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Impact of deforestation on known malaria vectors in Sonitpur district of Assam, India

Rekha Saxena[1], B.N. Nagpal[1], V.P. Singh[1], Aruna Srivastava[1], Vas Dev[2], M.C. Sharma[1], H.P. Gupta[2], Arvind Singh Tomar[1], Shashi Sharma[3] & Sanjeev Kumar Gupta[1]

[1]*National Institute of Malaria Research, Dwarka, New Delhi;* [2]*IDVC Project Field Unit, Guwahati, Assam;* [3]*Institute of Cytology and Preventive Oncology, Noida, India*

ABSTRACT

Background & objectives: An alarming rate of deforestation has been reported from Sonitpur district of Assam, India therefore, a study was initiated during 2009 using remote sensing (RS) to assess deforested areas in the district and to study the impact on malaria vectors in order to formulate appropriate control strategy.

Methods: RS imageries of 2000 and 2009 were used to assess deforested areas in the selected district. Entomological data were collected in four surveys during 2009–2011. The data were analyzed statistically using test of single proportions (χ^2) and pair-wise comparison. Vector incrimination was done using enzyme-linked immunosorbent assay (ELISA) and entomological inoculation rate (EIR) was calculated to estimate transmission intensity.

Results: The deforested areas were identified in north-western parts of Sonitpur district falling in Dhekiajuli Primary Health Centre (PHC). The forest cover of the PHC decreased >50% during 2000–2009. Five species of anopheline vectors were collected. *Anopheles minimus sensu lato* (*s.l.*) was collected least abundantly while *An. culicifacies s.l.* prevailed most abundantly and significant difference was observed between proportions of the collected vector species. Pair-wise comparison between *An. culicifacies s.l.* and *An. minimus s.l.* was also found statistically significant indicating that *An. culicifacies s.l.* is establishing its population in deforested areas. *An. culicifacies s.l.* was found ELISA positive and EIR was measured as 4.8 during transmission season.

Conclusion: An. culicifacies s.l. replaced *An. minimus s.l.*, the vector of malaria in northeast India and was found ELISA positive, therefore could have possible role in malaria transmission in the deforested areas of the district.

Key words Deforestation; entomological inoculation rate; GPS; remote sensing; vector incrimination

INTRODUCTION

Vector-borne diseases such as malaria are strongly affected by environmental factors which in turn influence the abundance and survival of the vectors. Environmental factors associated with the deforestation are closely related to vector-borne diseases. Deforestation is considered the beginning of change in the landuse system and is driven by a wide variety of human activities, including agricultural development, logging, transmigration, road construction, mining and hydropower development[1–2].

The state of Assam in the northeast India falls in tropical climate belt and is well-known for its rich flora and fauna. The state has been endemic for perennial malaria transmission and contributes >5% of the total cases recorded in the country annually[3]. India has experienced a large amount of deforestation due to increased need of the land by the growing population. The loss of forest cover in India between 2006–2007 and 2008–2009 was around 367 km^2 (*http://fsi.org.in/cover_2011/summary.pdf*). The recorded forest area in Assam is 34.21% of the total geographical area as per Forest Survey of India 2011 report (*http://fsi.org.in/cover_2011/assam.pdf*). The average density of human population in Assam (397 km^2) is higher than that of the whole country (382 km^2) (*http://censusindia.gov.in/2011census*). In order to meet the demand of growing population, the local people have cleared large areas of the forest in the state.

Land transformation due to deforestation alters every element of local ecosystem which has profound impact on breeding places, prevalence, density and composition of human disease vectors which in turn modifies the transmission of the diseases[4–5]. *Anopheles minimus s.l.* and *An. dirus,* now known as *An. baimaii* (Diptera: Culicidae) are the major anthropophagic vectors of malaria in north-eastern region of India which support the continued transmission of malaria in this region[6–10]. *Anopheles minimus s.l.* is found in forest fringe areas while *An. baimaii* is found in deep-forested areas[11–12]. *Anopheles philippinensis/nivipes, An. varuna, An. annularis* and *An. jeyporiensis* are secondary vectors of local importance[13]. Vast ecological changes have taken place in the region due to deforestation which opened up new land in forested areas either for crop cultivation or for human settlement resulting in enormous mosquitogenic conditions and changed species composition[14–16].

An alarming rate of deforestation has been reported from Sonitpur district of Assam[17]. Due to impracticability of ground based methods, satellite RS based imageries were considered better option for assessment of deforested areas. Normalized difference vegetation index (NDVI) is the well-known and widely used index to detect live green plant canopies in multi-spectral RS data[18]. NDVI analysis of different time periods can be used to monitor the change in forest cover.

The objectives of the present study were to assess deforested areas in Sonitpur district and to study the impact on malaria vectors. The study will be useful to provide decision support to develop strategic action plan for control of malaria in the proposed area.

MATERIAL & METHODS

Study site

Sonitpur lies between 92°20′ and 93°45′ east longitudes and 26°20′ to 27°05′ north latitudes covering an area of 5324 km^2 having seven block PHCs. The temperature of the district varies from 7 to 36°C with average annual rainfall ranging between 170 and 220 cm. The population of Sonitpur district increased by 15.5% during 2001–2011 (*http://www.census2011.co.in/census/district/165-sonitpur.html*).

Identification of deforested PHC

Geo-coded IRS-1D satellite LISS III imageries of 2000 and IRS-P6 satellite LISS III imageries of 2009 were procured from National Remote Sensing Agency, Hyderabad, India. Image processing was initiated with mosaicing of different images and superimposing the district boundaries to get false colour composite (FCC) bands 3, 2 and 1 of the area of interest. NDVI can be derived based on satellite bands that are most sensitive to vegetation information (near-infrared and red). The difference between near-infrared and red reflectance can be used to identify areas containing significant vegetation cover. The NDVI for IRS satellite data was calculated using the formula given below:

$$NDVI = (Band\ 3 – Band\ 2) / (Band\ 3 + Band\ 2)$$

The value of NDVI varies between –1 and +1, where +1 value tends towards dense vegetation. Depletion of forest cover during 2000–2009 as confirmed through NDVI is given in Fig. 1. PHC where deforestation occurred was identified by overlaying PHC boundary. The total area

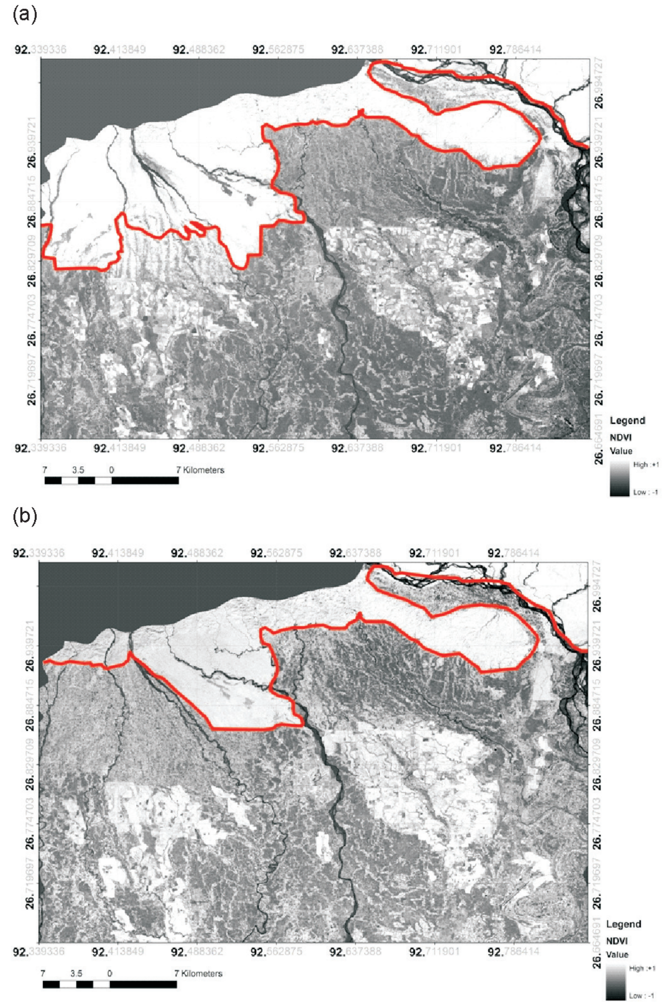

Fig. 1: Forest cover during the year: (a) 2000; and (b) 2009 as indicated by NDVI derived from satellite imageries of Sonitpur district, Assam. Area encircled by red line indicates dense forest.

covered by forests for the year 2000 and 2009 was calculated by counting pixels and presented in square kilometers. Global positioning system (GPS) was used to identify villages in deforested areas. Five villages were selected at random which remained same during all the surveys.

Entomological data collection

Four field surveys were undertaken during monsoon (August–September 2009), winter (November–December 2009), pre-monsoon (March–April 2010) and post-monsoon (October 2011) seasons to collect entomological data from deforested villages. Entomological data collection included indoor resting mosquito collection, total catch, outdoor collection, and whole night collection using CDC traps. Indoor resting collections were made from human dwellings/cattlesheds/mixed dwellings between 0500 and 0700 hrs by two experienced insect collectors for 15 min. Mosquito adults resting on the walls, hanging cloths, and under cots/tables/chairs, etc in houses were collected by suction tube aided by torch light. To cover the entire village, four fixed stations and three randomly selected houses and cattlesheds each were taken during each survey. Total catch was done from two houses of each village. Outdoor day time collection was carried out in each village using hand catch method by two insect collectors from boundary walls/fencing, tree holes, bushes, etc. Outdoor night collection was carried out using one CDC light trap in each village. In each village, where daytime collections were done, whole night indoor and outdoor collections also were done on human and cattle baits an hourly basis. All anophelines were identified to the species level. Test of single proportions was applied to see statistically significant difference between proportions of collected vector species (χ^2) using PASW statistics 18.0 software package. Man hour density (MHD) and room density of the most abundantly collected vector was calculated. Besides adults, larval collections were also done from different habitats.

Vector incrimination using ELISA and calculation of EIR

The head and thorax of collected individual specimen of *An. culicifacies s.l.* were removed and put in 1.5 ml micro-centrifuge tubes with perforated caps and kept dry with desiccant in zip-lock bags and transported from field to laboratory in Delhi. The specimens were assayed for the presence of sporozoites by ELISA using monoclonal antibodies against *P. falciparum* and *P. vivax* circumsporozoite proteins (*Pv* 210 and *Pv* 247) with appropriate positive controls (*http://www.mr4.org/Portals/3/Pdfs/Anopheles/3.3Plasmodium Sporozoite ELISAv 1.pdf*). EIR was calculated as number of mosquito bites/person/night × mosquitoes positive for sporozoites. EIR measures the intensity of malaria transmission in an area.

The study was approved by the Institutional Ethics Committee of National Institute of Malaria Research.

RESULTS

NDVI analysis suggested massive reduction in forest cover during 2000–2009 in north-western part of Sonitpur district and this area falls in Dhekiajuli PHC (Fig. 1). In Dhekiajuli PHC, the forest cover was 312.77 km^2 during 2000 and 145.24 km^2 during 2009. The forest cover of the PHC decreased >50% during 2000–2009. The purpose of deforestation worked out to be habitation and agricultural and deforested villages were inhabited mainly by ethnic groups like Assamese and Bodo shifted from nearby villages. During the field survey, deforested areas were seen with many new channels from streams for irrigation purpose (Fig. 2).

Fig. 2: Channels from streams for irrigation purpose in deforested areas of Sonitpur district, Assam.

Selected villages from deforested Dhekiajuli PHC for carrying out surveys were: Amlaiguri, Gulai Centre, Jiagabharu, Kalamati and Milanpur. A total of 1054 specimens of known malaria vectors were collected from these villages. Five species were collected, namely *An. annularis, An. culicifacies s.l., An. minimus s.l., An. philippinensis/nivipes* and *An. varuna* (Table 1).

An. culicifacies s.l. (62.24%), *An. annularis* (18.22%) and *An. philippinensis/nivipes* (14.8%) were collected most abundantly among the vector anophelines. *An. minimus s.l.* (3.98%) and *An. varuna* (0.76%) were collected least abundantly. Statistically significant difference was observed between different proportions of the collected vector species ($\chi^2 = 226.11$, $p < 0.001$). Pair-wise comparison between *An. culicifacies s.l.* and *An. minimus s.l.* was also found statistically significant ($\chi^2 = 53.72$, $p < 0.001$), indicating that *An. culicifacies s.l.* is establishing its population in deforested areas. MHD and room densities of most abundantly collected vector *An. culicifacies s.l.* were the highest during post-monsoon season followed by pre-monsoon season (Table 2).

Table 1. Vectors collected by indoor resting, total catch, outdoor and whole night collections from deforested areas of Sonitpur district of Assam

S. No.	Vector species	No. collected	% Total
1.	*An. annularis*	192	18.22
2.	*An. culicifacies*	656	62.24
3.	*An. minimus*	42	3.98
4.	*An. philippinensis/nivipes*	156	14.80
5.	*An. varuna*	8	0.76
	Total	1054	

Table 2. Man hour density (MHD) and room density of *An. culicifacies* during four seasons in deforested areas of Sonitpur district of Assam

Seasons	MHD	Room density
August–September 2009 (Monsoon)	0.086	0.8
November–December 2009 (Winter)	0.03	0.5
March–April 2010 (Pre-monsoon)	2.57	6.6
October 2011 (Post-monsoon)	3.23	14.0

Table 3. Vector incrimination using ELISA in Sonitpur district, Assam

Area	PHC	Villages	No. of mosquitoes positive and species of malaria parasite	Mosquito species
Deforested	Dhekiajuli	Gulai Centre	2 mixed	*An. culicifacies s.l.*
		Amlaiguri	4 mixed, 1 *Pv*	*An. culicifacies s.l.*
		Kalamati	1 mixed	*An. culicifacies s.l.*
		Jiagabharu	2 mixed, 2 *Pf*	*An. culicifacies s.l.*

Total samples collected: 35; Positive found: 12.

Larval collection confirmed the emergence of *An. culicifacies s.l.* from the study area.

A sample of 35 specimens of *An. culicifacies s.l.* collected from deforested villages during transmission season was analyzed using ELISA. Out of 35, 12 were found positive for malaria parasites (Table 3), thus, incriminating *An. culicifacies s.l.* as vector from deforested areas of Sonitpur district. EIR was measured as 4.8 during transmission season indicating high intensity of malaria transmission in deforested areas of Sonitpur district.

DISCUSSION

Another study carried out in Sonitpur district of Assam used NDVI analysis of different time periods to monitor the change in forest cover which established north-western part of Sonitpur district experiencing massive reduction in forest cover from 2000 to 2005[18]. In our study also, the similar area located in north-western part of Sonitpur, i.e. Dhekiajuli PHC was identified as deforested after analyzing RS imageries of 2000 and 2009.

Shifting cultivation, i.e. clearing of forest land for crop cultivation is a regular phenomenon in north-eastern states which induces deforestation and may involve local disappearance of native species and invasion of other new species into the area[19]. Vector replacement after deforestation has been reported from other parts of the world. Deforestation for rice cultivation and irrigation development in Sri Lanka resulted in changed vector species involved in malaria transmission[20]. Species replacement took place in Thailand where land was transformed from forest to cassava/sugarcane cultivations[21]. The current study also found *An. culicifacies s.l.* establishing its population in deforested areas of Sonitpur district of Assam and was found ELISA positive, therefore, could have possible role in malaria transmission in the study area. *An. culicifacies s.l.* has earlier been reported from other forest fringe areas of Assam and was incriminated as vector from Garubandha PHC of Sonitpur district during an outbreak of malaria[22–23].

MHD and room density indicated that the peak population of *An. culicifacies s.l.* was observed during pre- and post-monsoon seasons. Bimodal peaks of malaria vector population were also observed in other studies in Odisha and Uttarakhand, India[24–25].

Deforestation was found to be associated with a higher risk of malaria transmission in many countries of the world. Deforestation process in Amazon forest, Brazil for construction of hydro-electric power station increased the malaria incidence pattern of the area[26]. In Chantaburi, Thailand, deforestation done for rubber plantation and other fruit tree cultivations, favoured *An. dirus*, due to which malaria transmission was established at higher levels[27]. Deforestation followed by development of coffee plantations in southeast Thailand favoured the breeding of *An. minimus s.l.* and made the previously malaria-free region to hyperendemic[28]. A study done earlier in Sonitpur district carried out active surveillance in deforested villages during 2000, 2003 and 2005 and found significant upward trend of slide positivity rate[18]. Another study done in Sonitpur district found the similar area under high malaria risk category during 2008–2009[29]. No epidemiological data were collected in the present study, however, EIR indicated high intensity of malaria transmission in deforested areas of the district. In a similar study done in deforested areas of Peruvian Amazon, human biting rate—a component of EIR was reported higher in comparison to forested areas[30].

The present study is an attempt to understand the role of deforestation in malaria vector species composition in northeastern region of India. Further, studies are required in other areas of northeast where *An. culicifacies s.l.* and *An. minimus s.l.* have been recorded to establish the role in disease transmission.

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Conflicts of interest

The authors declare that they don't have any conflict of interest.

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Correspondence to: Dr B.N. Nagpal, Scientist 'F', National Institute of Malaria Research (ICMR), Sector–8, Dwarka, New Delhi–110 077, India.
E-mail: b_n_nagpal@hotmail.com

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