GEO-EYE

RESEARCH ARTICLE

OPEN ACCESS
Received: 24.02.2024
Accepted: 27.02.2024
Published: 12.03.2024

Citation: Choudhary P, Advitot SC. (2024). Malaria Risk Mapping in Northern Satpura Region of Jalgaon District: A GIS and Remote Sensing Approach . Geo-Eye. 13(1): 1-8. https://doi.org/10.53989/bu.ge.v13i1.6

* **Corresponding author**.
ankushshindegeo@gmail.com

Funding: None

Competing Interests: None

Copyright: © 2024 Choudhary & Advitot. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Published By Bangalore University, Bengaluru, Karnataka

ISSN
Print: 2347-4246
Electronic: XXXX-XXXX

Malaria Risk Mapping in Northern Satpura Region of Jalgaon District: A GIS and Remote Sensing Approach

Parag Choudhary[1], S C Advitot[2]*

1 *Ph.D Research Scholar, Department of Geography, CBK's B.Sci, R.V.Comm. & R.J. Arts College, Akkalkot, Maharashtra, India*
2 *Principal, Department of Geography, CBK's B.Sci, R.V.Comm. & R.J. Arts College, Akkalkot, Maharashtra, India*

Abstract

This document provides an analysis of the prevalence and transmission factors of malaria in the Satpura region of Maharashtra, India. The study utilizes multi-criteria assessment and remote sensing techniques to create a malaria risk map that integrates various environmental factors. The key environmental parameters affecting malaria transmission include land use/cover, elevation, slope, distance to the stream, and breeding sites. The findings highlight the importance of addressing barriers such as misconceptions about malaria, low use of preventive measures, and inadequate malaria prevention practices in order to enhance the effectiveness of control interventions. The study concludes that remote sensing is a valuable tool for targeting malaria control interventions and optimizing resource allocation.

Keywords: Malaria; Prevalence; Transmission; MultiCriteria Assessment; Remote Sensing; Environmental Factors; Control Interventions

1 Introduction

A greater percentage of people worldwide are afflicted with malaria, a dangerous vector-borne illness. The fact that the vectors of malaria need particular habitats with surface water for reproduction and moisture for adult mosquito survival, as well as the fact that temperature affects the development rates of both vector and parasite populations, make malaria fundamentally an environmental disease[(1)]. Numerous factors contribute to the rise in malaria prevalence, including changes in land use structure, parasite resistance to medication, mosquito resistance to insecticides, and a shortage of personnel and resources for control measures. The majority of determinants are not uniformly distributed and exhibit temporal and spatial variability. The temporal and spatial distribution of malaria vectors and the disease are significantly influenced by variables like topography, temperature, rainfall, land use, population movements, and deforestation levels. (FMoH, 2009).

Over 40 percent of the world's population is at risk from malaria, which occurs in over 100 countries. Malaria remains a significant global health concern, with an estimated 229-300 million cases annually[(2)], with over 2-3 million cases occurring in India[3] , where the disease is thought to represent a significant barrier to economic development due to its high transmission rates[4] . Malaria poses significant challenges to social and economic development in India, particularly in Satpura ranges region of Jalgaon district. Few malaria deaths occur in this region.

The studies by[5–7] provide insights into the occurrence of malaria in different regions. Shukla's investigation in Rajasthan identified stable malaria foci in areas with large bodies of water, while Srivastava's GIS-based study in Haryana highlighted the presence of active pockets in flood-prone, irrigation command, and non-catchment areas. Batra's work in the Thar region of Rajasthan found high slide positivity rates in canal irrigated, sand dunes, stone quarry, and desert plain areas. Wijayanti's case study in Indonesia revealed a high distribution of malaria cases in a plateau with a plantation area. These studies collectively suggest that malaria occurrence is influenced by various factors such as water bodies, ecological characteristics, and human behavior.

Malaria affectations a substantial economic incumbrance on India, with annual losses estimated at between US$0.5 to 1.0 billion[8]. This burden is primarily driven by lost earnings and treatment costs[9]. The disease is particularly prevalent in tribal and hilly areas, with a high proportion of cases induced by Malaria parasite falciparum[10]. The increasing malariogenic potential of the country and the changing pattern of severe malaria further exacerbate the situation[8]. These findings underscore the urgent need for effective spending and control measures to mitigate the economic impact of malaria in India.

The key drivers of malaria transmission in Maharashtra include the high incidence of malaria in districts like Gadchiroli, Jalgaon and Nandurbar, which have a significant tribal population living in remote forest areas. These areas have limited access to healthcare facilities and face challenges in implementing intervention measures. Factors such as inadequate coverage of indoor residual spray (IRS) and low compliance to fever radical treatment (FRT) contribute to the persistence of malaria in these districts. The main vector, Anopheles culicifacies, is found resting indoors and shows varying levels of sensitivity to insecticides used for IRS. Additionally, population movement, with people constantly moving between villages and cities, may contribute to the spread of malaria in both directions. Rainfall also plays a role, as there is a correlation between rainfall and the relative incidence of malaria cases.

The community's widespread misconceptions about malaria, low use of antimalarial services and preventive measures, treatment seeking from unqualified traditional healers, poor adherence to antimalarial medications, inadequate malaria prevention practices, culturally inappropriate malaria educational materials, lack of transportation for surveillance, and the high cost of treating malaria outside of a village are the main factors contributing to the ineffectiveness of malaria control interventions in north Maharashtra. These elements impede prompt and efficient malaria diagnosis, treatment, and prevention in the area. In order to increase the efficacy of malaria control interventions, it is imperative to address these barriers by increasing the distribution and use of insecticide-treated nets, addressing the difficulties associated with surveillance and treatment access, enhancing community knowledge through culturally appropriate health education materials, incorporating traditional healers in malaria control efforts, and promoting prompt diagnosis and treatment within villages.

Remote sensing has proven to be a valuable tool in the fight against malaria, with applications ranging from identifying mosquito habitats to mapping malaria risk. Hay et al.[11] and Padidar and Safavi[12] both highlight the potential of remote sensing in these areas, with Hay specifically noting the increasing sophistication of airborne and satellite-sensor technology. Roberts et al.[13] and Moss et al.[14] provide practical examples of this, with Roberts describing a NASA project in Mexico to develop a predictive model of vector population dynamics and malaria transmission potential, and Moss using remote sensing to identify spatial risk factors for malaria in Zambia. These studies collectively demonstrate the potential of remote sensing in targeting malaria control interventions and improving the efficiency of resources.

The present study was conducted in the northern Satpura region situated in the Chopda, Yaval, and Raver tehsil of Jalgaon district in Maharashtra, India, with the aim of creating a malaria risk map that identifies and integrates environmental factors that make conditions suitable for breeding, the occurrence of malaria outbreaks and the identification of mosquito habitat in the study area, development of a land use/land cover map and a map of various factors for malaria risk and hazard analysis. Finally, calculate the eigenvector for the developed factors and perform weighted overlay analysis in ArcGIS by integrating derived information to develop a malaria risk map showing malaria risk areas using remote sensing and GIS.

1.1 Aim and Objectives

The objective of the study is to discuss the prevalence of malaria in the study area and the factors that contribute to its transmission. The aim is to create a malaria risk map using multi-criteria assessment (MCE) and remote sensing in the Satpura region of Jalgaon district in Maharashtra, India.

2 Methodology

This is a popular method with a wide variety of applications in many different areas of Malaria risk identification. Malaria risk of the district was analysed from the following general risk equation

Risk = (Elements at risk) *(Hazard)*(Vulnerability)

Elements at risk (E) include the population, economic activities, public services, utilities and infrastructure, etc. at risk in a particular area.

Risk (R) is the expected magnitude of loss due to a specific natural phenomenon. It can be expressed as an intersection of hazard (H), vulnerability (V) and element at risk (E).

Hazard (H) is the probability of the occurrence of a potentially harmful natural phenomenon within a given period of time and within a given area.

Vulnerability (V) is the exposure of a specific constituent or set of constituents to the occurrence of a harmful phenomenon of a certain magnitude.

A multi-criteria assessment (MCE) was used to calculate the malaria hazard analyses. The selected environmental parameters, including land use/cover, elevation, slope and flow distance to the stream, and breeding sites, were developed and weighted to conduct MCE. Next, a malaria hazard map was created using the weighted overlay technique in the ArcGIS 10.8 environment with the AHP extension. The location of the health center in the Spatial Analyst/Module was used to create factor maps representing the distance to the health center for vulnerability analysis. The element risk factor map was produced utilizing a land use and land cover map. Finally, a spatial analysis/raster calculator tool was used in the ArcGIS9.2 environment to create a malaria risk map for the district. This specific tool multiplies the at-risk elements, susceptibility and hazard map that led to malaria risk.

2.1 Data Processing Analysis

Environmental factors that regulate mosquito maturity and parasite development are closely linked to malaria transmission. Breeding sites, elevation, slope and distance from the stream or water bodies are therefore prioritized. A multi-criteria assessment was conducted using GIS and remote sensing to determine the district's malaria risk. In order to achieve a specific goal, the MCE procedure requires the evaluation of several criteria.

To demonstrate the relative importance of each component in contributing to malaria risk, the standardized grid layers were weighted using the eigenvector. Consequently, the eigenvector representing the weighting of the factors was calculated using the extension software ArcGIS 10.8 /AHP. The calculated eigenvector, which is the result of the pairwise comparison matrix to generate the most appropriate weight set for the weight module, was: wetness index = 0.1854, elevation = 0.2447, slope = 0.3229, distance to stream = 0.1065 and Distance to breeding site = 0.1405. The consistency ratio (CR) of the calculated eigenvector was 0.0435, which is acceptable. When combining the corresponding factor maps in the Weighted Overlay of the Arc GIS environment, the calculated eigenvector served as the coefficient. Each factor in malaria risk assessment remained consistent with its weighted superposition and importance.

2.2 Factor Development

2.2.1 Elevation

Altitude is an important factor in the transmission of malaria. This is because altitude greatly determines the level of temperature and temperature in turn influences mosquito breeding as well as the length of the immature stage in the life cycle. At high temperatures, the egg, larval and pupil stages shorten, so turnover increases and also affects the length of the parasite's saprogenic cycle in the mosquito host, i.e., H. When the temperature rises to the period of the saprogenic cycle, a short circuit occurs. The district's elevation was derived from a 20-meter contour interval feature class digitized from a 1:50,000 scale SOI topographic map and further corrected in a GIS environment. This feature was converted to a 3D shape file using the 3D Analyst in the Convert Feature to 3D module by interpolating the contour using an attribute as a source. Additional TINs were developed using 3D analysts to create TINs from the feature 3D shape to the raster elevation plane. The TIN was converted to DEM using the TIN to Raster option in the 3D analysis tool. Using ArcGIS/ArcMap 10.8, the elevation raster layer was promoted, reclassified into five subgroups, and given new values according to the malaria risk assessment.

2.2.2 Slope

Slope is another topographic parameter that can be associated with the habitat formation of mosquito larvae. Aquatic habitat stability may be impacted by this measurement of the change in land speed per unit of distance[15]. The slope of the study area was derived from the 20-meter contour intervals feature class, which was digitized from a 1:50,000 scale topographic map and further rectified in ArcGIS/ArcMap 10.8. This feature was converted to a 3D shape file using 3D Analyst in the Convert Feature to 3D module by interpolating contours using an attribute as a source. Additionally, TIN was developed with the help of 3D analysts in creating TINs from features (3D shape). The TIN was converted to DEM using the TIN to Raster option in the 3D analysis tool. The slope was derived using the DEM-in-3D analysis tool using the Surface/Slope surface analysis module. The slope raster layer was further reclassified into five subgroups based on the predefined slope class. The newly classified subgroups of the slope grid layer were ordered according to the degree of their suitability for the occurrence of malaria in the locality. More specifically, the values with steeper gradients are associated with a lower risk of malaria, while the values with smaller gradients are associated with a higher susceptibility to malaria cases. And new values were reassigned in the order of malaria risk assessment.

2.2.3 Distance to stream

Stream flow distance determined as the distance from a downstream grid cell to a stream grid cell defined by the stream grid, can impact aquatic habitat availability. Flow distance to stream has an advantage over simple distance to stream because it takes into account both flow direction and landscape profile[15]. TauDEM Model is a dedicated grid analysis/flow distance-to-stream module that was used to generate the flow distance-to-stream grid layer from the DEM. Considering that the maximum flight distance of the Anopheles mosquito from the distance to the stream is two kilometres', this serves as the basis for reclassifying the distance to the stream layer. The river distance raster layer was then further classified into five subgroups using the Natural Break Standard reclassification method in ARC GIS 10.8 software. The classified subgroups of the stream outdistance raster layer were ordered based on the mosquito flight distance threshold, meaning that areas outside the threshold were classified as having a lower risk of malaria. In addition, new values were assigned according to the malaria risk classification.

2.2.4 Wetness index

The wetness index can affect the availability of mosquitoes in a particular area. The humidity index factor contributes to the risk of malaria as the wetness of the land increases the water storage capacity of the land and this would create a breeding ground for the mosquito. The moisture index of the study area was derived from the "20-meter contour intervals" feature class, which was digitized from a 1:50,000 scale topographic map and further corrected in a GIS environment. The wetness index raster layer was generated from the district's DEM using the ArcMap extension's grid analysis/slope/area module (Wetness Index Inverse) specialized for the TauDEM model. The grid was classified considering the maximum and minimum moisture index value of the study area. Then, the wetness index raster layer was promoted classified into 5 subgroups using the standard "Natural Break" reclassification method in ArcGIS 10.8 software, and the reclassified subgroups of the wetness index raster layer were ranked according to the wetness index value, which means that areas with lower wetness index value are taken into account Areas with a high wetness index value are considered areas with a high risk of malaria. And new values were reassigned in the order of malaria risk assessment.

2.2.5 Distance to breeding site

One of the environmental covariates that was significantly associated with transmission intensity was distance from water and wetland, indicating high transmission in the areas within 2 km of the water source (Malaria Journal of 2002). The breeding site was extracted from the wetness index factor raster map of the study area. The wetness index indicates the degree of moisture in the area being examined. An index value of more than 0.007 according to the wetness index value obtained from the DEM of the study area was considered a highly suspicious area for mosquito breeding. The wetness index raster layer was converted to a vector file using the raster-to-vector conversion tool in ArcGIS/ArcMap 10.8 software. The converted vector layer was queried in the same environment using the attribute selection tool to extract areas suspected of being mosquito breeding grounds. The straight-line distance of a spatial analysis tool was used to calculate the distance from the breeding site. Considering the maximum flight distance of the Anopheles mosquito from the breeding site, which is 2 km, as the basis for reclassifying the distance layers of a quadric body (Malaria Journal of 2002). Then, the Breeding Site Distance raster layer was further reclassified using the standard Natural Breaks reclassification method in ArcGIS 10.8, and the reclassified subgroups of the breeding site distance grids were ordered by the mosquito flight distance threshold, meaning that areas outside the flight distance, less malaria risk area is considered and new values are reassigned in the order of malaria risk assessment.

2.2.6 Vulnerability (Accessibility index)

Vulnerability (accessibility index) is an important factor in malaria vulnerability. It was generated from point data from the health station of the study area and a speed constant raster layer generated with the same minimum permitted speed for cars in the city, 20 km/h. The location of the healthcare facilities was digitized after georeferencing in the ArcGIS 10.8 environment. The spatial analyst/straight-line distance function was used to generate the distance to the grid plane of healthcare facilities. The Spatial Analyst/Raster Creation/Create Constant Raster Layer tool was used to generate a velocity constant layer. A spatial analyst/raster calculator was then used to generate the Healthcare Accessibility raster layer by dividing the distance to healthcare facilities by the Velocity Constant raster layer. The result obtained was a susceptibility (accessibility index) grid for malaria incidence. The pixel value should represent the time it takes for a person to travel to a nearby healthcare facility by car at the maximum allowable speed. The vulnerability grid was promoted classified into 5 subclasses. And the reclassified subgroups of the Vulnerability (Accessibility Index) raster layer were ordered by the maximum minute it would take to reach a nearby healthcare facility. As a less malaria-prone area, minimum minutes are required to get to nearby health facilities. And new values were reassigned in the order of malaria risk assessment.

2.2.7 Land use land cover

Land cover land use has been considered a vulnerable element affecting malaria incidence. Land use is the way and purpose for which people use the land and its resources. On the other hand, land cover denotes to the existent physical state of the land surface, such as that of farms, mountains, or forests (Meyer 1995). However, the high spatial resolution (14.25 m) panchromatic band 8 was spatially merged to increase the resolution of the data in ENVI 4.0 using Layers to improve stacking or image sharpening tools. The land use/land cover classes of the study area were classified using the Land Sat ETM+ satellite image, which had a spatial resolution of 30 m. Therefore, the coarse resolution bands (bands 1, 2, 3, 4, 5, and 7) were stacked layer by layer. Using the study area's corner coordinate value in ENVI 4.0, the image produced with a spatial resolution of 14.25 m was replaced. Streak removal and radiometric correction were applied to the partial image. The ROI was captured using on-site GPS. Based on the AOI collected in ENVI 4.0, a supervised classification method was performed to classify the image into seven basic classes (settlement, mixed land use, agricultural land, pasture land, bare land, forest and water body). The classified image was exported to the ArcGIS/ArcMap 10.8 environment for further classification and reclassification. In addition to land use, the land cover of Kersa district was reclassified into seven subgroups in terms of its vulnerability and suitability for malaria risk. Thus, the reclassified version implies 1 to 7, where 1 represents a highly affected land use/land cover element and 7 represents less affected land use/land cover elements.

2.3 Malaria hazard analysis

'Maleria-hazard' refers to the probability that malaria-carrying mosquitoes will be present in a given area. The methodology involved assessing environmental conditions for malaria transmission, taking into account physical and environmental factors. The next step was to estimate the weights of the hazard parameters after ensuring that all factor parameters were ready for hazard analysis. When creating a hazard map, it is necessary to estimate the weight of each individual hazard parameter. The steps involved in applying MCDM (Multi-criteria decision-making) to determine the weight of hazard parameters are explained in the following sections. For example, the following steps were taken to estimate weight during hazard mapping using the ranking method. In this study, 5 evaluation criteria - distance element to breeding site, elevation factor, slope factor, distance factor to stream and wetness index factor - were considered to determine the location of malaria risk. The first step was to rank the criteria based on their apparent, assessable value. In this regard, the factors elevation, slope, distance to a stream, wetness index factor and distance to a breeding site were ranked in order of importance. The five selected hazard parameter factors were covered in the ArcGIS 10.8/ArcMap AHP extension in a GIS environment to calculate the hazard layer after assigning the weight of each parameter based on its importance.

2.5 Malaria risk analysis

Based on the Risk Computation Model, a malaria risk map for the study area was created [16].

$$\text{Risk} = \text{Element at risk} * \text{Hazard} * \text{vulnerability} \tag{1}$$

The three factors of malaria risk analysis are danger, risk element and danger level. The malaria hazard layers were calculated by overlaying the five selected causal factors such as distance to breeding site, elevation, slope and distance from streams and the wetness index grid layer in the weighted overlay module of ArcGIS 10.8 software. The vulnerable element level was developed by rasterizing and reclassifying the land use/land cover image file based on the malaria susceptibility of each land use/land cover image file based on the malaria susceptibility of each land use/land cover class. In addition, the vulnerability layer was developed by calculating the distance modulus on the layer calculated by calculating the index density of health facilities per population based on the existing dispersion of health facilities per population distribution. In addition, all three risk components with equal importance for malaria risk were taken into account. Finally, a grid calculator was used to multiply the three risk components. The malaria risk raster layer, which was created by multiplying the risk components, was the end result. Subgroups based on risk level were then identified: very high, high, medium, low, and very low risk areas.

3 Results and Discussion

3.1 Located Malaria Hazardous Areas

Hazard refers to the likelihood of a harmful natural phenomenon occurring within a given timeframe. A risk associated with malaria is the mapping of the disease's incidence based on environmental factors that support Anopheles mosquito survival. A series of studies in Ethiopia have utilized GIS and remote sensing techniques to map malaria hazard areas. Manoharan et al. [17] identified very high to very low malaria hazard areas in the Jimma zone, with a significant portion falling in the high-risk category. Wondim (2017) similarly found a large portion of the Tekeze Basin Development Corridor to be at high or very high risk. Miheretie et al. [18] identified highly suitable areas for malaria hazard in East Gojjam zone. Abdulahi et al. [19] focused on the Korahey zone, mapping a majority of the area as very high or high risk. These studies collectively highlight the widespread and significant risk of malaria in various regions of Ethiopia.

This study considered elevation, slope, distance to streams, distance to breeding sites, and wetness index as the factors of malaria incidence in the study area in order to identify areas of malaria hazard. [20] states that areas with lower drainage density, a lot of wet lands, gentle slopes, still waters near rivers, and lower elevations are conducive to higher temperatures and malaria incidence. The areas susceptible to malaria were determined by superimposing these factors. Following the appropriate weighting of each factor in accordance with its relative significance for the incidence of malaria in this study, the overlay analysis was completed. The process of creating the pairwise comparison matrix involved comparing each of the five parameters pairwise. Following the five factors' overlay analysis—elevation, slope, distance to streams, distance to breeding site, and wetness index—a malaria hazard map was generated.

Table 1. Coverage and percentage of malaria hazard area

No.	Classification	Area (Km^2)	Area (%)
1	Very Low	64.012	2.20
2	Low	290.105	9.97
3	Moderate	505.376	17.37
4	High	1967.445	67.64
5	Very High	81.861	2.81

The information in Table 1 represents the classification of a malaria hazard map based on different risk levels along with the corresponding area coverage and percentage distribution.

Very Low (Area: 64.012 km^2, Percentage: 2.20%): This category represents areas with the lowest risk of malaria The relatively small area share suggests that a small part of the overall map is classified as very low risk. This might point to areas where malaria-carrying mosquitoes are less likely to find suitable breeding grounds or where other favourable conditions help prevent the spread of malaria or a lack of suitable breeding sites for malaria-carrying mosquitoes.

Low (Area: 290.105 km^2, Percentage: 9.97%): The low-risk category covers a larger area than the very low risk category. There may be some risk of malaria transmission in these areas, but the risk is still considered low. These could include regions with moderate prevention measures or environmental factors that are less conducive to malaria transmission.

Moderate (Area: 505.376 km^2, Percentage: 17.37%): Moderate risk areas cover a significant portion of the map. This suggests that a significant portion of the region is at moderate risk of malaria transmission. Malaria control and prevention efforts in these areas may need to be intensified to further reduce the risk.

High (Area: 1967.445 km^2, Percentage: 67.64%): The high-risk category covers most of the map area, indicating that a significant portion of the region is vulnerable to malaria transmission. This could be due to factors such as a high prevalence of malaria-carrying mosquitoes, the lack of effective prevention measures, or environmental conditions that favor malaria transmission. It is crucial to focus on targeted interventions and control measures in these high-risk areas.

Very High (Area: 81.861 km^2, Percentage: 2.81%): The very high-risk category represents a smaller area but is still significant. These areas are at highest risk of malaria transmission and urgent and comprehensive measures are likely to be required to prevent and control the spread of malaria in these regions. High and very vulnerable areas should be given priority to effectively distribute resources and implement targeted measures such as insecticide-treated bed nets, indoor residual spraying and distribution of anti-malarial drugs.

To adopt tactics in response to shifts in the environment, in human migration patterns, and in other variables that impact malaria transmission, ongoing surveillance and monitoring are crucial. For comprehensive malaria control programs to be implemented and the disease's overall burden to be decreased, cooperation between health authorities, local communities, and foreign organizations is essential.

3.2 Identified Malaria Risk Areas

When assessing the area in need of urgent attention in the fight against malaria, hazard mapping based solely on natural conditions is not enough, but socioeconomic factors such as population density, distribution of health facilities and land use should also be included. Only then can you pinpoint the area where there is a high risk of malaria. The malaria hazard map, health facility per population index and land use land cover map were multiplied and a malaria risk indicator map was created. The basis for calculating the map was the risk calculation model developed according to [16].

Table 2. Malaria risk assessment, area coverage and percentage

No.	Classification	Area (Km^2)	Area (%)
1	Very Low	1137.153	39.09
2	Low	801.220	27.54
3	Moderate	756.618	26.01
4	High	189.557	6.52
5	Very High	24.252	0.83

The information provided outlines the classification of a malaria risk map based on different risk levels as well as the corresponding area coverage and percentage distribution. Let's analyse the results and discuss their implications.

Very Low (Area: 1137.153 square kilometers, Percentage: 39.09%): This category represents a significant part of the map and indicates areas with the lowest risk of malaria. The high percentage suggests that a significant portion of the region is classified as very low risk for malaria. This could be due to effective control measures, environmental factors or other reasons that make these areas less conducive to malaria transmission.

Low (Area: 801.220 square kilometers, Percentage: 27.54%): The low-risk category covers a significant area and indicates regions where the risk of malaria transmission is relatively low but still present. This category could include areas with moderate control measures or environmental conditions that contribute to a lower risk of malaria.

Moderate (Area: 756.618 square kilometers, Percentage: 26.01%): Moderate risk areas make up a significant portion of the map, suggesting a moderate risk of malaria. Interventions in these areas may need to be tailored to specific factors that contribute to moderate risk, such as environmental conditions, population movements, or health infrastructure.

High (Area: 189.557 square kilometers, Percentage: 6.52%): The high-risk category represents a smaller area but is still notable. There is a higher risk of malaria transmission in these areas. Targeted efforts are likely needed to reduce the risk and prevent the spread of the disease. Increased vector control measures and improved access to health services may be needed in high-risk areas.

Very high (area: 24.252 square kilometers, percentage: 0.83%): The very high-risk category covers the smallest area but represents regions with the highest risk of malaria transmission. In these areas, urgent and comprehensive interventions are crucial to effectively prevent and control the spread of malaria. This could include a combination of vector control, treatment programs and community engagement. Distributing malaria risk across different categories provides valuable insights into the different risk levels in different regions. Resources and interventions can be prioritized depending on the level of risk, with a focus on high and very high-risk areas to maximize the impact of control measures.

Continuous surveillance and surveillance are essential to adjust strategies based on changes in risk factors and to ensure the continued effectiveness of malaria control programs. Collaboration between health authorities, communities and international organizations is critical to implementing and sustaining comprehensive malaria control measures.

4 Conclusion

In summary, this manuscript sheds light on the prevalence of malaria in India, particularly focusing on the Satpura region (Chopda, Yaval, and Raver tehsil) of Jalgaon district in Maharashtra. The study uses multi-criteria assessment (MCE) and remote sensing to create a malaria risk map that takes into account various environmental factors that contribute to malaria transmission. These factors include land use/cover, elevation, slope, distance to stream, and breeding sites. Research shows that these important environmental factors significantly influence malaria transmission in the region. In addition, the study highlights the importance of addressing barriers to effective malaria control measures, such as widespread misconceptions about malaria, low uptake of antimalarial services and prevention measures, and inadequate malaria prevention practices. It is crucial to remove these barriers to increase the effectiveness of control measures. The study concludes that remote sensing is a valuable tool for targeting malaria and improving resource efficiency. By using GIS and remote sensing techniques, researchers were able to create a malaria risk map that can help identify and integrate environmental factors that contribute to suitable breeding conditions for mosquitoes and the occurrence of malaria outbreaks. This information can guide targeted interventions and allocate resources effectively. Overall, this study provides valuable insights into the factors affecting malaria transmission in the Satpura Tehsil region and highlights the need for comprehensive and integrated approaches to malaria control in India.

Here are a few suggestions to combat the prevalence of malaria in the northern Satpura region of Jalgaon district in Maharashtra, India: Increase access to insecticide-treated nets and indoor residual spraying. Improve access to antimalarial services and prevention measures. Promote rapid diagnosis and treatment in villages. Improve community knowledge through culturally appropriate health education materials. Involve traditional healers in malaria control efforts. Implement targeted interventions based on risk assessment. Improve monitoring and monitoring. Collaborate with health authorities, communities and international organizations. These efforts will help address barriers to malaria control and improve the effectiveness of interventions in the region.

References

1) Ashenafi M. Design and water management of irrigation systems to control breeding of Anopheles mosquitoes. Case study: Hara irrigation project. Arba Minch, Ethiopia; Wageningen. The Netherlands. 2003.
2) Fikadu M, Ashenafi E. Malaria: An Overview. 2023. Available from: https://doi.org/10.2147/IDR.S405668.
3) Valecha N, Staedke S, Filler S, Mpimbaza A, Greenwood B, Chandramohan D. Malaria-attributed death rates in India. Elsevier BV. 2011. Available from: https://dx.doi.org/10.1016/s0140-6736(11)60380-2.
4) Robert V, Duchemin JB, Macintyre K, Warren MC, Keating J, Beier JC, et al. Malaria transmission in urban sub-Saharan Africa. *The American Journal of Tropical Medicine and Hygiene*. 2003;68(2):169–176. Available from: https://dx.doi.org/10.4269/ajtmh.2003.68.169.
5) Shukla RP, Pandey AC, Mathur A. Investigation of malaria outbreak in Rajasthan. *Indian journal of malariology*. 1995;32:119–147.
6) Srivastava A, Nagpal BN, Saxena R, Wadhwa T, Mohan S, Siroha GP, et al. Malaria epidemicity of Mewat region. *District Gurgaon*. 2004;86:1297–1303. Available from: https://www.jstor.org/stable/24109942.
7) Wijayanti EPN, Martini M, Hestiningsih R, Wuryanto MA, Yuliawati S, Mawarni A. Case study of malaria patients: distribution of cases and maps of Anopheles sp. breeding place in Kaligesing subdistrict, Purworejo district. *Journal of Physics: Conference Series*. 2020;1524(1):012122–012122. Available from: https://dx.doi.org/10.1088/1742-6596/1524/1/012122.
8) Sharma VP. Malaria: cost to India and future trends. 1996.
9) Gupta I, Chowdhury S. Economic burden of malaria in India: The need for effective spending. *WHO South-East Asia Journal of Public Health*. 2014;3:95–102. Available from: https://doi.org/10.4103/2224-3151.206894.
10) Dash AP, Valecha N, Anvikar AR, Kumar A. Malaria in India: Challenges and opportunities. *Journal of Biosciences*. 2008;33:583–592. Available from: https://doi.org/10.1007/s12038-008-0076-x.
11) Hay SI, Snow RW, Snow RW, Rogers DJ. From predicting mosquito habitat to malaria seasons using remotely sensed data: practice, problems and perspectives. *Parasitology today*. 1998;14(8):306–319. Available from: https://doi.org/10.1016/s0169-4758(98)01285-x.
12) Padidar M, Safavi KE. Using remote sensing for risk mapping of malaria: A review of remote sensing approaches in environment. *2nd International Conference on Chemical*. 2010;p. 363–366. Available from: https://doi.org/10.1109/ICBEE.2010.5651020.
13) Roberts DR, Rodríguez MH, Rejmánková E, Pope KO, Hm S, Rodríguez-Ramírez A, et al. Overview of field studies for the application of remote sensing to the study of malaria transmission in Tapachula. *Preventive Veterinary Medicine*. 1991;11:269–275. Available from: https://doi.org/10.1016/S0167-5877(05)80013-3.
14) Moss WJ, Hamapumbu H, Kobayashi T, Shields T, Kamanga A, Clennon JA, et al. Use of remote sensing to identify spatial risk factors for malaria in a region of declining transmission: a cross-sectional and longitudinal community survey. *Malaria Journal*. 2011;10:163–163. Available from: https://doi.org/10.1186/1475-2875-10-163.
15) Mushinzimana E, Munga S, Minakawa N. Landscape determinants and remote sensing of mosquito larval habitats in the high land of Kenya. *Malaria journal*. 2006. Available from: https://doi.org/10.1186/1475-2875-5-13.
16) Shook G. An assessment of Disaster Risk and its Management in Thailand. *Disasters*. 1997;21(1):77–88. Available from: https://dx.doi.org/10.1111/1467-7717.00045.
17) Manoharan R, Alemu M, Legesse B, Abajihad M. Malaria Hazard and Risk Analysis Using Geospatial Techniques in the Case of Selected Woredas of Jimma Zone. *Earth Systems and Environment*. 2020;5:115–126. Available from: https://doi.org/10.1007/s41748-020-00170-w.
18) Miheretie AA, Assefa B, Kefyalew T. Identifying Malaria Hazard Areas Using GIS and Multi Criteria: The Case Study at East Gojjam Zone. Ethiopia. 2020.
19) Abdulahi A, Wudad A, Abajihad M, Mohammed F. Malaria Hazard and Risk Analysis Using GIS and Remote Sensing in Korahey Zone of Somali Regional State. Eastern Ethiopia. 2020.
20) Fisseha N. Identifying, Mapping and Evaluating Environmental factors Affecting Malaria Transmission Using GIS and RS in Selected Kebeles of Adama district. Oromia Region. AAU. 2008.