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ACKNOWLEDGEMENTS. We thank Prof. H. S. Moon, Yonsei University, Seoul for EPMA analyses, and Mysore Minerals Ltd for cooperation during fieldwork. The Department of Science and Technology, Government of India funded this research. An anonymous referee is acknowledged for detailed review of the paper.

Received 18 October 2003; revised accepted 28 January 2004

Malaria epidemicity of Mewat region, District Gurgaon, Haryana, India: a GIS-based study

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A GIS-based study was initiated in Mewat region, District Gurgaon, Haryana, an integral part of traditionally known malaria epidemic belt of the Northwestern Plains of India. The study included (i) delineation of malaria paradigms at macro level; (ii) identification of eco-epidemiological characteristics of each paradigm, and (iii) identification of the paradigm receptivity for malaria. Using RS and GIS, the five easily recognizable malaria paradigms, namely irrigation command, catchment/non-catchment, mining, urban and flood-prone areas, were mapped. Each paradigm exhibited its own eco-epidemiological characteristics and potential for maintaining malaria transmission of varying intensity. Paradigm-wise receptivity revealed that during 1996, an epidemic year, different paradigms responded differently. Although all paradigms showed upward trend, maximum amplification occurred in urban/semi-urban paradigms. During 1993 and 1998, i.e. in the last two inter-epidemic periods, flood-prone paradigm, irrigation command area II and non-catchment area continued to retain active pockets of malaria, namely Akera and Malab sections in Nuh block; Uleta and Kankar Kheri in Nagina block; Biwan in Ferozpur Jhirka block; Punhana, Hathan gaon, Sunhera and Tirwara in Punhana block. With the current inter-epidemic period starting from 1998 onwards, any ecological change in the scenario influencing the above three paradigms favourably, may flare up malaria cases from hot pockets. Therefore there is a need to strengthen surveillance in these areas and pay special attention to these pockets.

MEWAT region, District Gurgaon, Haryana carved out of erstwhile Punjab in November 1966 as a result of reorganization of states, is an integral part of traditionally known malaria epidemic belt of the Northwestern Plains of India. This belt is associated with unusual monsoon rains and other socio-economic factors, changing the malaria scenario at an interval of 7–9 years[1–3]. During the post-independence period, the Government of Haryana established the Mewat Development Authority for this region to regulate developmental and economic activities, aimed at improving irrigated and rain-fed agriculture, flood control, recharging of groundwater, provision of safe drinking water to villages and a host of other activities, viz. crop development, horticulture and livestock improvement (P. V. Ramesh *et al*., 1999, unpublished report).

Proponents of Global Malaria Control Strategy (1993)[4] recognizing that the malaria problem varies enormously from epidemiological, ecological, social and operational view-points, recommended identification of easily recognizable eco-epidemiological types, namely malaria paradigms for local analysis for formulation of eco-friendly, cost-effective and sustainable control strategies. It is in this context that a GIS-based study was initiated for (i) delineation of malaria paradigms at macro level; (ii) identification of eco-epidemiological characteristics of each paradigm, and (iii) identification of the paradigm receptivity for malaria in Mewat region. The results of this study are presented in this communication.

The study area comprises of six blocks, viz. Nuh, Nagina, Taroru, Ferozpur Jhirka and Punhana in Gurgaon district and a small portion of Hatin block of Faridabad district, Haryana, which is located about 120 km south of Delhi (Figure 1). The total population of the region is 0.89 mil-

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lion, spread over 84 sections/491 villages, each section consisting of 4 to 10 villages. Agriculture is mainly rainfed; there is no major industry in the region, except mining work and about 62% of the population is below poverty line. The statistics of Mewat region is given in Table 1.

The area has uneven topography of plain and undulating patches of land dotted with hillocks sandwiched between two parallel ranges of Aravali hills running apart by 5–10 km. The Aravali ranges in the area run along NS to NNE-SSW direction. SW of Punhana, sporadic ridges and hillocks fall in the shape of a semicircle. Extreme climatic conditions prevail in Mewat, which it falls under sub-tropical, semi-arid climatic zone. The average annual rainfall is about 480 mm and is distributed over a period of 25 to 35 days. Even this is erratic and shows great variance. There is high temperature variation in different seasons. Relative humidity is low and the occurrence of high-velocity desiccating winds in summer is a common phenomenon. The area experiences sporadic drought (C. S. Raghuvanshi, 1999, unpublished report; M. L. Gupta, 2000, unpublished report).

The study was conducted in collaboration with Harayana Space Application Centre (HARSAC), Hissar. Maps on landuse, slope, drainage, watershed, village, block boundary, etc. were procured from HARSAC. The malaria data consisting of yearwise (1991–2001) annual parasite incidence, species-wise malaria cases and total population were procured from District Malaria Office, Gurgaon. Section-wise map and other attribute information were collected from Mewat Development Authority.

Table 1. Mewat region statistics

Area		
Total area (km^2)	:	1874
Villages	:	491
Towns (Semi-urban)	:	5
Population (1991 census)		
Total population	:	893,587
Rural population (%)	:	92.94
Urban population (%)	:	7.06
Irrigation		
Total area irrigated (ha)	:	42,600
Tubewells and pump sets (number)	:	14,595
Forest		
Area under forest cover (km^2)	:	58.63
Percentage of the total area	:	3.95
Animal husbandry		
Total livestock (000)	:	480.2
Health		
Community Health Centre†	:	4
Primary Health Centre	:	14
Sub centres	:	82
Education		
Literacy (%)	:	21.7
Rural literacy (%)	:	19.23
Urban literacy (%)	:	52.28
Economy/industry		
Working force (%)	:	30.35
Agricultural workers (%)	:	71.99
Industrial (%)	:	2.70
Other workers (%)	:	25.31

†These are equivalent to sub-district hospitals.
Source: M. L. Gupta, 2000, unpublished report.

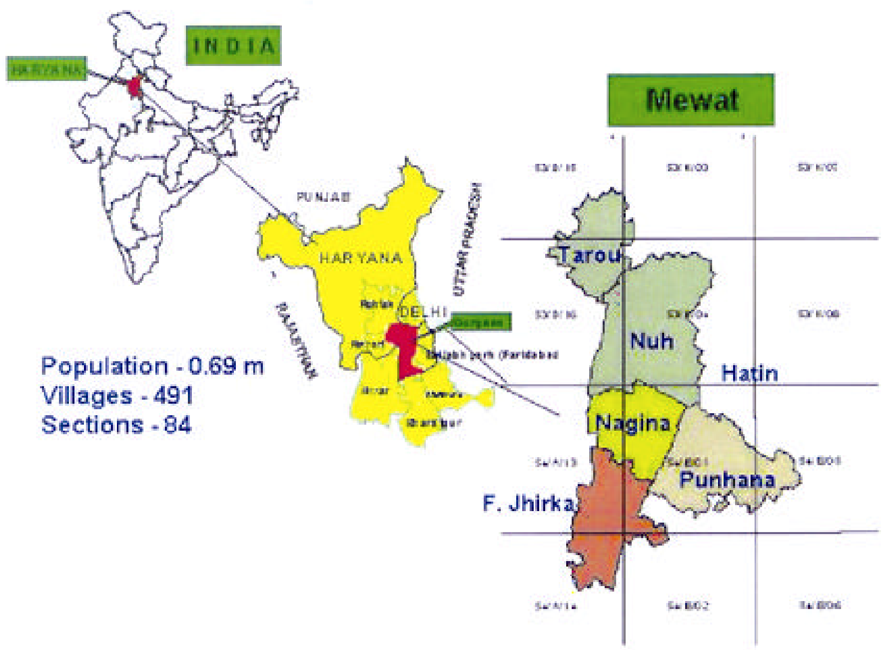

Figure 1. Location of the study area.

Table 2 gives the ecological parameters affecting the dynamics of malaria transmission considered for GIS analysis in the present study.

Thematic maps were prepared using RS images and Survey of India toposheets in the scale 1 : 50,000. Digitization, integration of maps and analysis were done using GIS Arc/Info NT and Arc View 3.1. A GIS database was generated by linking attribute information with digitized map for spatial attribute projection.

Since malaria is a local and focal problem, from an operational point of view it may vary in different ecological and socio-economic situations with different risk factors and control strategies. Most malaria cases fall in a few major, easily recognizable eco-epidemiological types (paradigms). Five malaria paradigms, namely irrigation command, catchments, mining, urban and flood-prone were identified according to guidelines of Global Strategy for Malaria Control[4]. The methodology to map the paradigms in Mewat is given in Table 3 and Figures 2 and 3.

Malaria incidence of sections falling in each paradigm for 1991 to 2001 was pooled to estimate paradigm-wise malaria receptivity and trend.

In Mewat, using annual parasite incidence (API; i.e. the number of malaria positive cases × 1000/total population) during 1991–2001, a trend analysis was done. It revealed that from 1991 to 1993 there was a declining trend and API reached below 2; then during 1994 and 1995, API increased to about 5. In 1996, API was around 33, statistically more than (average + 2SD) and 1996 was declared as an epidemic year. Thereafter, a decline was observed and API reached below 2 in 1998; subsequently by 2001, it was less than 0.5 (Figure 4; an area with API < 2 is considered a low risk area and need not be covered by indoor residual spray according to the National Anti Malaria Programme norms[3]). Statistically, incidence of malaria during 1993 and 1998 was similar. Thus the entire cycle, 1991 to 2001, a span of 11 years was classified into different epidemic phases, such as inter-epidemic (1991–93), pre-epidemic (1994–95), epidemic (1996), post-epidemic (1997) and once again as the inter-epidemic phase from 1998 onward. A post-epidemic investigation[5] in 1996, revealed that *Plasmodium vivax* was the prominent species of malaria, but *P. falciparum* was also prevalent in some pockets. Major malaria vector

Table 2. Ecological parameters and their utility to study impact on transmission dynamics of malaria

Parameter/map	Utility to study impact on transmission dynamics
District, block, section and village boundaries, road network, habitation/settlement areas and settlement locations	To map entomological, parasitological data and identify boundaries of malaria paradigms and ground surveys
Water bodies, drainage/stream/canal system, watershed boundaries, rainfall	Availability of surface water to correlate with vector breeding and malaria receptivity
Elevation, slope, contour, spot height, soil type	Mapping of areas receptive to water-logging/water harvesting
Landuse, location of mines, urban towns, etc.	To identify vulnerable and receptive areas for malaria and to associate socio-economic practices with malaria
Parasitological and entomological data; vector and disease control	Trend analysis, determining the different epidemic phases and identify sections of active malaria and their epidemiological characteristics in relation to malaria paradigms.

Table 3. Methodology for identification of malaria paradigm in Mewat

Paradigm	Methodology
Command area AI Command area AII	There are two command areas. (i) Dubalu minor area (AI), within lat. 28°9′ to 28°3′ and long. 77°5′ to 77°11′. (ii) Banarsi–Umra–Gangwani minor area (AII) within latitude 28°1′ to 27°52′ and long. 76°56′ to 77°7′. Sections falling in the two command areas were identified and extracted using GIS (Figure 3 *a*).
Flood-prone area	Contour map digitized from Survey of India toposheets was used to develop a 3D TIN model. Area < 188 m was taken as flood-prone, section map was overlaid on 3D map and using GIS, sections falling in low-lying areas were extracted which are likely to be flooded during heavy rains or inundation of flood waters from the adjoining states (Figure 3 *b*).
Catchment/non-catchment area	From Survey of India toposheets in the scale 1 : 50,000, natural drainage map was digitized and watershed was developed by HARSAC; this constituted the catchment area. Using GIS, section map was overlaid and sections falling in catchment and non-catchment areas were extracted (Figure 3 *c*).
Urban area Mining area	Remote-sensing images LISS III of IRS 1D in the resolution 23.5 × 23.5 of October 97 and February 98 were obtained, and the hard copy was interpreted visually and digitally by HARSAC. Semi-urban/urban and mining areas were identified in remote-sensing image and ground-verified. Using GIS, section-wise map was overlaid on landuse map for identification of geographic location of the semi-urban/urban and mining areas (Figure 3 *d*).

Anopheles culicifacies was responsible for the epidemic and has been incriminated from the region. *An. stephensi* an important vector of urban areas, was also detected in this region[5].

Using GIS, the five easily recognizable malaria paradigms were extracted. Eco-epidemiological characteristics are discussed in the Table 4.

It may be seen from the Figure 4 that during 1991, overall API in all the paradigms was around 5; it then declined to around 2 by 1993, again increased during 1994 and 1995, representing the pre-epidemic phase when it touched around 7 in all paradigms. The epidemic phase started in 1996, 1997 was the post-epidemic year and 1998 onwards once again represents the inter-epidemic period. During 1996, different paradigms responded differently, maximum amplification occurred in urban/semi-urban paradigms with API about 45. This was followed by flood- prone, command area AII and non-catchment paradigms, which exhibited the same amount of amplification and API reached around 40. Mining paradigms showed about an API of 20. The lowest incidence of malaria was observed in command area AI (about 10 API). By 1998 malaria incidence reached below 2 API in all the paradigms. API declined further to reach below 1 by 1999 and subsequently below 0.5 in all paradigms.

Sections with API ≥ 2 were extracted for the years 1993 and 1998, and overlaid on paradigm maps to study the eco-epidemiological profile of malaria during inter-epidemic phase (Figure 5). It reveals that in 1993 and 1998, flood-prone paradigm, irrigation command area AII and non-catchment area retained active pockets of malaria transmission, namely Akera and Malab sections in Nuh block; Uleta and Kankar Kheri in Nagina block; Biwan in Ferozpur Jhirka block; Punhana, Hathan gaon, Sunhera and Tirwara in Punhana block.

Regression analysis of paradigm API and total API of the models formulated is given in Table 5. Though it is not a cause and effect relationship, it is a reflection of paradigm API on total API. The slope values of these regression models reveal that in general, total API of Mewat is being represented by API of irrigation command area AI, urban and mining paradigms. It may be concluded that the population in flood-prone paradigm, irrigation command area AII and non-catchment area is at higher risk.

In 1996, in the Mewat region epidemic was a result of unprecedented inundation of flood waters from the adjoining state of Rajasthan. At the macro level, malaria incidence was correlated with rainfall in Mewat and it was found to be independent of normal rainfall ($P > 0.05$). Rainfall within Mewat is variable, therefore rainfall for

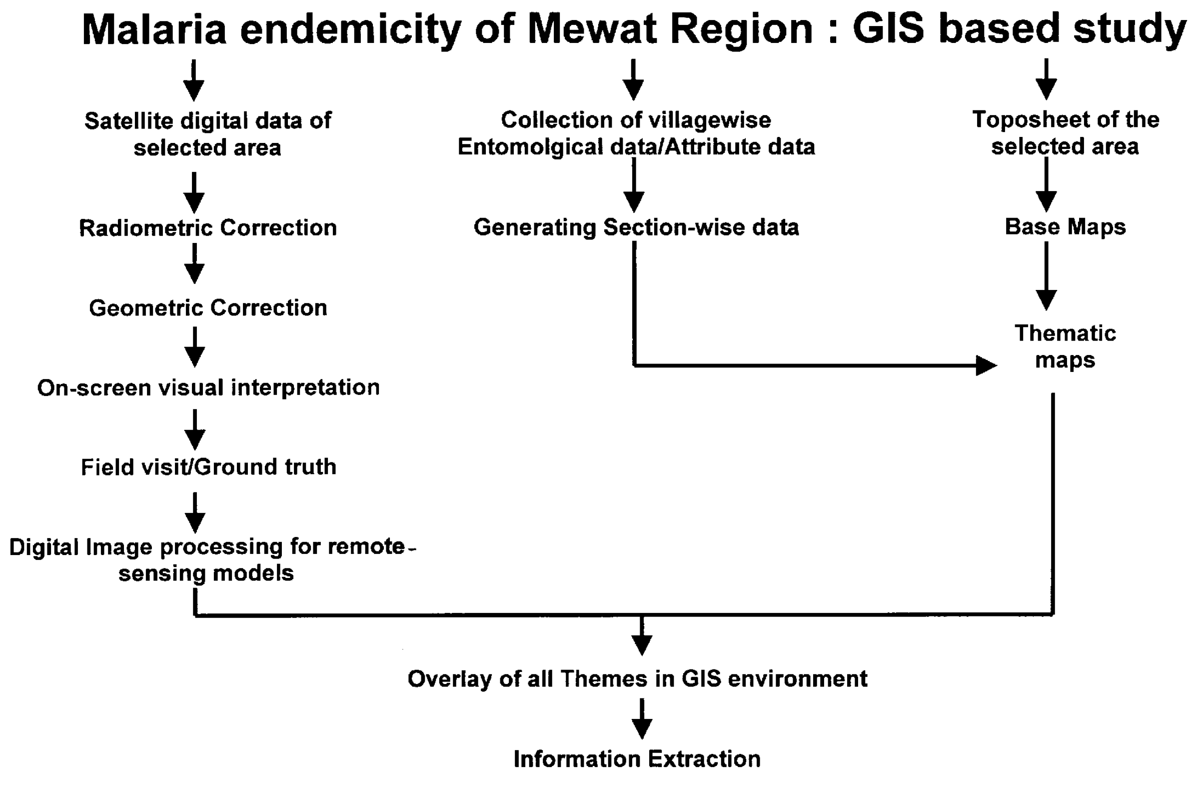

Figure 2. Flowchart to map malaria paradigm in Mewat.

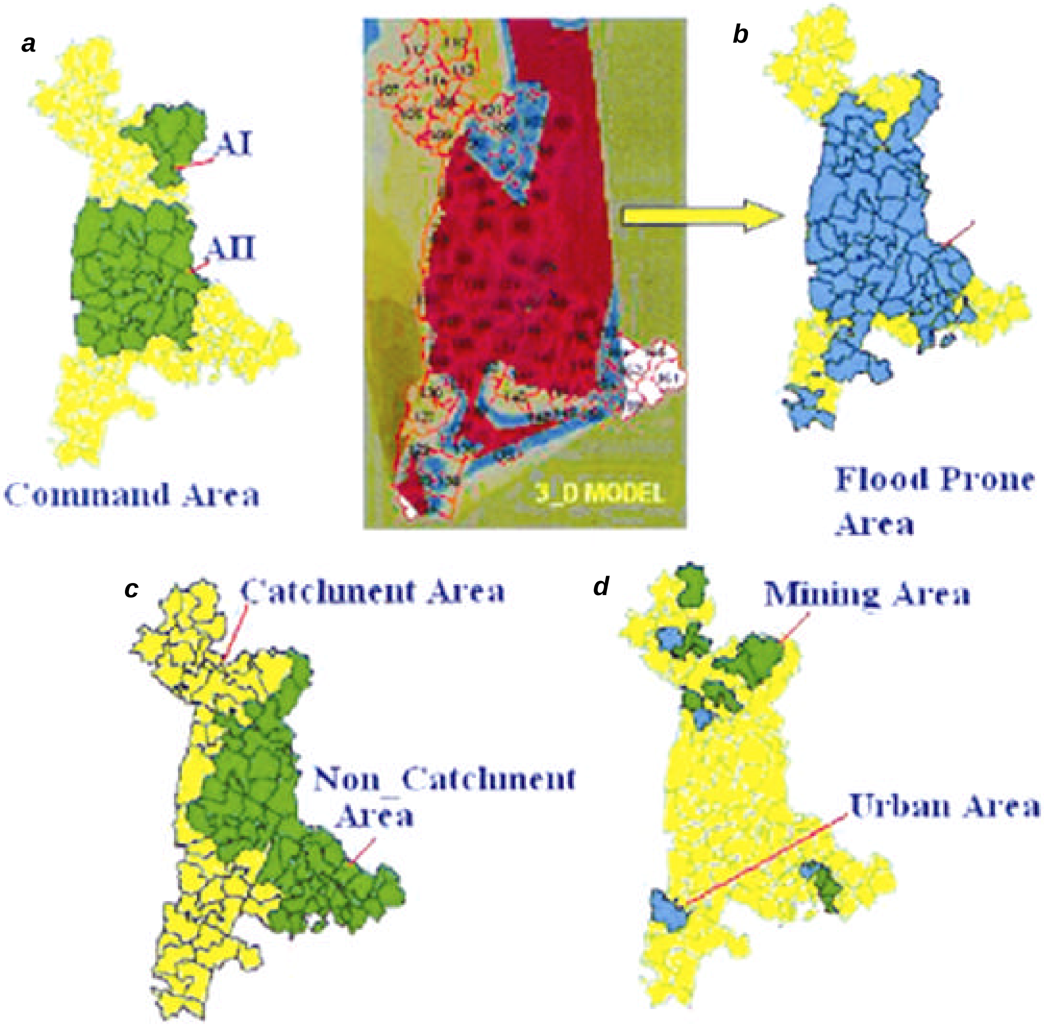

Figure 3. ***a***, Command areas AI and AII in Mewat. ***b***, Flood-prone areas. ***c***, Catchment and non-catchment areas. ***d***, Urban and mining areas.

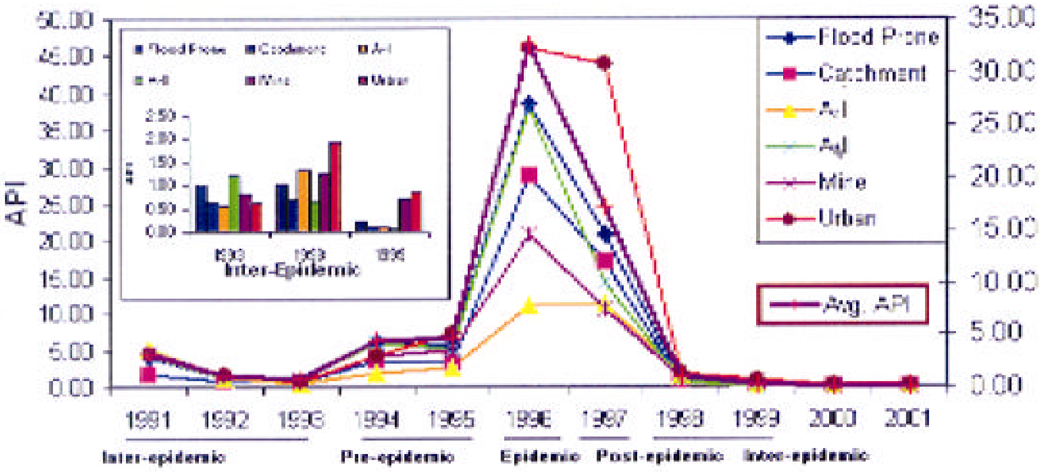

Figure 4. Paradigm-wise annual parasite incidence (API) through different epidemic phases and API in Mewat (1991–2001).

Table 4. Eco-epidemiological characteristics of malaria paradigms

Malaria paradigm	Characteristics
Irrigated area AI: 68 km^2 command area	Irrigated by Dubalu minor. Two crops, i.e. Rabi (winter) and Kharif (monsoon). Very few seepages/leakages from canal system; *An. culicifacies* breeding potential low. Few villages with piped water supply, *An. stephensi* breeding potential low. Livestock in good numbers; *zooprophylaxis*. Inhabited by farmers with lower economic background.
AII: 320 km^2 command area	Irrigated by network of canal minors; leakages/seepages from canal system; *An. culicifacies* breeding potential high. Some villages with piped water supply; low *An. stephensi* breeding potential. Two crops, viz. Rabi and Kharif. Livestock in good number; *zooprophylaxis*. Inhabited by farmers of high to low economic background.
Catchment area/ non-catchment area	Tapping of run-off water by check dams/canalization. One crop only (Kharif–monsoon season). Horticulture/poultry as secondary income. Displacement of population in case of heavy inundation built up of epidemics; high vulnerability to malaria in catchment area. Marginalized and poor farmers. Non-catchment area is low-lying.
Flood-prone area	Encompasses the central and southern catchment and irrigated area AII. Provide additional potential for breeding of *An. culicifacies*, the vector species. Aggravate malaria situation in the absence of adequate drainage. Displacement of human and cattle population if flooding is enormous; built up of epidemics.
Mining area	Restricted to hilly ranges of Aravali. Heavy excavations with water stagnation; high potential for *An. culicifacies* breeding. Migratory labour; high potential for importation of infection reservoir. Vulnerable to local/focal outbreaks of malaria.

each of the five blocks was correlated with its API and it was found that blocks Taoru ($r = 0.75$, $P = < 0.05$), Nagina ($r = 0.86$, $P = < 0.05$), and Ferozpur Jhirka ($r = 0.84$, $P = < 0.05$) have significant correlation, whereas blocks Nuh ($r = 0.59$, $P = > 0.05$), and Punhana ($r = 0.804$, $P = > 0.05$) showed no significant relation. It is observed that all the sections of residual malaria of 1993 and 1998 fall in Nuh and Punhana blocks. Thus because of persistent malaria in these blocks, rainfall does not exhibit correlation with API. Climatic sensors to record at micro level the temperature of air and water bodies, rainfall and soil moisture, have been fixed to correlate climatic factors to malaria morbidity.

The entire cycle, 1991 to 2001, the 11-year epidemic phase of Mewat region revealed the presence of different epidemic phases, namely inter-epidemic, pre-epidemic, epidemic, post-epidemic and inter-epidemic phase. RS and GIS analysis demarcated five malaria paradigms, viz. irrigation command area, catchment area, mining area, urban area and flood-prone area, which showed different eco-epidemiological characteristics. During 1996, different paradigms responded differently, maximum amplification occurred in urban/semi-urban paradigms with API about 45. This was followed by flood-prone, command area AII and non-catchment area paradigms. The lowest malaria incidence was observed in mining paradigms and command area AI.

Table 5. Regression analysis of paradigm API and total API

Paradigm	Regression model
Flood-prone	$y = 0.8158x - 0.1116$
Catchment	$y = 1.0816x + 0.3392$
AI	$y = 2.1706x - 1.0517$
AII	$y = 0.8557x + 0.2970$
Mine	$y = 1.9672x - 1.6150$
Urban	$y = 0.5477x + 0.8040$
Non-catchment	$y = 0.9246x - 0.1911$

Spatio-temporal distribution map of malaria for the years 1991–2001 depicted spatial spread of malaria in Mewat. It is apparent from the study that during 1993 and 1998, i.e. the inter-epidemic period, flood-prone paradigm, irrigation command area AII and non-catchment area continued to retain active pockets of malaria, namely Akera and Malab sections in Nuh block; Uleta and Kankar Kheri in Nagina block; Biwan in Ferozpur Jhirka block; Punhana, Hathan gaon, Sunhera and Tirwara in Punhana block. Inter-epidemic period started from 1998 onwards; any ecological change in the scenario influencing the above

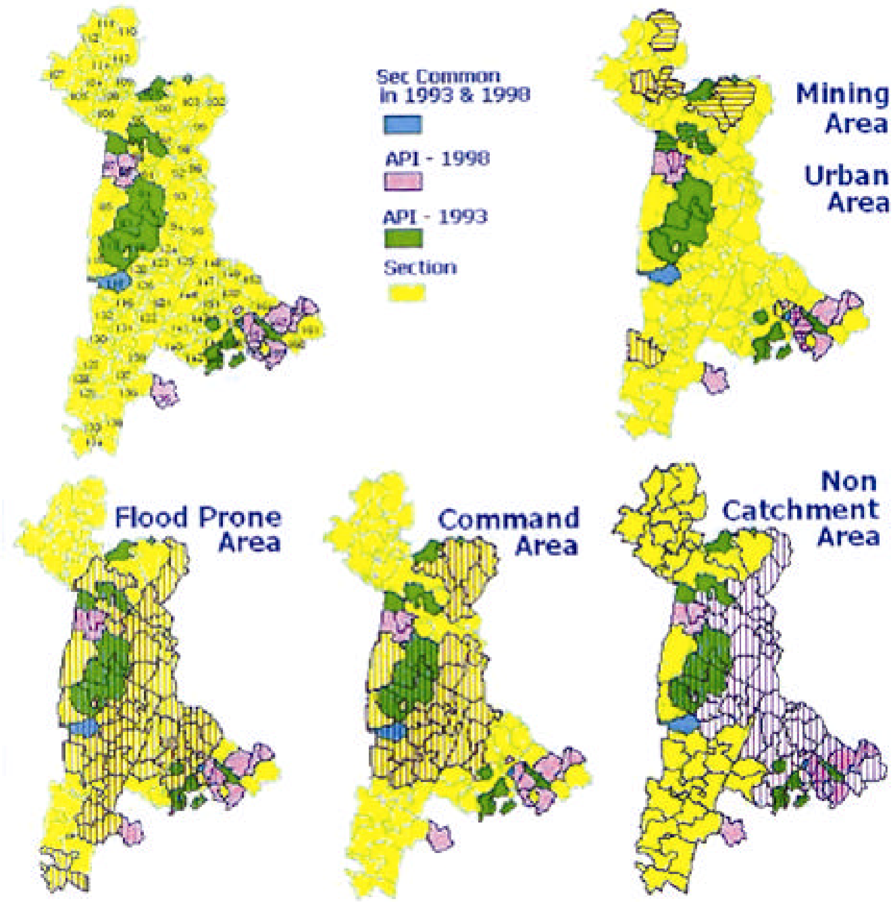

Figure 5. GIS identified malaria-active sections during inter-epidemic period and their related paradigms. Active pockets are confined to three paradigms, namely flood-prone, non-catchment and command area AII.

three paradigms favourably, may flare up malaria cases from the hot pockets. Therefore there is a need to strengthen surveillance in these areas and pay special attention to these pockets.

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ACKNOWLEDGEMENTS. We thank Mr N. L. Kalra, former Dy. Director, National Anti Malaria Programme for reviewing the manuscript and providing critical comments and useful suggestions. We also thank Dr V. P. Sharma, Former Director, Malaria Research Centre for providing facilities to initiate the work, and Mr Pawan Kumar, Mr Sanjeev Kumar and Mr Vijay Kumar for helping with the analysis and collecting the attribute information of Mewat region.

Received 11 June 2003; revised accepted 10 December 2003