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Species composition and land use pattern of mosquito vector species in Sonitpur district, Assam

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Abstract
The risk of mosquito-borne diseases has put world under threat for long years. Many dependant variables, particularly physical and biological parameters of the breeding site directly influence the species richness and abundance patterns of mosquito species. The present study is an attempt to map the mosquito vector distribution in Sonitpur district of Assam, an endemic district in terms of mosquito borne diseases. Mosquito vectors are collected using CDC light traps from 21 different habitats along with their geographic coordinates. Geospatial technologies have been used for better interpretation of the mosquito distribution pattern. This study reveals that, the *Anopheles* and *Culex* mosquitoes are the dominant species. Malaria vectors are dominant in the northern part of the district due to the high extents of forest patches. *Culex* species is mainly distributed in the wetlands associated area and *Mansonia* species does not show affinity towards a particular habitat. Result of the study will be a significant endeavour in improving the scientific understanding and effective controlling the mosquito-borne diseases.

Keywords: mosquito-borne diseases, GIS, remote sensing, LULC

1. Introduction

Mosquitoes are one of the most important organisms and diseases spread by it not only affect mankind physically but also distress humans socio-economically. Every year, mosquito borne diseases affecting a very large human population which leads to high mortality rates worldwide. According to WHO, vector borne diseases cause more than one million deaths each year [1]. The diseases that are spread by mosquito vectors are malaria by *anopheles*; dengue, chikungunya, yellow fever, Zika, and rift valley fever by *aedes*; West Nile fever, Japanese encephalitis and lymphatic filariasis by *culex* [2, 3, 4]. In 2015 malaria alone caused 438000 deaths. The worldwide incidence of dengue has risen 30-fold in the past 30 years, and more countries are reporting their initial outbreaks of the disease [5]. Ecologically mosquitoes are very successful group of insects inhabiting a diverse habitat and very closely associated with the human settlement and agricultural activities. They can survive in any environmental condition, with an exception of extreme weather conditions. They prefer to stay in forests, slow flowing streams, marshy lands, tall grasses and weeds, and seasonal wet ground.

Control and management of the mosquito borne diseases put a heavy toll on state exchequer every year [6, 7, 8]. The challenges in controlling the mosquito borne diseases are increasing resistance of mosquitoes on insecticide, drug resistance of parasites, pesticide safety of humans, lack of expertise in vector control, surveillance of the mosquito borne diseases and its vectors, sanitation and access to safe drinking water facilities, environmental changes challenges, etc [9]. Geospatial mapping of mosquito distribution in any geographical area can be of immense help for control of vector borne diseases. Policy making, optimal mobilization and judicious utilization of resources are of primary importance for successful implementation of any vector control program. GIS mapping can play a very important role in managing these diseases as GIS is very useful in visualizing and analyzing disease epidemiology, prevalence and its relationship with various factors.

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In the present study an attempt has been made to map the mosquito vector distribution in Sonitpur district of Assam in India as the district is listed as one of the endemic districts in terms of mosquito borne diseases [10, 11]. Assam is located in northeastern part of India and it reports a very high number of cases of the mosquito borne diseases like malaria, JE and dengue. Hot and humid climate, long rainy season and abundant diverse mosquito breeding habitat are some of the important factors which influence the high prevalence of the vector borne diseases.

2. Materials and Methods

Sonitpur district is located between 92° 16′ E and 93°43′E longitude and 26°30′N and 27°01′ N latitude. This district is surrounded by foothills of eastern Himalaya in north and by Brahmaputra river on its southern side. The area of undivided Sonitpur district is approximately 5324 km^2 and average altitude range from 70 meters to 75 meters above mean sea level. Several forest reserves are located in the foothill region of the district, having an area of approximately 1417 sq.km providing rich biodiversity to this area [12, 13]. The population is 1.9 million primarily comprise different ethnic groups like Bodo, Nepali, Aadivasi and Assamese [14]. The average temperature is between 32°-35 °C in summer and 15°-20 °C in winter. Mean annual rainfall ranges from 170 to 220 cm and plays a major role in determining the climate of the region. The monsoon starts in June and ends in September; however, the occasional rain starts in early April. Many rivers which start from the eastern Himalaya in the north and flow over the plains of Sonitpur merge in the Brahmaputra River. The prevailing climatic condition of Sonitpur district is conducive for the breeding and proliferation of vector mosquitoes. The health infrastructure includes six government hospitals, eight primary health centres (PHCs), 11 dispensaries and 288 health sub-centres to provide health services to the people.

The selection of the mosquito trapping sites was made on the basis of random selection of houses from the study area considering the different physiographical conditions in the district. Altogether 21 different locations, which have different types of habitat (Fig.1), were selected across the district. The adult mosquito sampling was carried out using Centre for Disease Control (CDC) Light traps. A minimum of six trap collections were obtained from each of the study sites along the different habitat (Fig.2). In some cases the numbers of traps were more than six. The collections were made from both human dwellings and cattle sheds. The collected mosquitoes were identified using standard taxonomical keys. The latitudinal and longitudinal co-ordinate positions of the selected sites were marked with Garmin Oregon 550 GPS device to locate exact position of CDC light traps. An approximate distance of around 500 meters was maintained to obtain reliable information on spatial variation of mosquito's types. Geographical Information System (GIS) was used for better interpretation of the mosquito distribution pattern wherein GPS data and mosquito types trapped in the field were integrated. The collected mosquitoes were identified based on standard keys and with help of medical entomologists of the Defence Research Laboratory, Tezpur under Defence Research and Development Organisation (DRDO). The mosquitoes that were identified by experts belong to genera of *Anopheles, Culex, Mansonia, Aedes,* etc. Pearson's correlation (significant at the 0.05 level (2-tailed))

was performed to understand the affinities between the different habitat and mosquito vectors. Mosquito species were grouped based on the disease vector such as *Anopheles* primary vectors, *Anopheles* secondary vectors, *Anopheles* non vector, Vectors for Malaria, *Culex,* and *Mansonia and correlated with the* different land use pattern (Wetland, River, Disturbed vegetation in including the human habitat, Agriculture field, and dense forest). Cluster analysis was among species abundance in different location to understand the similarity of mosquito abundance in each study locations of Sonitpur district.

The map of the study area (1:50,000 scale) was acquired from Survey of India (Government of India) and was brought into GIS platform using ESRI Arc Map 9.2 (Redlands, CA, USA) for preparation of the base map having different layers like river, district boundary, etc. Ground positions were marked using a handheld global positioning system (Garmin Oregon 550 GPS). LISS III satellite images of the study area were used for preparation of Land use and land cover (LULC) map. A buffer of two kilometers from the point of mosquito trap sites was created using GIS software, considering the flight range of mosquitoes. It has been assumed that the mosquitoes collected in each trap travelled up to a flight range of two kilometers before getting captured in the CDC light trap. The same buffer of two kilometers from each site was used to mask the land use land cover (LULC) map that was generated from the LISS III satellite image. The purpose is to find the correlation between different categories of land use features within the flight range of mosquitoes in a site and the mosquito species collected in the same site. For preparation of predictive distribution map of malaria vectors, interpolation with the help of raster kriging techniques using spatial analyst tool of Arc GIS 9.2 software was used. This helps in better visual representation of mosquito species distribution in unknown locations.

3. Results
3.1 Mosquito species assemblage along different locations and the habitats

During the field survey different mosquito species under different genera of the mosquito were encountered from the 21 sites under surveillance. Mosquitoes belonging to the genera *Anopheles, Culex, Aedes, Mansonia, Armigeres* and *Coquilletidia* were recorded from the survey sites of the Sonitpur district. The highest collection of mosquitoes per trap night (per trap night density) was recorded from Kalabari (1755.2 per trap) followed by Thelamara, Dhobikata, Tetunbari, Sialmari and Rangapara survey sites (Fig. 2; Table.1). Many locations like Mainangshree, Biswanath Charali, Misamari, Pavoi, Rihajuli, Jamuguri, and Khanamukh (Table. 1) recorded low density of mosquitoes (minimum 41.17 per trap). It is very evident that, the Kalabari location has very high mosquito abundance (1755.2 per trap). However, Thelamara also shows very high mosquito abundance and these two locations were lying different from other locations of the study area (Fig.3). Cluster analysis also showed that Rihajuli and Mainangshree area have high similarly in the mosquito species composition Fig.3).

Highest numbers of *Anopheles* mosquitoes were recorded from the northern part of Sonitpur district, and *Culex* species were recorded primarily from the southern and central part of the Sonitpur District (Fig. 4). Most of the study sites recorded mosquitoes belonging to four (4) genuses *Culex, Anopheles,*

Mansonia and *Armigeres*. However, *Aedes* mosquitoes were recorded from a few sites only this may be due to night trap collection of adult mosquitoes. The result of Pearson's correlation between land use and mosquito species indicates that, The *Culex* mosquito shows negative correlation with wetlands (r = -0.629). Whereas, *Anopheles* mosquitoes show significant positive correlation with area which has denser forest patches (r = 0.854) and negative correlation with size of the agricultural lands (r = -0.745). *Mansonia* species does not show any correlation with area and it shows distribution of *Mansonia* is highly depend on the specific micro-habitat irrespective of the size of the habitat (Table. 2).

The *Anopheles* mosquitoes were abundantly found in the northern belt of the district, which has mostly dense vegetation habitat (Table.1). High abundance of *Anopheles* mosquitoes were recorded from Rihajuli (71.64%), followed by Mainangshree (69.64%), Misamari (46.15%) and Aamlaiguri (44.54%). The primary vectors of *Anopheles* that are responsible for malaria dominate in areas of Misamari (20.38%), Seijosa (10.63%), Pavoi (6.57%), Rihajuli (6.3%) and Chapai Raumari (5.69%). The areas where secondary vector dominates by more than 10% are Rihajuli (22.94%), Misamari (16.67%), Chapai Raumari (12.01%), Aamlaiguri (10.81%) and Seijosa (10.31%).The central and the southern part of the district reveals the abundance of *Culex*, which is predominantly observed in Kalabari (18.73%), Thelamara (30.85%), Dhobikata (57.91%), Tetunbari (54.74%), Sialmari (59.73%), Rangapara (64.57%), Jaisiddhi (68.63%), Aamlaiguri (47.96%), Singri (54.08%), Thandapani (69.12%), Chapai Raumari (61.41%), Solmara (69.1%) and Gangmouthan (74.64%). *Mansonia* mosquito genus dominated in the flood plain of Brahmaputra along the southern part of the district (Table.1). Whereas, mosquitoes belonging to genus *Armigeres* is predominant mainly in the central part of the district. Hence, it is clear showed that, the density of mosquito species varies from place to place depending upon the topography and vegetation cover.

In this study, the interpolation technique for *Anopheles* primary vectors were carried out and it revealed the abundance of vectors in the north-western part of the district. The generated raster map shows the most important primary vector of malaria dominates in the northern part of Dhekiajuli, Rangapara, Balipara and North Jamuguri PHCs of the district (Fig. 5). However, *Anopheles* secondary vectors were dominated in the North-eastern Part of the district (Fig. 6). As per record of the district health authority, this northern part of the district is a malaria endemic area. The presence of primary vectors of malaria and the parasite produce ample scope for transmission of malaria in the concerned area. Superimposing the malaria epidemiological map, a close relationship and association of the vector and parasite has been observed in this part of the study area, thereby suggesting high endemicity of malaria.
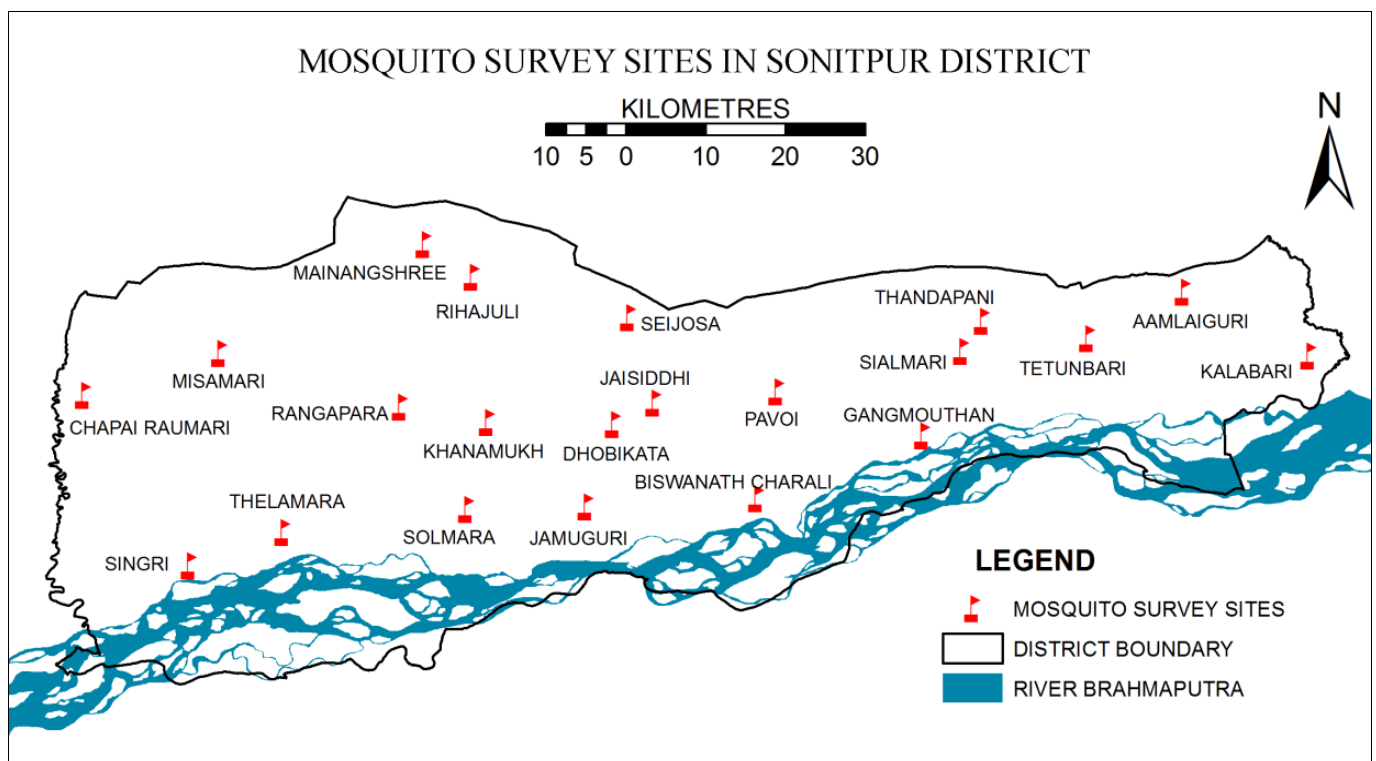

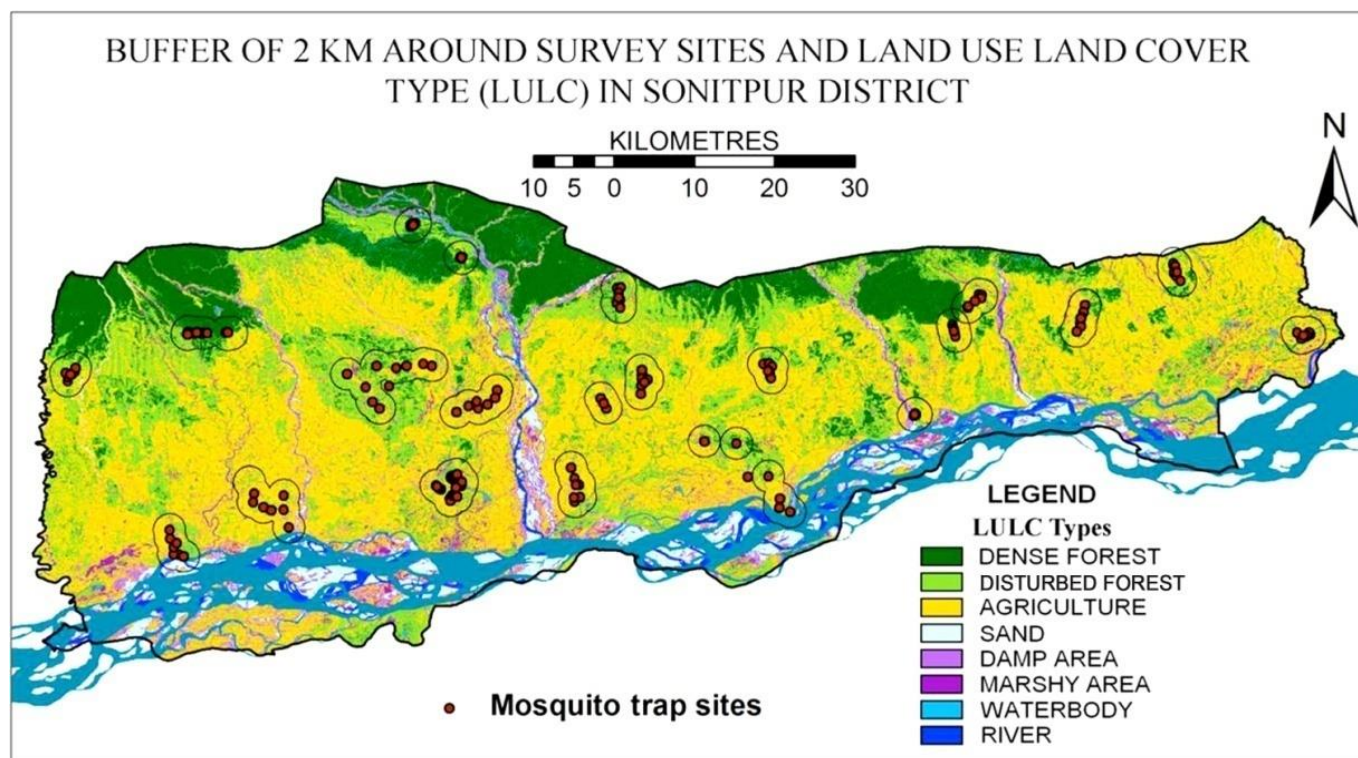**Fig 1:** Map shows the different study locations in the study area

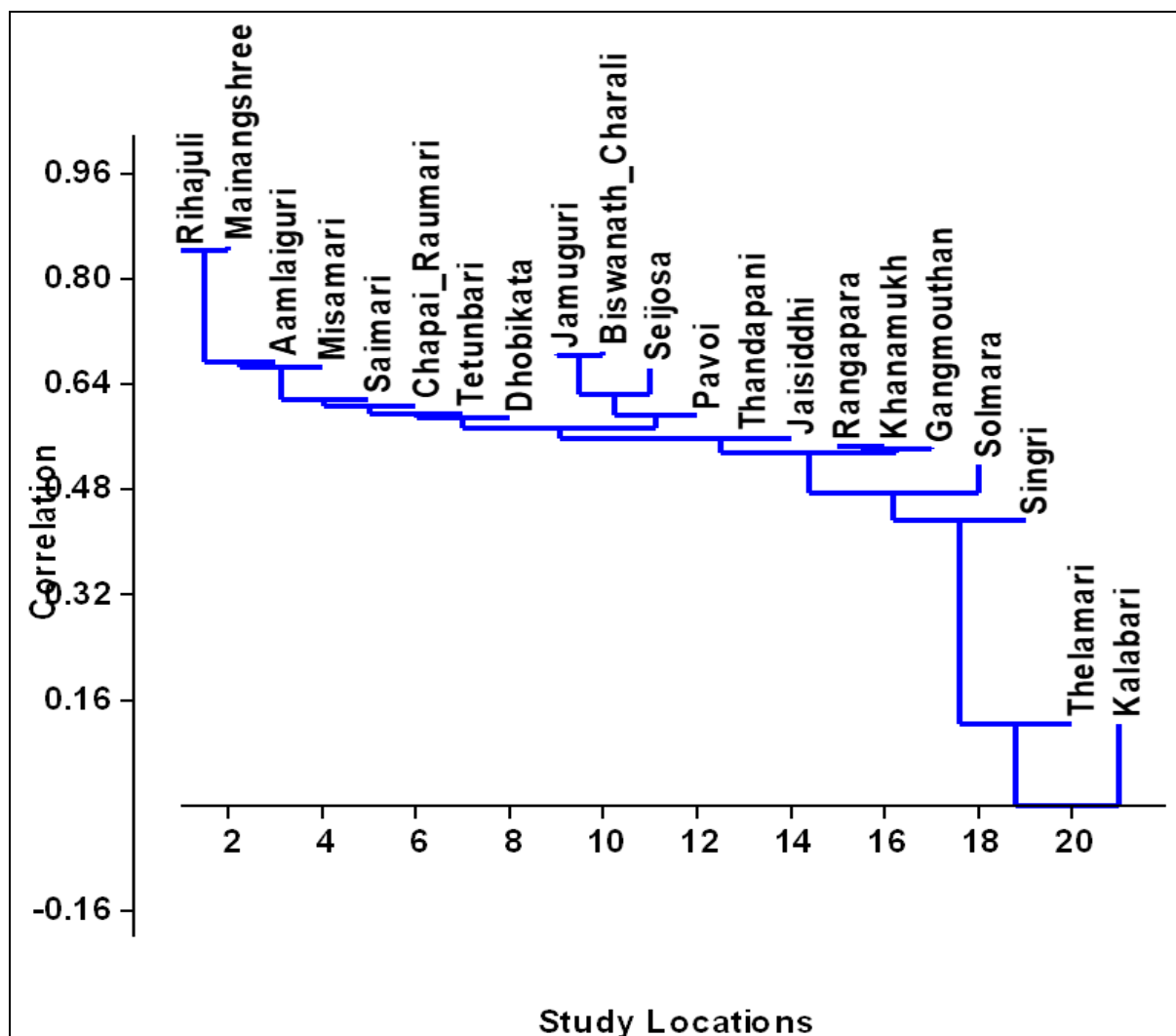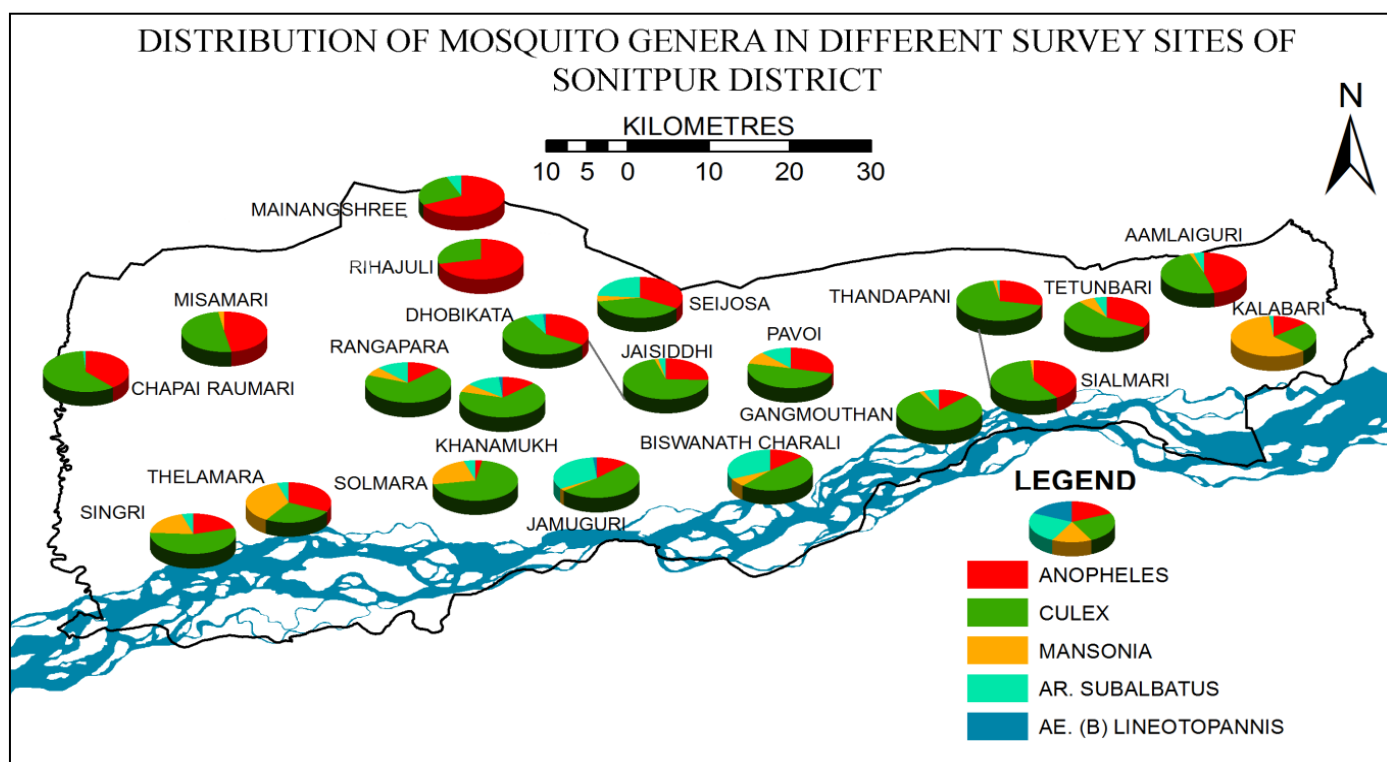**Fig 2:** Map shows the different sampling sites and habitat types of the study area

Fig 3: Cluster analysis of correlation showing the similarity of mosquito abundance in each study locations of Sonitpur district

Source: Defence Research Laboratory, Tezpur (DRDO)

Fig 4: Mosquito genera in different survey sites of Sonitpur district
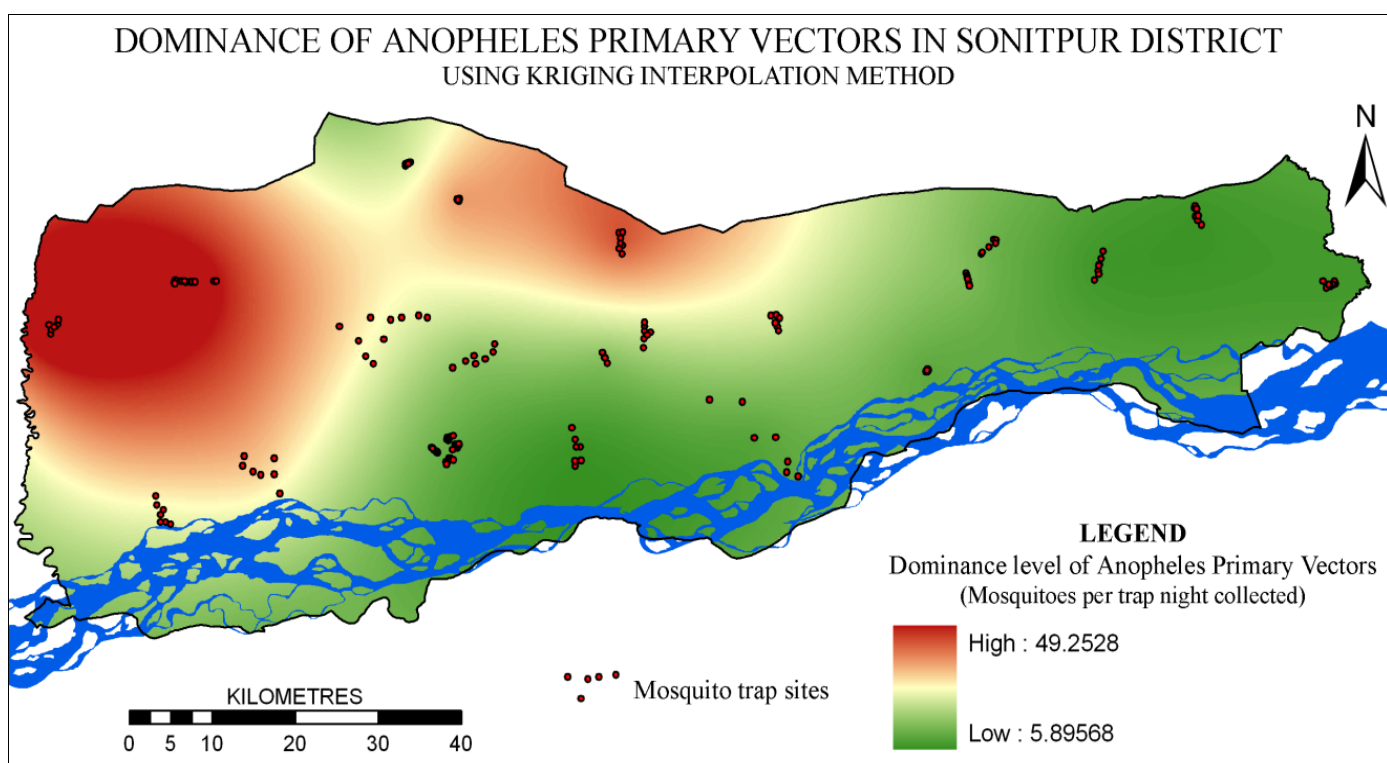

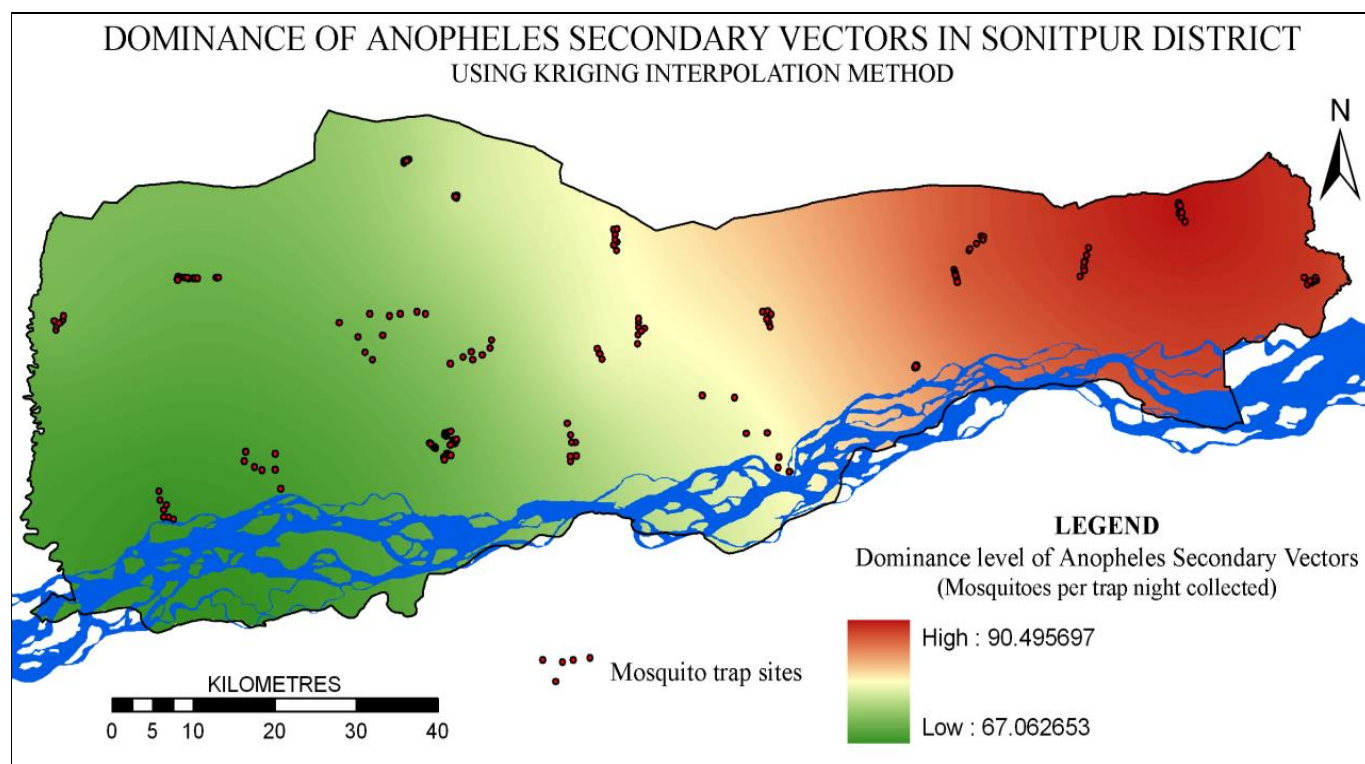**Fig 5:** Dominance of *Anopheles* primary vectors in Sonitpur district

Fig 6: Dominance of *Anopheles* secondary vectors in Sonitpur district

Table. 1: Per trap night mosquitoes collected from different survey sites in Sonitpur district

Sl. No	Locations	*Anopheles*	*Culex*	*Mansonia*	*Armigeres*	*Aedes*	*Coquilletidia*	**Total**
1	Kalabari	286.20	328.80	1095.20	40.50	0.00	4.50	1755.20
2	Thelamara	346.00	354.30	370.70	69.80	1.50	6.20	1148.50
3	Dhobikata	175.00	323.70	3.30	49.00	8.00	0.00	559.00
4	Tetunbari	161.40	286.30	36.30	35.00	2.50	1.50	523.00
5	Sialmari	188.40	295.20	9.30	0.00	0.00	1.30	494.20
6	Rangapara	54.10	233.30	20.50	53.40	0.00	0.00	361.30
7	Jaisiddhi	77.20	207.20	5.50	12.00	0.00	0.00	301.90
8	Aamlaiguri	132.50	142.70	5.70	15.80	0.80	0.00	297.50
9	Singri	63.20	159.00	53.80	18.00	0.00	0.00	294.00
10	Thandapani	73.20	183.80	4.70	4.20	0.00	0.00	265.90
11	Chapai Raumari	94.90	162.00	1.20	4.70	1.00	0.00	263.80
12	Solmara	13.30	170.60	48.10	14.80	0.00	0.08	246.88
13	Gangmouthan	29.00	150.70	4.70	16.00	0.00	1.50	201.90
14	Seijosa	33.50	44.20	3.70	25.30	0.00	0.00	106.70
15	Khanamukh	12.70	52.70	4.30	12.00	1.70	0.00	83.40
16	Jamuguri	12.00	42.00	1.50	24.00	1.70	0.70	81.90
17	Rihajuli	57.90	21.30	0.00	1.70	0.00	0.00	80.90
18	Pavoi	19.00	33.70	5.50	9.70	0.70	0.00	68.60
19	Misamari	24.00	26.40	1.70	0.00	0.00	0.00	52.10
20	BiswanathCharali	7.50	22.80	2.80	14.30	0.00	0.00	47.40
21	Mainangshree	28.67	9.33	0.00	3.17	0.00	0.00	41.17

Source: Defence Research Laboratory, Tezpur (DRDO)

Table 2: Pearson's correlation among different types of mosquitoes and size of the land use land cover types

Mosquito types Habitat	*Anopheles*	*Anopheles* primary (A)	*Anopheles* secondary (B)	*Anopheles* non vector	Vectors for Malaria (A+B)	*Culex*	*Mansonia*
Wetlands	0.466*	0.163	0.496*	0.334	0.376	-0.629*	0.287
River	-0.268	-0.186	-0.295	-0.138	-0.268	-0.046	0.093
Disturbed vegetation	0.207	0.336	0.394	-0.101	0.403	-0.022	-0.257
Dense forest	0.725*	.754*	0.799*	0.236	0.854*	-0.191	-0.271
Agri. fields	-0.502*	-0.674*	-0.683*	-0.002	-0.745*	0.162	0.251

*. Correlation is significant at the 0.05 level (2-tailed).

4. Discussion

The favorable mosquito breeding areas vary from genus to genus and species to species. The *Anopheles* mosquito generally prefers to breed in slow flowing streams and rivers [15, 16]. The grasses that grow abundantly near the slow flowing streams offer favorable breeding grounds for colonization of *Anopheles* mosquito. Similarly, paddy fields are suitable sites for vector breeding during monsoon seasons [17]. Mosquitoes like *Culex* and *Mansonia* prefer diverse habitats to breed. All study sites have extended agricultural than other habitats and it positively effects the diversity as well as abundance of *culex* mosquitoes species. However, the percentage of *Anopheles* mosquito is found high in the case of more patches of dense forest area.

While investigating the distribution pattern of *Anopheles* mosquito, the malaria disease carrying the mosquito, variation in the primary, secondary and non vectors are observed to vary from place to place. Primary vectors of *Anopheles* were observed in dense forest areas. The areas like marshy land, river, agricultural fields, damp area, and the sandy areas indicate negative correlation with *Anopheles* mosquito species which may leads to discouraging malaria. The secondary vectors were prevalent in all the areas except the flood plains of Brahmaputra River. The *Anopheles* non vectors were recorded in all areas of the district. Studies showed that, the malaria hotspots are exactly proportional to the area where dominated by the primary *Anopheles* vectors [18]. The interpolation map of the studies can be used to take necessary steps towards the management of future malarial outbreak. This is an effective method that overcomes the areal bias problem and the isopleth maps become much easier to comprehend [19]. Thus, it can be stated that the habitation of the malaria vector species in some particular areas could well be correlated with the transmission of the malaria parasite. As mentioned earlier about the three elements essentials for malaria transmission - mosquito, parasite and human, the presence of recent settlers in the forest areas completes the cycle of malaria transmission. The recent settlers are non-immune to parasite, which in turn risk their life to malaria attack, whereas the early settlers have adapted to the parasite. The children are more prone to malaria because of their non immunity to the parasite.

Malaria is also known as poor man disease and the poor new settlers' clears large part of reserved forest over a period of time for acquiring land for agricultural activities. They are also actively associated with illegal forest wood smuggling, which encountered them with *Anopheles* mosquitoes while stay in the jungle. The severity of the disease and its' association with deforestation is well established by Nath *et al*. (2011) [12] and Pattanayak *et al*. (2006) [20], in their study *An. minimus*, which is a species of the hill and foothills occupying ecotone zones, closure to the forest is being considered as the major vector of malaria in NE region of India [11]. As such the presence of malaria mosquito vectors and both symptomatic and asymptomatic people around such mosquito vectors in suitable environmental conditions increases the risk of disease in the community.

All the districts of Assam, in recent years, have been covered under Japanese Encephalitis (JE) vaccination. The vaccination campaign under multipronged strategy for prevention and control of JE is mainly for the children in the age group between 1-15 years [21]. The urgency of the vaccination, to cover entire districts of Assam shows the severity of the disease which is spread by some species of *Culex* mosquito vector. JE has become a serious threat for the common masses in Sonitpur district which is one of the top ten endemic district for JE [22-24]. The abundance of *Culex* mosquito ranging from 18.73% to 74.64% in the central and the southern part of the district from the study sites shows the dominance of the species over the places and validates the relevance of the vaccination campaign in the district.

Effective control measures for mosquito vector borne diseases required evidence-based utilization of data resources and proper techniques. Characterizing spatial patterns of risk through maps is an important tool to guide control programmes which can be achieved using geospatial techniques [25, 26]. These have become powerful tools to study many health related aspects like vector borne diseases, water borne diseases, environmental health, TB transmission patterns, prevalence, monitoring and control programs for onchocerciasis, diffusion of HIV-AIDS, etc.

Meteorological and land cover variables influences the mosquito vector borne diseases that is being monitored by earth–observing satellites through multiple pathways. It monitors vegetation and water balance of a region as well as it observes the rate of development of pathogen in mosquitoes, based on certain climatic and weather phenomena. Certain satellite based precipitation products like the Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Mission (GPM) can give data in 0.25 and 0.1-degree grid at a minimum temporal resolution of 3 hours. This gives an advantage over old methods with high accuracy estimating of surface water accumulation and surface runoff on a satellite derived digital elevation models. This models further helps in determining the density of mosquito species.

Study showed that, the high loss of mosquito larvae due to excess water and flooding, where as water is one of the most important components influencing mosquito density [27]. Similarly different land cover characteristics derived for imagery are associated with information about pools for mosquito abatement, larval habitats and also habitats of different mosquito species by using indices like Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Normalized Difference Moisture Index (NDMI) etc [28, 29, 30]. Remotely sensed land surface temperature is often used as a proxy for air temperature and as the temperature affects mosquito life cycles, a change can determine mosquito specific density mapping.

Satellite based remotely sensed data of land cover along with geospatial techniques, epidemiological data and data on mosquitoes help us better to understand the environmental factors of disease outbreaks. As human exhibits lagged responses to environmental variability, it provides a basis for forecasting future malaria risk. Time series models were used to association malaria outbreaks with remotely sensed environmental variables in Ethiopia [29]. Similarly, In South Dakota, West Nile Virus (WNV) outbreak years are characterized by high mosquito infection rates, warm winters, and hot summers. As a result, it is possible to forecast WNV outbreak years using lagged environmental data [30].

5. Conclusion

To contain the vector borne diseases, it is necessary to understand the mosquito biology and its underlying interactions with the abiotic and biotic factors. Different

mosquito vectors disseminating different diseases are sensitive to different environment factors. Also, the local geography plays an important role that strongly effects the environment that is mediated by natural physical landscape features and human land use pattern. Sophisticated automated system incorporated with latest geospatial techniques is essential to facilitate early warning of diseases in a country like India where a large section of population is at stake. Thus, there is indeed a need for workflows and products specifically customised for public health applications integrated with earth observatory satellites. This study on mapping of mosquito vector distribution and its relation with land use pattern further incorporating with disease epidemiology will definitely help in evaluating models and to improve the scientific understanding of the mosquito borne disease epidemiology.

6. Acknowledgement

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