areas it varied from 5–10 to 10–15 days. Treatment expenditure was mostly ≤Rs. 500 and on food ≤Rs. 250. Majority of the patients in Kerala received information for treatment from local hospitals and other sources. Chikungunya case management facility was provided by all the health facilities surveyed in the highest incidence district.

3.1.5 Studies on the Epidemiology of Urban Malaria in Mega, Medium and Small Cities of India

With the objective to study magnitude of the problem of urban malaria in mega, medium and small cities of the country, to measure the level of malaria transmission in selected cities and to develop a cost-effective control strategy in Integrated Vector Management (IVM) mode, a study was initiated in three cities, namely Ajmer, Rajasthan (small city), Visakhapatnam, Andhra Pradesh (medium city) and Delhi (mega city).

Major problem for malaria in all the three urban areas, viz. Delhi, Visakhapatnam and Ajmer was found to be the migration of population. In Delhi, most of the migration is due to labours congregations from endemic areas for constructions of housing societies, malls, roads, etc. In Visakhapatnam, migration is due to ports and industries and Ajmer being a religious places for both Hindus and Muslims attracts many tourist visitors.

Most of the malaria cases were recorded by private hospitals. In Delhi, during 2006–07 (till September), MCD recorded 364 cases, whereas from 19 laboratories about 300 cases were recorded. In Ajmer, during 2006–07 (till June) Municipal Corporation recorded 33 cases whereas a total of 120 cases were recorded from six laboratories. The Municipal Corporation, Visakhapatnam recorded 1610 cases during 2006–07 (till June) whereas, five laboratories recorded 1351 cases (Fig. 3.1.16).

A survey done by the National Institute of Malaria Research revealed paradigms having highest malaria cases. In Delhi, it was mainly low income group followed by industrial labour; in Ajmer, it was recreation centre (Urs

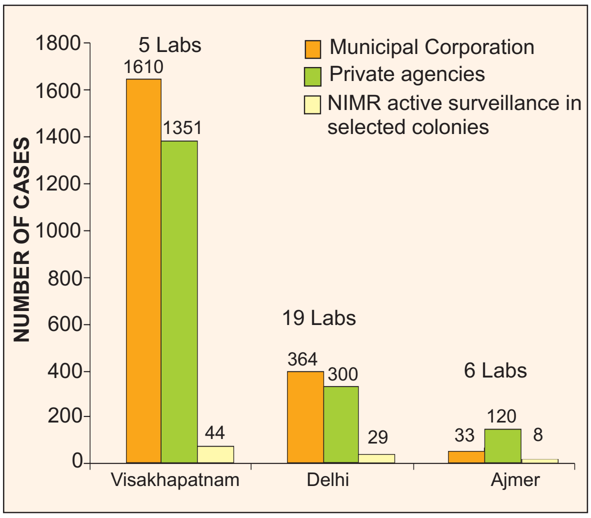

Fig. 3.1.16: Malaria burden in mega, medium and small urban cities (2006–07)

Mela Haz); and in Visakhapatnam, it was low income group followed by transport. There are around 2000 registered hospitals, labs, clinics in Delhi, 54 in Visakhapatnam and 14 in Ajmer. Therefore, the actual number of cases

> *"The actual number of malaria cases could be much higher than recorded by Municipal Corporation in urban areas"*

could be much higher than recorded by Municipal Corporation. The transmission period in Delhi was from July to November, in Ajmer from August to October, whereas in Visakhapatnam it is from June–July and October–November. GIS mapping revealed that in

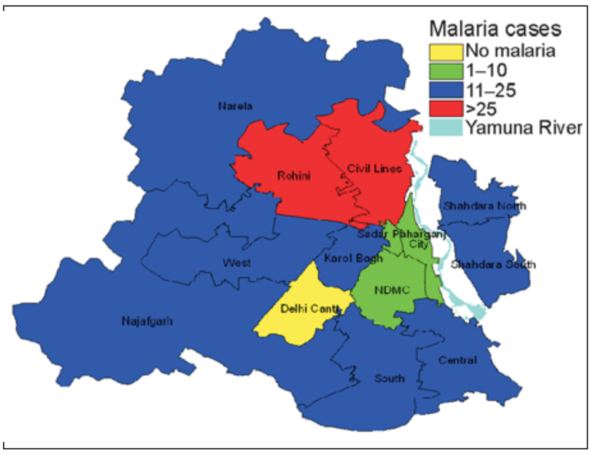

Fig. 3.1.17: GIS mapping of malaria cases during 2006 in Delhi

the year 2006, malaria was recorded from 13 out of 14 zones of Delhi (Fig. 3.1.17). *An. stephensi* and *An. culicifacies* were recorded from Delhi and Ajmer but only *An. stephensi* was recorded from Visakhapatnam.

In Delhi, the man hour density of *An. stephensi* was highest in July, in Ajmer, it is in November and July, whereas in Visakhapatnam it is in September. In Delhi, the man hour density of *An. culicifacies* was highest in June to Au-

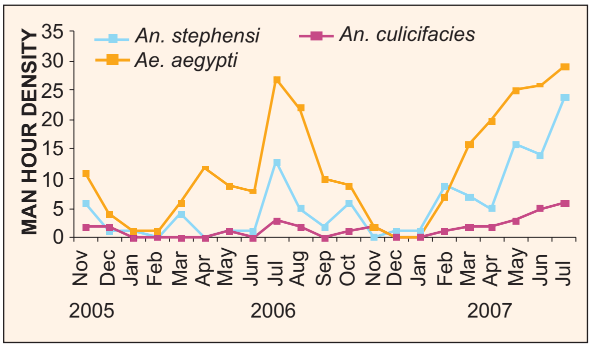

Fig. 3.1.18: Man hour density of *An. stephensi*, *An. culicifacies* and *Ae. aegypti* in Delhi (November 2005 to July 2007)

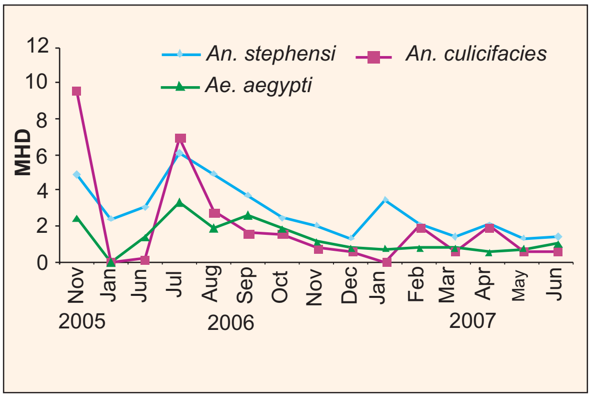

Fig. 3.1.19: Man hour density of mosquitoes in Ajmer (November 2005– June 07)

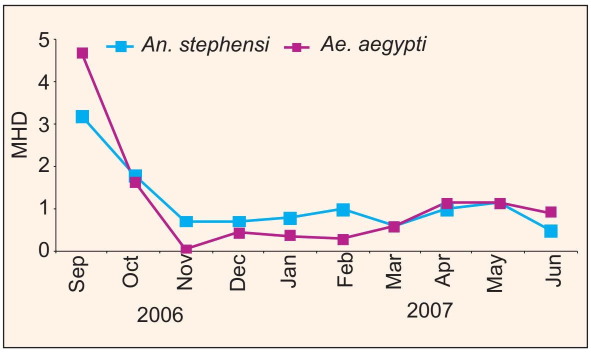

Fig. 3.1.20: Man hour density of *An. stephensi* and *Ae. aegypti* in Visakhapatnam (2006–07)

gust, whereas in Ajmer in July to September (Figs. 3.1.18 to 3.1.20).

Peak biting time of *An. stephensi* on human/animal bait was 2200 to 2400 hrs in Delhi; 0200 to 0400 hrs in Ajmer; and 2000 to 2200 hrs & 0100–0300 hrs in Visakhapatnam. The key containers supporting breeding of vectors of malaria, dengue and chikungunya are overhead tanks, tyre dumps and underground tanks in Delhi; ground cement tanks and tankas in Ajmer; and ground cemented tanks, tyre dumps and OHTs in Visakhapatnam (Fig. 3.1.21).

Fig. 3.1.21: Mosquito breeding habitats in Delhi, Ajmer and Visakhapatnam

Very high breeding of *Ae. aegypti* was recorded from all three areas. It is noteworthy to mention that *Ae. aegypti* has not been recorded for more than one decade in Ajmer. From all the three areas, suspected and confirmed chikungunya cases were recorded in 2006.

The health seeking behaviour survey showed that the community in all the three areas has limited knowledge about the source of vector breeding. Nobody knows about the insecticide-treated bednets. Most of the community (70–100%) is using coils and mats as mosquito repellents.

3.1.6 Identification of Epidemiological Risk Factors of Malaria for Development of Strategic Action Plan for Malaria Control in Problematic Districts of Karnataka

This ICMR sponsored project was continued to identify epidemiological and ecological risk factors of malaria in canal irrigated areas of Upper Krishna Project (UKP) area, and to validate the detection of landscape features in southern Karnataka. Based on village-wise data of past three years, villages from highest and lowest malaria endemic districts, i.e. Gulberga, Bijapur, Raichur and Bagalkot were selected for detailed survey (Fig. 3.1. 22). Field surveys were carried out for point prevalence of malaria during peak (November), and low peak (April), breeding habitats, man hour density of adult malaria vectors for mosquitogenic potential in and around each village. The area had rivers, irrigation channels, drains and borrow pits as breeding habitats. Satellite images of IRS P6 LISS IV MX were also procured for UKP area (Fig. 3.1.23).

To validate the relationship between Remote Sensing derived landscape features and malaria endemicity in Tumkur and Chitradurga

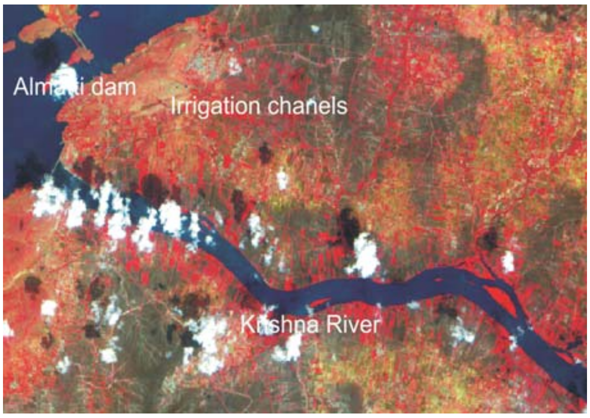

Fig. 3.1.23: False colour composite image of Almatti Dam area (Source: IRS P6 LISS IV, 15 October 2006).

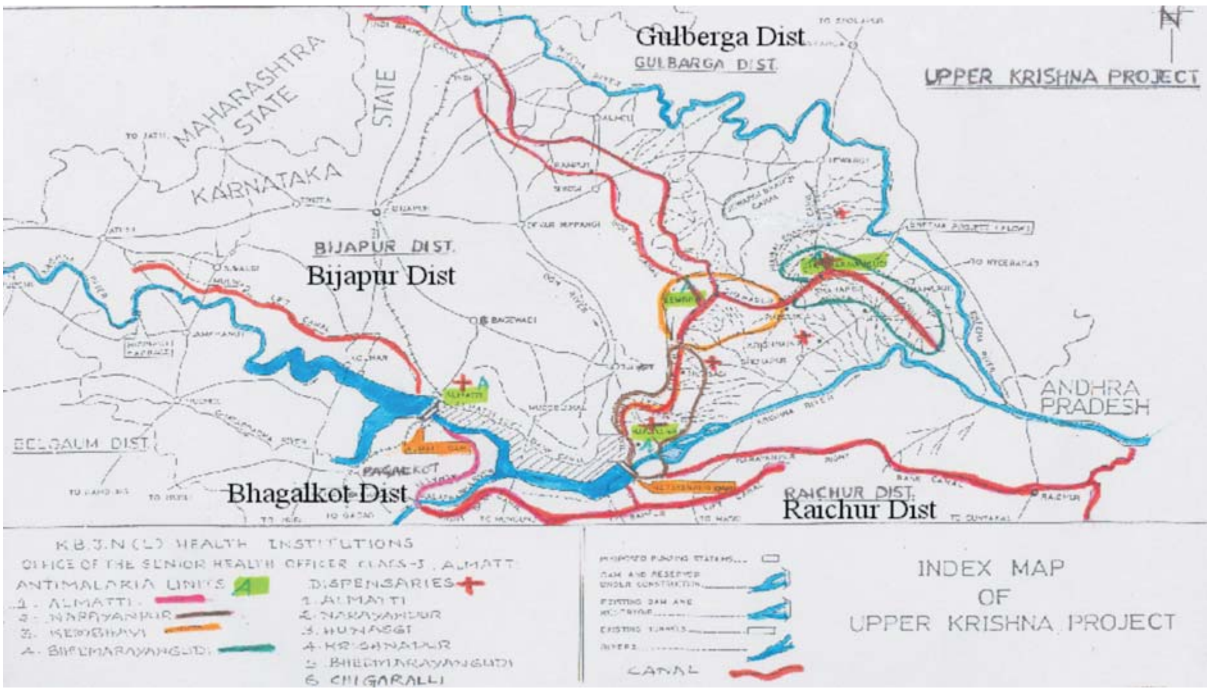

Fig. 3.1.22: Upper Krishna Project area in Karnataka

Fig. 3.1.24: Photographs of Upper Krishna Project area showing mosquito breeding habitats

districts, Ranganathpura and Yelladakere PHCs under Hiriyur taluka were selected from Chitradurga district, while Kallembela, Tarur and Taverakere PHCs under Sira Taluka were selected from Tumkur district. Ground truth of ecological features identified from FCC was undertaken in selected villages of Ranganathpura and Kallembela PHCs. All the villages under Kallembela and Taverakere PHCs were listed. FCC based on merged satellite data of LISS III and PAN sensors was generated, and statistics of landscape features in respect of four villages was generated.

"Irrigation channels, inhabitation near channels and labour congregation were found to be the eco-epidemiological factors responsible for high malaria incidence in project areas"

Eco-epidemiolological risk factors were found to be introduction of irrigation channels in hitherto water scarce area, vicinity of human settlements near channels/seepage drains, local migration and settlement of rehabilitated colonies. Rivers, seepage drains, irrigation channels, borrow pits, ditches, cement tanks and rice-fields were found as the main breeding habitats of anopheline mosquitoes in ground truth surveys (Fig. 3.1.24). River, irrigation channels, borrow pits, seepage drains and rice-fields were identifiable in satellite images, while cement tanks and small ditches could not. Highest larval density was found in borrow pits and seepage drains. Man hour density of *An. culicifacies* in low endemic villages was up to 0.5 and up to 24 in high endemic villages.

3.1.7 Identification of Malaria Risk Factors in Different Ecosystems of Assam using Remote Sensing

It is an ongoing project with an objective to identify environmental and ecological risk factors of malaria in forested and plain ecosystems of Assam. Field visits were undertaken in selected Primary Health Centres of Sonitpur and Kamrup districts. One PHC with highest risk and another with lowest risk of malaria were selected from each district. Monthly retrospective epidemiological data of malaria were collected from six districts of Assam. Meteorological data of these districts were also collected. Entomological, parasitological and ecological data were generated in 16 villages.

The transmission windows of malaria were identified with respect to Kamrup and Tezpur districts based on minimum temperature and relative humidity (RH) required for ensuing transmission of *P. falciparum* malaria (18°C temperature and 55% RH) and seasonal occurrence of cases.

"High risk malarious villages were located near foothills with problem of accessibility in Assam"

Ground truth survey revealed that the high risk malarious villages were located near foothills with problem of accessibility. The major breeding habitats were ponds, streams, ricefields, etc. Satellite data of LISS III sensor with 23.5 m resolution did not help in delineation of mosquitogenic landscape features at village level. Data of higher resolution were not available for the peak transmission season, i.e. May/June.

In both Kamrup and Sonitpur districts, the peak incidence of *P. falciparum* reaches in June/July, while the lowest peak is in December to February. Based on minimum required temperature and RH, transmission windows are supposed to remain open for 10–11 months. The density of *An. minimus* ranged from six to nine per man hour in high risk villages. Surprisingly, in some of the low risk villages the MHD of vector species was also found up to eight. Malaria endemicity was high in Kamrup district as compared to Sonitpur district which is basically due to difference in topography. Parasite incidence in Kamrup and Sonitpur districts was 44.3 and 8.4 in November 2006, 17.3 and 4.8 in July 2007, and 7 and 4.4 in November 2007, respectively.

Preliminary analysis indicates that the delineation of mosquitogenic/malariogenic conditions at village level would be difficult by satellite images with 23.5 m resolution in selected areas of Assam.

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