

Research Article

Changing patterns of Jhum cultivation in Tripura, India and their impact on malaria

Syed Shah Areeb Hussain¹, Kuldeep Singh², Gaurav Kumar³, Suresh Chandra^{4a}, Meenakshi Jeena⁵, Shweta Pasi⁶, Jaspreet Kaur⁵

¹ Molecular Biology, ICMR-National Institute of Malaria Research, ² Vector Biology and Control, National Institute of Malaria Research, ³ Vector Biology and Control, ICMR-National Institute of Malaria Research, ⁴ NIMR, ICMR-National Institute of Malaria Research, ⁵ Vector Genomics, ICMR-National Institute of Malaria Research, ⁶ Biological Sciences, ICMR-National Institute of Occupational Health

Keywords: Malaria, Shifting cultivation, agriculture practices, Jhum, Tripura

<https://doi.org/10.29392/001c.122050>

Journal of Global Health Reports

Vol. 8, 2024

Background

Tripura is hyperendemic for malaria and is one of the few states in India that still fall under Category 3 for malaria elimination (i.e., state annual parasite incidence (API) > 1, i.e., number of malaria cases per thousand inhabitants in a year). Tribal communities in Tripura are largely dependent on Jhum cultivation for their sustenance, and several studies have highlighted Jhum as a major risk factor for malaria.

Methods

To assess the relationship between Jhum distribution and malaria in Tripura, Jhum hotspots were identified from Landsat-8 OLI spectral images using the Normalized burn ratio index and compared with secondary data on malaria incidence and the state/district-wise total area under Jhum for the years 2017 and 2019.

Results

The study's results show that between 2017 and 2019, the total area under Jhum reduced from 39.56 km² to 27.4 km², which was accompanied by a shift in several Jhum hotspots from Dhalai and North Tripura in 2017 to West Tripura in 2019. Malaria cases showed a strong correlation with Jhum production both at the district and state level, which was significant at the 95% confidence interval. Furthermore, a stronger correlation in 2019 indicated that the share of malaria cases in Jhum cultivators may be increasing.

Conclusions

The present study presents preliminary evidence based on secondary data analysis on the possible implications of Jhum cultivation for malaria epidemiology in an endemic north-eastern state of India. It is suggested that real-time evidence should be generated on malaria prevalence among Jhum cultivators and their families. Based on the evidence, future intervention strategies for the state should focus on the elimination of malaria risk from Jhum cultivators by minimizing outdoor exposure to malaria vectors and improving access to diagnostics and treatment.

Tripura in India is a land-locked state that shares 84% of its border with Bangladesh. It is characterized by a number of hill ranges interspersed by undulating plains. About 19 different tribal communities exist in Tripura, constituting 31% of the total population of the state. Most of the tribals live in the hilly forested regions along the border with Bangladesh¹ and are largely dependent on shifting cultivation, also known as Jhum, for their sustenance.² Shifting

cultivation, or Jhum, in any form involves the clearing of vegetation, followed by slashing and burning the remaining plant parts and debris to clear the land for cultivation. Once cropping and harvesting is completed, the land is left fallow and vegetative regeneration is allowed until the plot becomes cultivable once again.

Considering the significant population expansion in India, the demand for cultivable land has significantly in-

^a SSAH, KS, GK and SC contributed equally to this work.

creased across the country and this is true for Tripura as well. In response to this, the fallow period of the Jhum cycle has reduced from 15-20 years to 2-3 years resulting in a significant loss of nutrients from the topsoil and lower yields. This is also forcing farmers to migrate to virgin lands for cultivation.²

The north-east region of India constitutes less than 5% of the total population of India, yet contributed 11.52% to the total malaria cases and 18.89% to the total malaria deaths across the country in 2021.³ Various north-eastern states belong to hyper-endemic malaria zone,⁴ Tripura, with more than 10,000 cases occurring annually for the past few years, and severe malaria outbreaks every couple of years.³ Frequent outbreaks of malaria occur in the Tripura Tribal Areas Autonomous District Council (TTAADC), where the majority of the tribals engaging in Jhum cultivation reside.¹ Despite efforts to combat malaria, Tripura has remained highly malarious as compared to the neighbouring northeastern states, highlighting the need for identifying the underlying risk factors that are influencing malaria transmission in Tripura. Studies have identified Jhum cultivation as a major risk factor for malaria in the region.⁵⁻⁷ Communities residing in remote locations at forest edges for farming places the Jhum cultivators at an increased risk of biting by the forest fringe vectors such as *An. minimus* and *An. baimaii*, which have been found to breed particularly well along the forest edges and in Jhum and rubber plantations.⁸

The present study was therefore undertaken to develop an understanding of the relation between Jhum cultivation and malaria transmission based on publicly available data on malaria cases and Jhum production. The study aims to pave the way for future research in the region to analyze the role of Jhum cultivation in driving malaria endemicity in Tripura.

METHODS

STUDY AREA

Tripura is the third smallest state in India, bordered by Bangladesh towards the north, west, and south. It lies between the coordinates 22° 56' N to 24° 32' N and 91° 09' E to 92° 20' E. The state has 5 anticline hill ranges that extend largely from the north to the south, with intervening synclines. The altitude in the state varies from 780 metres above sea level in the northeast to 15 metres in the western parts of the state.

Tripura has a tropical savanna climate (Aw) as per the Koppen classification of climate in India. The summer temperature in the state ranges from 17.8 °C to 35.6 °C, whereas in winters the temperature ranges from 5.2 °C to 26.9 °C. The annual average rainfall varies from 1900 mm to 2800 mm. Conducive temperatures for most parts of the year and a long and wet monsoon season makes the state suitable for perennial transmission of malaria, and a significant number of malaria cases are reported every month. However, a majority of the malaria cases occur during the monsoon season that extends from May to September.

DATA SOURCES

Data for the district wise and annual incidence of malaria in Tripura were obtained from the National Centre for Vector Borne Diseases Control (NCVBDC). Data for the district wise Land Use/Land Change classification in Tripura for the years 2011 and 2017 was obtained from the Natural Resources Census Project of National Remote Sensing Centre (NRSC), ISRO.⁹ The district wise dataset also classified areas of shifting cultivation and was used to assess the spatial association between Jhum cultivation and malaria across different districts of Tripura. Annual data (2006-2016) of area under Jhum and Jhum production for the whole state of Tripura, was obtained from a report sponsored by the Ministry of Agriculture and Farmer's Welfare, Government of India.¹⁰

GEOSPATIAL ANALYSIS OF JHUM AREA IN TRIPURA

For the geospatial identification of Jhum areas in Tripura, Landsat 8 OLI spectral images were obtained for 2017 (2/5/2017) and 2019 (16/11/2019) based on the least cloud cover available from the US Geological Survey (USGS) Global Visualization Viewer with a data resolution between 15-100m. The Near Infrared (NIR – band 5) and the short-wave infrared (SWIR – band 6) bands were used to determine the Normalized burn ratio based on the formula below

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

The normalized burn ratio is able to identify deforested burned area and has been used as a proxy for identifying the Jhum area with high accuracy.^{11,12}

STATISTICAL ANALYSIS OF JHUM AND MALARIA IN TRIPURA

The district wise distribution of area under Jhum (2011 and 2017), as well as the annual state wise trend in the area under Jhum (2006-16) in Tripura was visualized as graphs and maps (**Figure 1, 3-5**). Spearman's rank correlation was used to analyze the spatial as well as temporal association between malaria incidence and Jhum cultivation. Spearman's rank correlation provides a better estimation of the relation as malaria case incidence is an ordinal variable that exhibits a non-normal distribution. The spatial association was determined using the district wise data of malaria cases and Jhum area over two time periods i.e. 2011 and 2017, for computing the correlation coefficient. On the other hand, temporal association between the variables was determined by using the annual cases of malaria and area under Jhum in the whole state since 2006.

RESULTS

PERSISTENCE OF MALARIA IN TRIPURA

The tropical climatic conditions with ample rainfall and vegetation in Tripura are highly favourable for mosquito breeding and active transmission of the malaria parasite.¹³ Due to this, Tripura suffers from persistent year-round

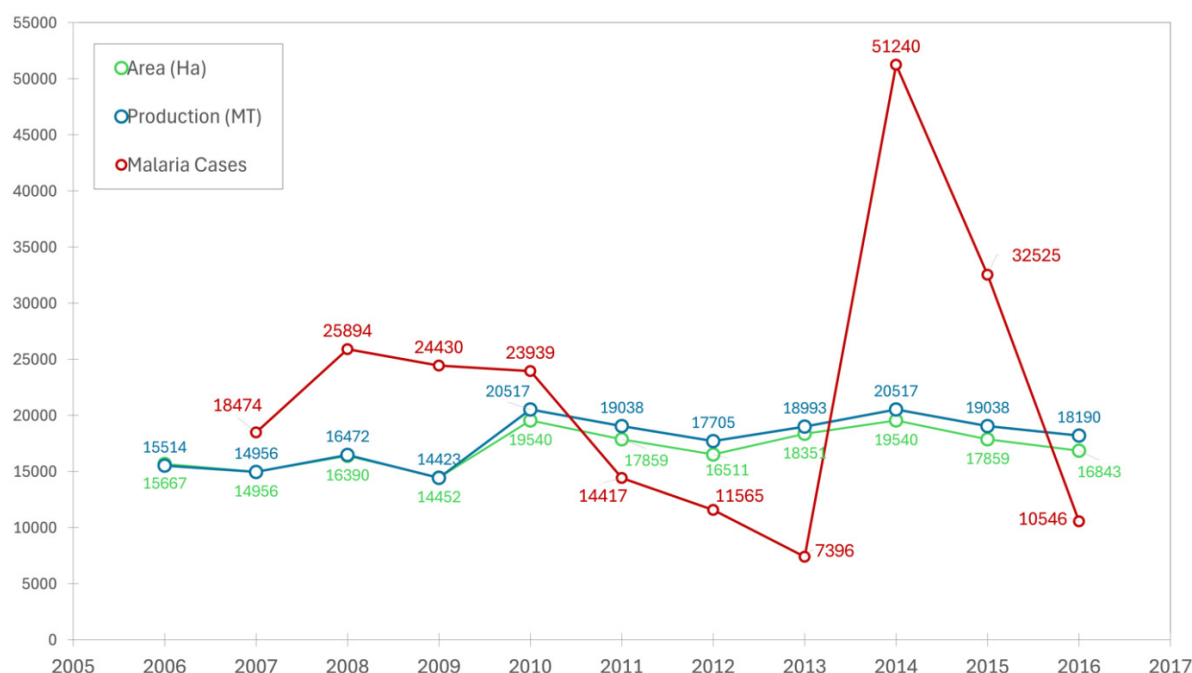


Figure 1. Trend of annual Area under Jhum cultivation, agricultural production from Jhum and malaria (cases) in Tripura from 2007- 2017

transmission of malaria, with a large majority of the cases occurring in the monsoon months extending from May to November. The introduction of LLINs in the north east in 2010, and changes to the national drug policy to make Artesunate+Sulfadoxine / Pyrimethamine and Artesunate + Lumefantrine as the first line of treatment in 2010 and 2013 respectively,^{14,15} have resulted in a steady decline of malaria in Tripura in the past decade. However, this decline in cases is marred by notable outbreaks of malaria that occurred in 2014 and 2018, resulting in several folds increase in malaria cases (Figure 1). In the north east, malaria transmission in the foothills is attributed to *An. minimus*, whereas *An. baimaii* drive transmission along the forest fringes.^{8,16} Open paddy fields in forest clearings created for Jhum cultivation serve as an ideal breeding ground for *An. minimus*,¹ whereas rubber plantations along forest edges, with ample shade, have been found to be highly suitable for *An. Baimaii*.⁸

CHANGING PATTERN OF JHUM CULTIVATION IN TRIPURA

The area under Jhum cultivation has been estimated to have reduced from 254.11 sq. km in 2010¹⁷ to 94.82 sq. km. in 2019¹⁸ in previous studies. At the same time, evidence points to a decrease in the Jhum cycle to 2-3 years as a result of growing population burden and demand for land. Jhum cultivation in Tripura is overwhelmingly concentrated in the districts of Dhalai and North Tripura (Figure 2).

Recent advances in satellite remote sensing and geospatial technologies have significantly improved Jhum mapping and temporal monitoring of Jhum areas over short periods. Image classification techniques are increasingly

being used to identify the areas of Jhum cultivation and techniques such as differential spectral response of various features and spectral enhancement as well as several indices such as the Normalized Burned Index (NBI), Burned Area Index (BAI) and infra-red burned index can significantly improve the classification to accurately segregate Jhum areas from other vegetation.^{11,12} Based on this, the distribution of Jhum fallow hotspots were identified in Tripura for the years 2017 and 2019 using the Normalized Burn Index and it was found that the overall shifting cultivation fallow area in Tripura state reduced from 39.56 km² in 2017 to 27.40 km² in 2019, a reduction of almost 30%. At the same time, while the districts of Dhalai and North Tripura had the highest concentration of Jhum hotspots in 2017, West Tripura had the highest concentration of Jhum hotspots in 2019.

ROLE OF JHUM CULTIVATION IN MALARIA ENDEMICITY IN TRIPURA

The reduction of the Jhum cycle to 2-3 years coincides with the occurrence of severe outbreaks in malaria every few years (Figure 1), and raises questions on the role of Jhum cultivation on sustaining malaria endemicity in Tripura.

During the period, from the onset of the monsoon rains in May/June to the end of autumn in August/September, Jhum cultivators stay on the site of cultivation to protect the crops, remove weeds and collect early crops. As the farmers sleep in the open and work all day in fields at the forest edges, they are at very high risk for malaria. The problem is further aggravated due to the lack of access to health in the remote areas where Jhum cultivation is carried out. This leads to high rate of transmission of malaria

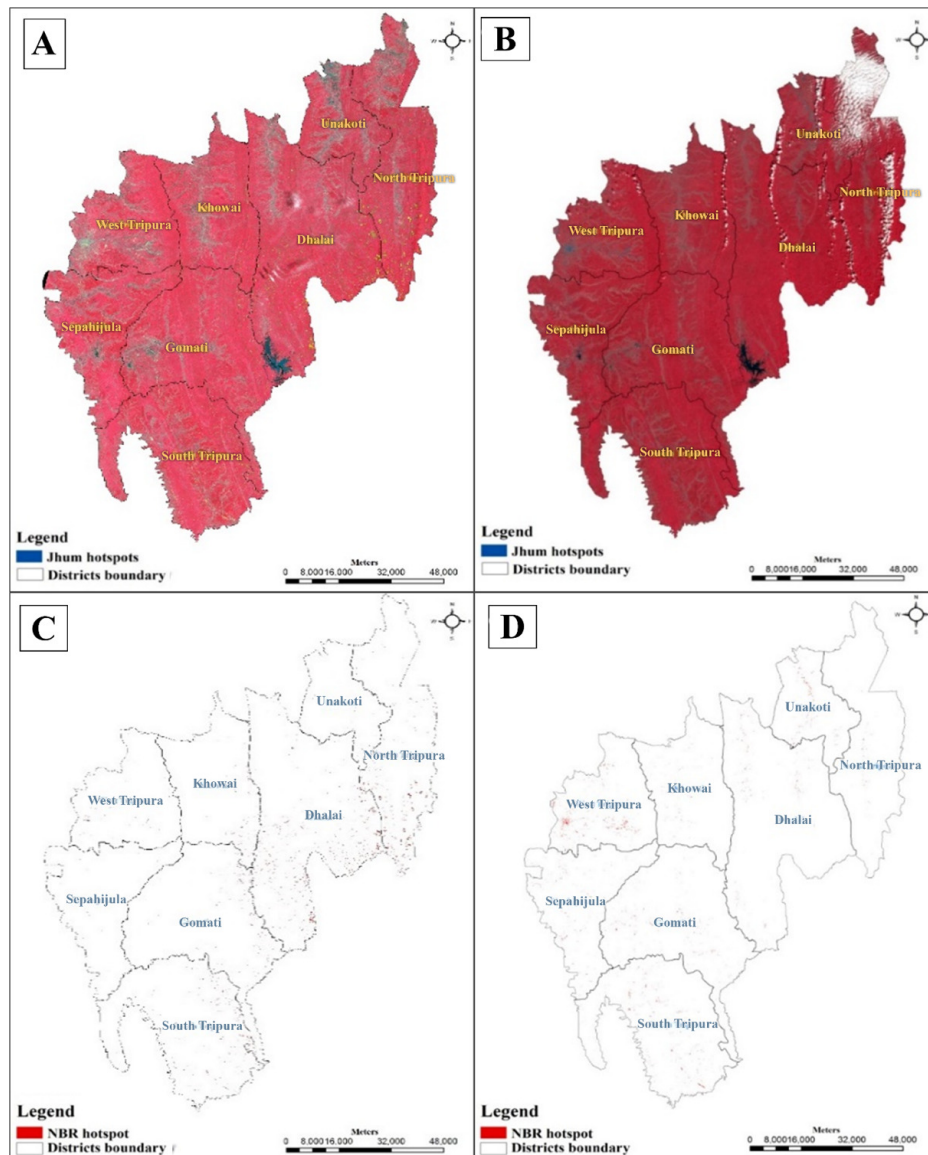


Figure 2. Jhum Hotspots in Tripura for the years (A) 2017 and (B) 2019, identified from Landsat-8 OLI spectral images using the Normalized burn ratio index as a proxy for (C) 2017 and (D) 2019 respectively.

among Jhum cultivators, as observed in previous studies done in Bangladesh.^{6,7} The period of Jhum cultivation corresponds to the peak incidence of malaria in Tripura, highlighting the significant role that Jhum plays in transmission of malaria in Tripura (Figure 3).

More than one-third of the population of Tripura is comprised of tribals that are largely involved in Jhum cultivation (Table 1). Among the different districts of Tripura, Dhalai has the largest share of the tribal population with more than half of the population (55.7%) categorized as Scheduled tribes as per the 2011 census data.

The distribution of malaria across the districts of Tripura is also not uniform, and Dhalai, which has the largest share of tribal population, accounts for more than half of the total malaria cases in the state.⁷ Other districts that also report high incidence of malaria– Gomati, Khowai and North Tripura (Figure 3), have witnessed an increase in the proportion of area under Jhum cultivation since 2011 (Figure 4).

ASSOCIATION OF JHUM AND MALARIA INCIDENCE IN DISTRICTS OF TRIPURA

In order to assess the relation between Jhum cultivation and malaria, Spearman's rank correlation coefficient was estimated between the district wise cases of malaria and the district wise area under Jhum production over two time periods – 2011 and 2017. The results show strong correlation between district wise malaria cases and total area under Jhum in both the time periods (Table 2) (significant at 98 and 99 % confidence interval respectively). Furthermore, the magnitude of association is much stronger in 2017 than in 2011, even though the total number of malaria cases in the state have decreased (Figure 1). This indicates that the share of malaria among Jhum cultivators has increased over the years, while it has decreased in other communities. A possible cause for this could be due to the fact that Jhum cultivators spend a large part of the year living away from home in the fields, where they are deprived of protective

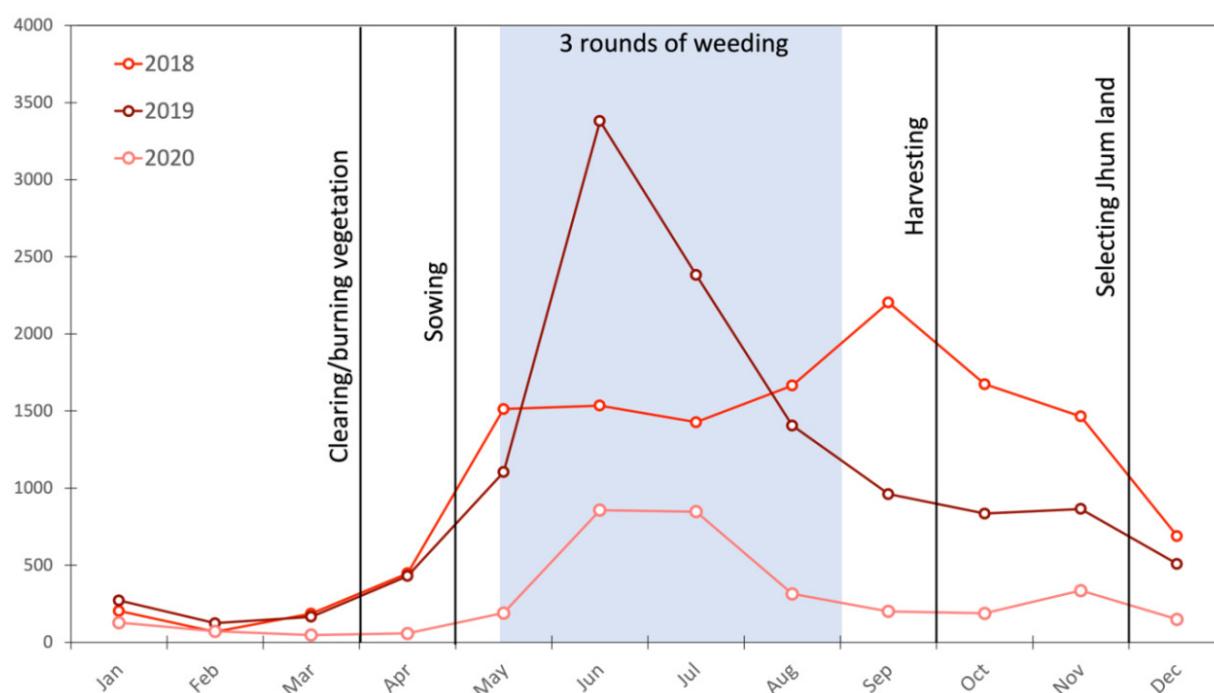


Figure 3. Monthly malaria cases and Jhum cycle

Table 1. District wise demographics of Tripura based on the 2011 census

District	Total Population	Tribal Population	Population of Children (<6 yrs)	Total No. of Literates
Dhalai	378230	210608	56011	276217
North Tripura	693947	179426	99204	520402
South Tripura	876001	344835	111949	646810
West Tripura	1725739	431944	190850	1361354

measures such as Long Lasting Insecticidal Nets (LLINS) that have shown to significantly reduce malaria incidence in other communities.¹⁵

A very strong correlation (0.870 at 97% confidence interval) is also observed between the annual incidence of malaria and area under Jhum since 2010, further corroborating this point. While this correlation between the distribution of Jhum areas and malaria cases may not signify causation, it highlights the important role that Jhum can play in malaria transmission in Tripura, and warrants a more comprehensive study on the impact of Jhum cultivation on malaria incidence.

DISCUSSION

India has put forth the goal of malaria elimination by the year 2030 and undoubtedly there is a steady decline in the disease incidence over the years. However, despite intensification of control efforts, a few parts of the country particularly in the north-east region, the pace of disruption of malaria transmission is slow and the region also witnesses frequent outbreaks. The practice of Jhum cultivation makes the region distinct from rest of India in terms of types of agricultural practices and therefore it becomes important

to decipher and understand the association, if any, between the occupation and the disease.

The 19 tribes of Tripura that reside in the hilly regions have been historically dependant on slash and burn form of cultivation since long ago. However, the burden of this practice on the environment was noted as far back as in 1876, when regression of forests in Jhum areas was observed.¹⁹ The Indian Forest Act of 1927 brought the practice of Jhum cultivation under the purview of the state, as a privilege, subject to control and regulation. One of the first plans to resettle Jhumias was adopted in 1953-54 in which each family was allotted a piece of land and some remuneration for land development and purchase of equipment.²⁰ From 1950s to 1990s, several different strategies were adopted by the Tribal Welfare Department, Forest Department, the Agricultural Department and the Watershed Development Programmes, such as the rubber / tea based resettlement schemes, rehabilitation through soil and water conservation schemes, NEC assisted schemes etc.²⁰ However, these schemes had limited success and between 1961 to 1987, the number of families involved in Jhum cultivation increased from 26,000 to 55,049 respectively.²¹ Though the 21st century has witnessed some decline in Jhum cultivation, the number of families dependent on

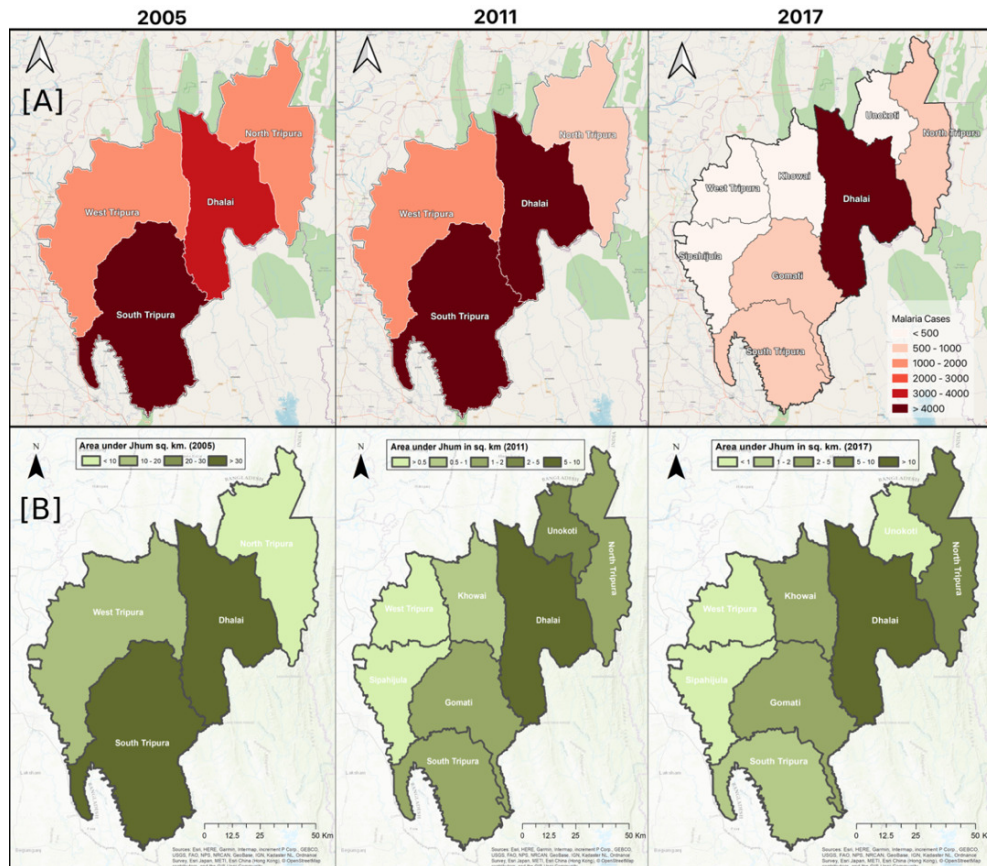


Figure 4. District wise distribution of [A] malaria cases and [B] Jhum cultivation in districts of Tripura for the years 2005, 2011 and 2017

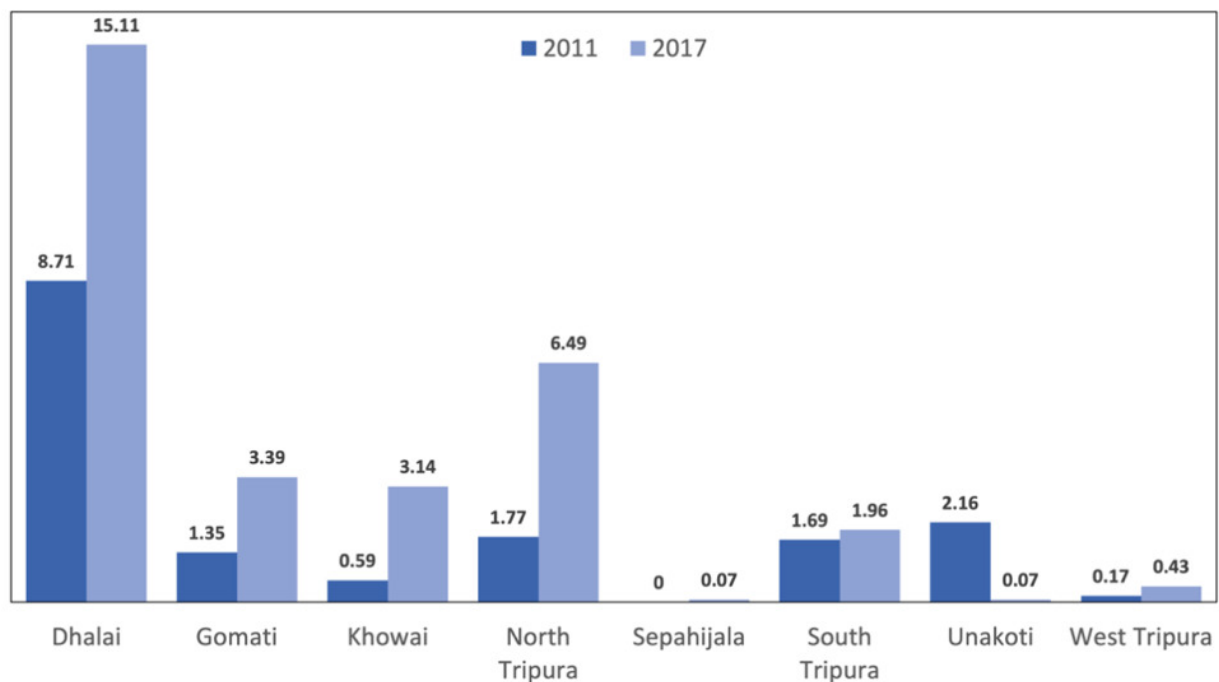


Figure 5. Change in Jhum Cultivation over two time periods in different districts of Tripura

Jhum was still as high as 27,278 in 2007,²¹ similar to the levels in 1950s.

In the present study, we underscored the impact of changing patterns of Jhum cultivation on malaria through

Table 2. District- wise correlation between area under Jhum cultivation and malaria cases over two time periods

Time Period	Correlation Coefficient	p-value
District wise Correlation		
2010-11	0.662	0.019
2016-17	0.826	0.011
State-wise annual Correlation		
2011-2017	0.870	0.024

secondary data analysis. We used the Normalized burn index as a proxy for identification of Jhum hotspots in Tripura for the years 2017 and 2019, and compared it to the incidence of malaria within the same time period. We also used publicly available data on the district wise, and state-wise annual area under Jhum cultivation and associated it with malaria cases. The results reveal a reduction in the Area under Jhum in Tripura from 39.56 km² in 2017 to 27.4 km² in 2019. This reduction in Jhum area is also accompanied by a shift in the distribution of Jhum cultivation sites from Dhalai and North Tripura in 2017 to West Tripura in 2019. It is well highlighted that there is a significant correlation at both temporal and spatial scales between Jhum cultivation and malaria incidence over the years that needs to be further investigated through prospective studies. Furthermore, our results suggest that the share of malaria burden may be rising in Jhum cultivators over the years, which needs further investigation.

A few studies conducted in Chittagong Hill districts of Bangladesh along the Indian border, find high rates of malaria infection among Jhum cultivators and their families. These studies highlight Jhum cultivation as a well-recognized risk factor for malaria in Bangladesh. A study in Laos also found strong association of malaria endemicity with the distribution of shifting cultivation sites in the Laos Savannakhet Province.²²

In Indian context the Jhum-Malaria relationship is poorly understood. In a report by Dev et al (2004),²³ the authors noted significantly higher malaria API among Jhum cultivators living in foothill villages along the north and south banks of Brahmaputra in Assam, as compared to the villages in plane areas.²³ Notably, Tripura in India specifically shares a large portion of its border with Bangladesh.

In light of this risk, it is important to analyse the pattern of Jhum in the country, and how that could affect intervention efforts for the control of Malaria, particularly in Tripura. Burned area indices are a well-accepted proxy for identifying Jhum fallow hotspots and have been used to estimate the area of shifting cultivation in the North East for the years 2014, 2016 and 2018.¹¹ The study has shown a decreasing trend in Jhum area in the states of Assam, Mizoram and Tripura, similar to our results. Another study found that the area under Jhum in the Baramura-Deotamura range in West Tripura reduced from 27.55 sq. km in 2003-04 to 8.99 sq. km in 2008-09. However, by 2012-13, the area under Jhum increased slightly to 12.68 sq. km, denoting that some rehabilitated Jhumias had reverted to their traditional practice, possibly due to slow progress in

rehabilitation, lack of proper transport and communication, physiographical isolation, lack of technical know-how and distressed economic conditions.²⁴ In contrast, Das *et al*, (2021)¹² estimated a 24% reduction in area under Jhum from 2000-01 to 2014-15, and a further 23% decline between 2014-15 to 2017-18 in the North East in general. Despite the reduction in area under Jhum, the number of new patches of Jhum were found to be increasing since the last 30 years.¹²

Jhum cultivation can support malaria transmission due to¹ abundance of mosquitoes in the remote areas at the forest edges where Jhum cultivation usually takes place,² lack of use of insecticide-treated bed nets at Jhum cultivation sites where cultivators stay during the cropping season,³ Lack of access to treatment for malaria at the Jhum cultivation sites⁴ inability of cultivators to seek treatment during the cultivation season as the farmers cannot leave the cultivation site.^{6,25}

Potential limitations of present study include limited reporting of malaria cases among Jhum cultivators. Further, inconsistencies in land use classification may add to bias. Also, a longitudinal data analysis couldn't be done due to limited data availability.

CONCLUSIONS

The present study highlighted Jhum hotspots in Tripura based upon normalized burn ratio index through spectral images and the cycle of Jhum cultivation and its relation with the malaria cases. The study further underscores the need to generate real-time evidences of malaria prevalence especially among the Jhum cultivators and their families in the malaria endemic North-eastern states of India who could be significant contributors to the reservoir of infection. Furthermore, future interventions should be planned to address the issue of outdoor exposure of Jhum cultivators to malaria vectors. Improved access to malaria diagnostic and treatment along-with LLINs, customized interventions such as hammock LLINs, mosquito repellents, repellent based products may also aid in making strides towards the goal of malaria elimination.

ACKNOWLEDGEMENTS

SSAH, MJ, SC are thankful to Department of Science and Technology (DST) for fellowship. Authors are thankful to

ICMR-NIMR for providing support. Authors are also thankful to Director, NIMR for critical review of the manuscript. Ethics Approval was not applicable.

FUNDING

No specific funding for the present work has been received.

DATA AVAILABILITY

Data on malaria incidence was obtained directly from the National Vector Borne Disease Control Programme (NVB-DCP). District wise Land Use/Land Change classification including areas of shifting cultivation in Tripura is available from Natural Resources Census Project of National Remote Sensing Centre (NRSC), ISRO.⁹ Annual data (2006-2016) of area under Jhum and Jhum production for Tripura, was obtained from.¹⁰ The Landsat 8 data provided by the US Geological Survey is made available under the USGS data policy, which aligns with the U.S. Government's open data policy and is available at (<https://catalog.data.gov/dataset/land-sat-8>).²⁶

AUTHORSHIP CONTRIBUTIONS

SSAH: writing draft, Data acquisition, Data analysis, prepared figures; GK: Data analysis, Review and editing man-

uscript; MJ: Data acquisition, Data analysis, prepared figures; SC: Data acquisition, Data analysis, prepared figures; SP: Conceptualisation, Review and editing manuscript; JK: Conceptualisation, Review and editing manuscript

DISCLOSURE OF INTEREST

The corresponding author completed the Unified Competing Interest form at <http://www.icmje.org/disclosure-of-interest> and declare no conflict of interest.

CORRESPONDENCE TO:

Jaspreet Kaur
ICMR-National Institute of Malaria Research
Sector-8 Dwarka, New Delhi 110077
India
kaur.jaspreet0708@gmail.com; dr-jaspreet.kaur@icmr.gov.in

Shweta Pasi
ICMR-National Institute of Occupational Health, Meghani-nagar, Ahmedabad 380016, Gujarat, India
shweta.pasi@gmail.com; shweta.pasi.nimr@gov.in

Submitted: March 22, 2024 BST, Accepted: June 17, 2024 BST



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-4.0). View this license's legal deed at <http://creativecommons.org/licenses/by/4.0> and legal code at <http://creativecommons.org/licenses/by/4.0/legalcode> for more information.

REFERENCES

1. Dev V, Adak T, Singh OP, Nanda N, Baidya BK. Malaria transmission in Tripura: disease distribution & determinants. *The Indian Journal of Medical Research*. 2015;142(Suppl 1):S12. [doi:10.4103/0971-5916.176597](https://doi.org/10.4103/0971-5916.176597)
2. Das S, Das M. Shifting Cultivation in Tripura-A Critical Analysis. *Journal of Agriculture and Life Sciences*. 2014;1(1).
3. NCVBDC. *Malaria Situation in India Since 2018*. National Centre for Vector borne Disease Control, Ministry of Health and Family Welfare; 2022.
4. Lalmalsawma P, Balasubramani K, James MM, et al. Malaria hotspots and climate change trends in the hyper-endemic malaria settings of Mizoram along the India–Bangladesh borders. *Sci Rep*. 2023;13(1):4538. [doi:10.1038/s41598-023-31632-6](https://doi.org/10.1038/s41598-023-31632-6)
5. Ahmed S, Galagan S, Scobie H, et al. Malaria Hotspots Drive Hypoendemic Transmission in the Chittagong Hill Districts of Bangladesh. *PLOS ONE*. 2013;8(8):e69713. [doi:10.1371/JOURNAL.PONE.0069713](https://doi.org/10.1371/JOURNAL.PONE.0069713)
6. Galagan SR, Shwai Prue C, Khyang J, et al. The practice of Jhum cultivation and its relationship to plasmodium falciparum infection in the Chittagong Hill Districts of Bangladesh. *American Journal of Tropical Medicine and Hygiene*. 2014;91(2):374–383. [doi:10.4269/ajtmh.13-0592](https://doi.org/10.4269/ajtmh.13-0592)
7. Bhowmick IP, Nirmolia T, Pandey A, et al. Dry post wintertime mass surveillance unearths a huge burden of p. Vivax, and mixed infection with p. vivax p. falciparum, a threat to malaria elimination, in dhalai, tripura, india. *Pathogens*. 2021;10(10):1259. [doi:10.3390/PATHOGENS10101259/S1](https://doi.org/10.3390/PATHOGENS10101259/S1)
8. Sarmah NP, Bhowmik IP, Sarma DK, et al. Role of Anopheles baimaii: potential vector of epidemic outbreak in Tripura, North-east India. *J Glob Health Rep*. 2019;3:2019036. [doi:10.29392/joghr.3.e2019036](https://doi.org/10.29392/joghr.3.e2019036)
9. National Resource Centre. Digital Database Bhuvan-Thematic Services, Land Use Land Cover (50K). Published online 2011. <https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php>
10. Das AK, Bordoloi J. *Jhuming to Mainstream Farming as an Alternative Way of Livelihood amongst the Tribal Farmers of Tripura*. Agro-Economic Research Centre for North-East India, Assam Agricultural University; 2019.
11. Pasha SV, Behera MD, Mahawar SK, Barik SK, Joshi SR. Assessment of shifting cultivation fallows in Northeastern India using Landsat imageries. *Tropical Ecology* 2020 61:1. 2020;61(1):65–75. [doi:10.1007/S42965-020-00062-0](https://doi.org/10.1007/S42965-020-00062-0)
12. Das P, Mudi S, Behera MD, Barik SK, Mishra DR, Roy PS. Automated Mapping for Long-Term Analysis of Shifting Cultivation in Northeast India. *Remote Sensing* 2021, Vol 13, Page 1066. 2021;13(6):1066. [doi:10.3390/RS13061066](https://doi.org/10.3390/RS13061066)
13. Nizamuddin M, Kogan F, Dhiman R, Guo W, Roytman L. Modeling and forecasting malaria in Tripura, India using NOAA/AVHRR-based vegetation health indices. *International Journal of Remote Sensing Applications*. 2013;3(3):108–116.
14. Mohapatra PK, Sarma DK, Prakash A, et al. Molecular Evidence of Increased Resistance to Anti-Folate Drugs in Plasmodium falciparum in North-East India: A Signal for Potential Failure of Artemisinin Plus Sulphadoxine-Pyrimethamine Combination Therapy. *PLOS ONE*. 2014;9(9):e105562. [doi:10.1371/JOURNAL.PONE.0105562](https://doi.org/10.1371/JOURNAL.PONE.0105562)
15. Sarma DK, Mohapatra PK, Bhattacharyya DR, et al. Malaria in North-East India: Importance and Implications in the Era of Elimination. *Microorganisms*. 2019;7(12). [doi:10.3390/MICROORGANISMS7120673](https://doi.org/10.3390/MICROORGANISMS7120673)
16. Prakash A, Ranjan Bhattacharyya D, Mahanta J. Investigation on Malaria Vectors and Mosquito Fauna in South Tripura District. *Tripura State Article in Indian Journal of Malariology*. Published online 1998. <https://www.researchgate.net/publication/12802201>
17. Pant RM, Tiwari BK, Choudhary D. Shifting Cultivation: Towards a Transformational Approach. *Report of Working Group III*. Published online 2018.
18. Roy M, Saha S, Das J, Roy M. Transition from shifting cultivation to rubber cultivation in Tripura : socio-economic and ecological impact. *Clarion: International Multidisciplinary Journal*. 2015;4(2):64–74.
19. Hunter W. *A Statistical Account of the Hill Tippreah*. Tribal Research and Cultural Institute, Govt. of Tripura; 1875.

20. Kandpal BK, Bhowmik SN. Shifting Cultivation in Tripura: Challenges, prospects and alternatives. In: Prakash N, Roy SS, Ansari MA, et al., eds. *Jhum Improvement for Sustaining Farm Livelihood and Natural Resource Conservation in North Eastern Hill Region*. ICAR Research Complex for NEH Region; 2017:57-72.
21. Directorate of Economics & Statistics. *Tripura Human Resource Development Report, 2007*. Planning (Statistics) Dept, Govt. of Tripura; 2007. Accessed March 3, 2022. <https://planning.tripura.gov.in/hdr>
22. Tojo B. Statistical Analysis on Geographical Condition of Malaria Endemic Area: A Case of Laos Savannakhet Province. *Health in Ecological Perspectives in the Anthropocene*. Published online 2019:55-67. [doi:10.1007/978-981-13-2526-7_5](https://doi.org/10.1007/978-981-13-2526-7_5)
23. Dev V, Phookan S, Sharma VP, Anand SP. Physiographic and entomologic risk factors of malaria in Assam, India. *American Journal of Tropical Medicine and Hygiene*. 2004;71(4):451-456. [doi:10.4269/ajtmh.2004.71.451](https://doi.org/10.4269/ajtmh.2004.71.451)
24. Das S, Choudhury S, Roy A. The Success Story of Rehabilitation of Jhumias in Tripura-A Study on Baramura-Deutamura Range. *International Journal of Engineering and Science*. 2012;1(10):25-29.
25. Saha A, Sarker M, Kabir M, Lu G, Müller O. Knowledge, attitudes, and practices regarding malaria control among the slash and burn cultivators in Rangamati Hill tracts of Bangladesh. *Malaria Journal*. 2019;18(1). [doi:10.1186/S12936-019-2849-0](https://doi.org/10.1186/S12936-019-2849-0)
26. U.S. Geological Survey. Landsat 8. Sioux Falls, South Dakota, USA. Archived by National Aeronautics and Space Administration, U.S. Government, U.S. Geological Survey. Published online 2013. Accessed March 15, 2022. https://cmr.earthdata.nasa.gov/443/search/concepts/C1235542031-USGS_LTA.html