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

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Abstract:

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, multi-criteria assessment, remote sensing, environmental factors, control interventions.

Introduction:

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.

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 (Negasi Fisseha, 2008 and Roberts, D.R. et-al 1991). 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.

Aim and Objectives :

The objective of the study is to discuss the prevalence of malaria in the study area and the factors

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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.

Methodology :

This is a popular method with a wide variety of applications in many different areas of Malaria risk identification. The malaria risk of the study area was analysed by the Shook (1997) 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 and 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.

Factors Development :

a) Elevation :

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. 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.

b) Slope :

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 the 3D module by interpolating contours using an attribute as a source. TIN was developed with the help of 3D analysts in creating.

c) Wetness index :

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 and 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.

d) Distance to the breeding site :

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 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.

e) 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 was 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 and classified into 5 subclasses. 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, a minimum minutes required to get to nearby health facilities. And new values were reassigned in the order of malaria risk assessment.

f) Land use land cover :

Land cover land use has been considered a vulnerable element affecting malaria incidence. 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.

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. 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.

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Malaria risk analysis :

Based on the Risk Computation Model, a malaria risk map for the study area was created (Shook, 1997). 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 the breeding site, elevation, slope and distance from streams and the wetness index grid layer in the weighted overlay module of ArcGIS 10.8 software. In addition, the vulnerability layer was developed by calculating the distance modulus on the layer 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 result. Subgroups based on risk level were then identified: very high, high, medium, low, and very low-risk areas.

Results and Discussion :

Located Malaria Hazardous Areas :

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 to identify areas of malaria hazard. Negasi (2008) 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 by 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 the 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

(Source: computed by researchers.)

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.

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.

Identified malaria risk areas :

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 (Shook, 1997).

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

(Source: computed by researchers.)

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 km^2, 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 km^2, 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.

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 km^2, 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.

Very high (area: 24.252 km^2, 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.

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. 1)Research shows that important environmental factors significantly influence malaria transmission in the region. 2)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. 3)The study concludes that remote sensing is a valuable tool for targeting malaria and improving resource efficiency. 4)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. 5)The 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.

Suggestions :

1) To combat the prevalence of malaria in the northern Satpura region of Jalgaon district.
2) Increase access to insecticide-treated nets and indoor residual spraying.
3) Improve access to antimalarial services and prevention measures.
4) Promote rapid diagnosis and treatment in villages.
5) Improve community knowledge through culturally appropriate health education materials. Involve traditional healers in malaria control efforts. These efforts will help address barriers to malaria control and improve the effectiveness of interventions in the region.

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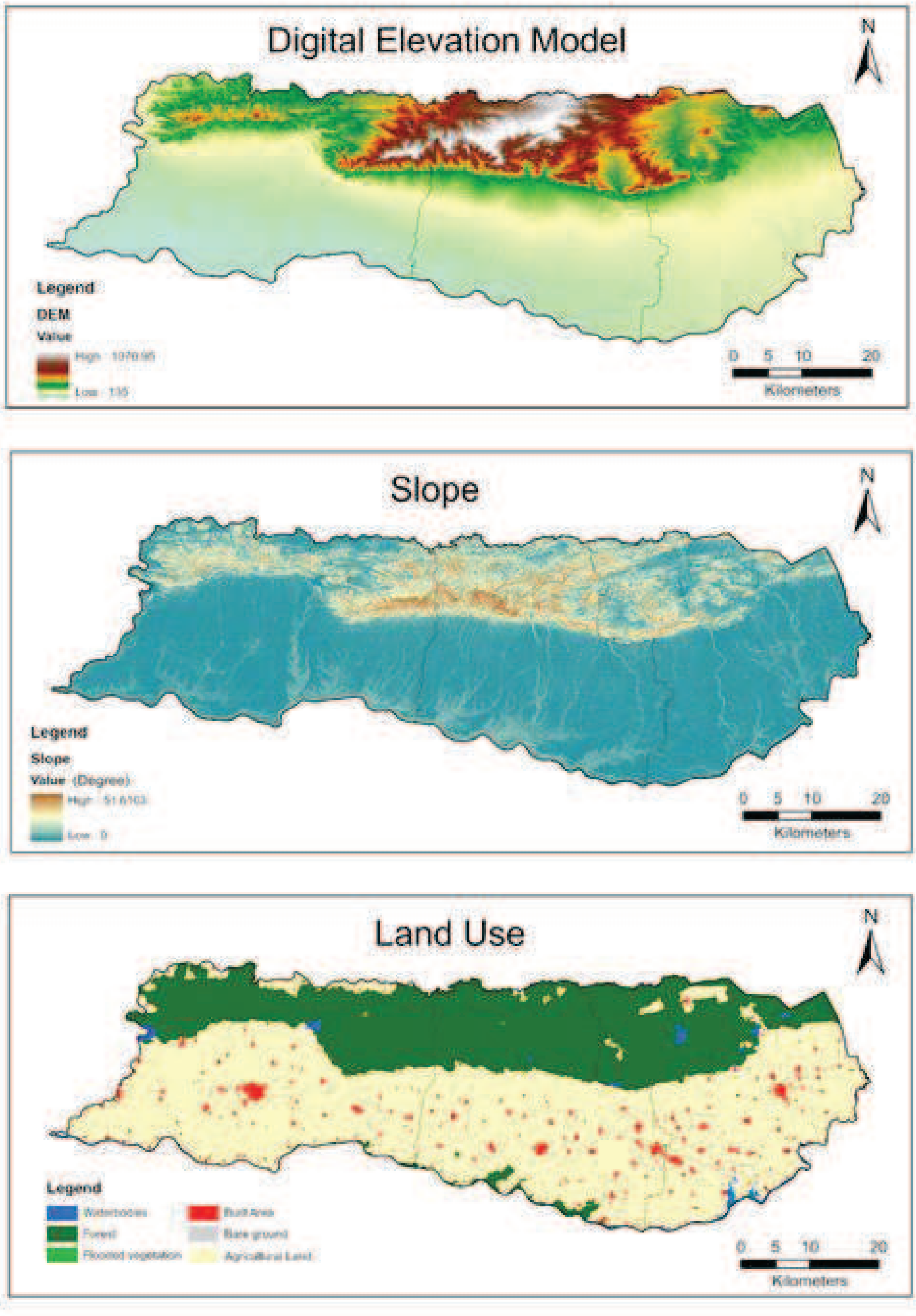

Figure 1 DEM, Slope and Land use of the study area (Source: Digital Elevation Model, Landsat 9 satellite data and GIS data Processing)

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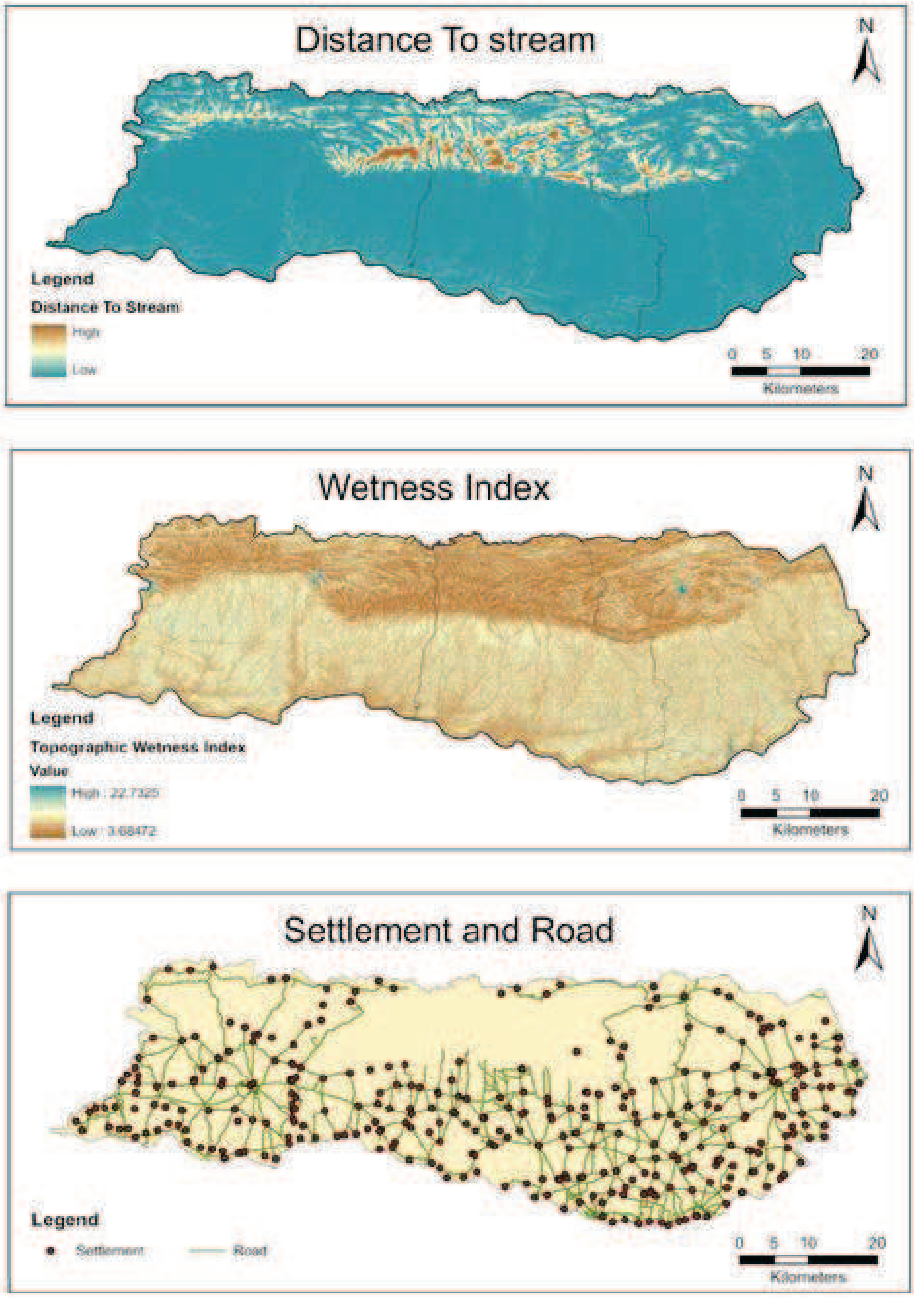

Figure 2 Distance to stream, wetness index, settlement and road in the study area (Source: Digital Elevation Model, Landsat 9 satellite data and GIS data Processing)

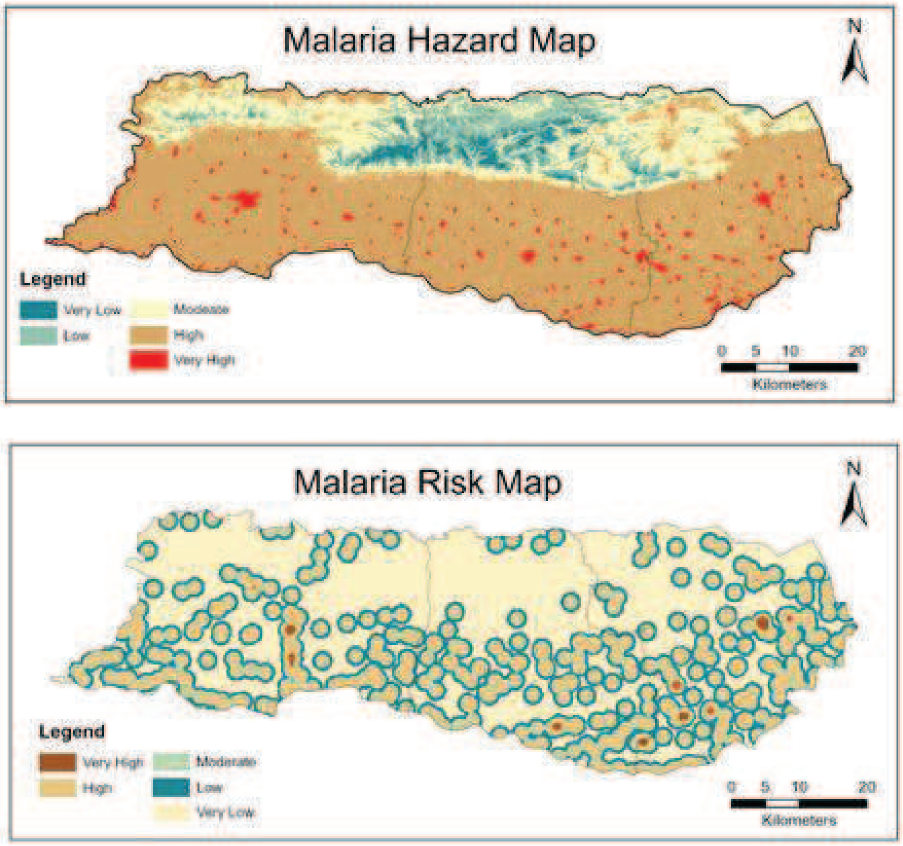

Figure 3 Malaria Hazard and Risk Map (Source: AHP analysis in ArcGIS)

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