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RESEARCH ARTICLE

INTEGRATING REMOTE SENSING AND GIS FOR INVESTIGATING MALARIA RISK AREAS IN MOROBE PROVINCE-PAPUA NEW GUINEA

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ABSTRACT

Tropical countries suffer the largest death tolls from the vector borne diseases like Malaria. The Malaria parasites are carried by the female anopheles mosquito. Tropical countries, being located in equatorial region normally have hot humid climate, the ideal breeding ground for such vector borne diseases. Papua New Guinea is one of those countries in tropical region where malaria happens to be the most dreaded disease. Malaria infection is transmitted from human to human through mosquito bite when a female anopheles mosquito has to complete their reproductive life cycle by sucking human blood. The paper tries to identify the possible geographical features or the input factors and then integrates them into the composite mapping units. Finally these units pinpoints the possible areas of different proneness for malaria in Morobe province of Papua New Guinea. GIS and remote sensing technology are basically used here for spatial analysis with a view to identifying various degrees of risk areas for malaria. Several factors responsible for attracting the vectors were identified and investigated using GIS and remote sensing and these are; elevation of the study area from mean sea level, distance from breeding site, slope factor, vulnerability index and Land use land cover type of the study area. Multi criteria evaluation (MCE) and AHP technique was attempted in GIS environment for assessing these factors' contribution to malaria diseases in the Morobe province and the risk areas were identified and mapped with the aid of on MCE.

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INTRODUCTION

Papua New Guinea is one of the tropical countries where incidence of malaria is widespread and contributes to one of the largest death tolls in the country. According to Joseph. T. 2013, malaria is a disease that keeps threatening most tropical countries, apart from sub-Sahara Africa. It is the environmental factors, human activities, economical condition, as well as traditional values that help abet in multiplication of the mosquito's lavas and or increasing of the breeding sites. For example, suburban and rural people having substandard living condition, are creating wells for water storage and consumption or are using cask or drums to fill rain water for consumption. Thus people through their traditional living standard boost the prospect of the mosquito's lava population and hence amplifying the chance of malaria hazard in an area.
It is common through our understanding that mosquitoes breed in still waters, areas of wetness or water logged and mildly flowing streams.

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Relating to the environmental condition, mosquitoes would have suitable breeding condition in all coastal areas where the prevailing warm, humid conditions are aptly suited for proliferation of the vector. Thus anopheles mosquitoes inhabit in the places where such ambience is likely to be encountered, that is biophysical conditions are adequate for its life cycle (Joseph, 2013). Malaria occurs in over 100 countries and more than 40% of the people in the world are at risk. The World Health Organization estimates that each year 300-500 million cases of malaria occur worldwide and more than two million people die of malaria (A. Ahmed, 2014). These may be because of people having difficulties travelling to the clinic or aid post, lack of awareness creates more areas for mosquitoes to breed. Owing to socioeconomic issues people are forced to locate themselves at coastal regions where the temperature is ideal for mosquitoes to breed, large percentage of people living in the clutch of extreme indigence. Based on the facts as stated above, the study was carried out within GIS environment to investigate geographical factors like elevation, slope, wet area/water logged areas which is breeding site area, land use land cover and vulnerability, meaning accessibility to malaria prevention area, that is a clinic or aid post or the feeder road connections (A. Ahmed, 2014). Based on the data availability of Morobe province (PNG), the factors were generated and assessed. Overlay analysis was done for every factors using ArcGIS 10 software, Mathematical calculation was also carried out using raster calculator in ArcGIS 10 for the factors generated. This is to delineate mosquitoes risk area of the province. The factors as mentioned above are the key geographical factors that determine the multiple of anopheles mosquitoes, hence increasing malaria hazard in PNG. Assessing and integrating those factors in GIS environment leads to final output as risk areas for malaria hazard in Morobe province (PNG). Thus these will help communities to identify risky areas of malaria in which they inhabit. Prevention measure or precautionary steps can be acted upon, in the aftermath of identification of the risk areas.

Study area

Morobe province is one of the provinces located in coastal area of Papua New Guinea in tropical region of the world- precisely in the southwest pacific region. The province is made up of a wide variety of biodiversity and mosquitoes are one of the crops of those biodiversity. The province covers the total area of 33, 730 square kilometres. The topography has both extremes: several mountainous areas as highlands of PNG and also coastal areas/regions. The province is composed of lots of hydrological parameters like rivers, wetlands, lakes, streams and rivers. The province's main city is 'Lae' which is the industrial hubs of the country of PNG. The study area is located around 147°00'00''E and 7°00'00''S. Below is the location map illustrating the study area.

DATA USED AND METHODOLOGY

For this study different types of data layers were integrated within GIS environment to come up with final output of malaria vector borne diseases risk areas in the province. The data layers used are tabulated below in table 1. Thus the malaria risk of the Morobe province was analyzed using the following general risk equation (Shook, 1999). That is;

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

After preparing all the factors, that is elevation, slope, distance to breeding site, land use land cover and vulnerability index, they were overlaid, weighed and reclassified according to their importance of causing malaria risk in the province in a GIS environment using the software ArcGIS 10. The final task carried out was integrating each of these factors which was weighed and reclassified, into the equation above.

That is for the factor element at risk it was considered or taken from Land use land cover of the Province. The land use land cover classes were weighted according to which land use type is more common for mosquito's survival and breeding place or which land use type are at risk at a given area. The higher weight age value was given to type of land cover that is suitable for mosquitoes survival and breeding. For the hazard factor, as stated by A. Ahmed, 2014, "Hazard (H)" is the probability of occurrence of a potential damaging natural phenomenon within a specified period of time and within a given area".

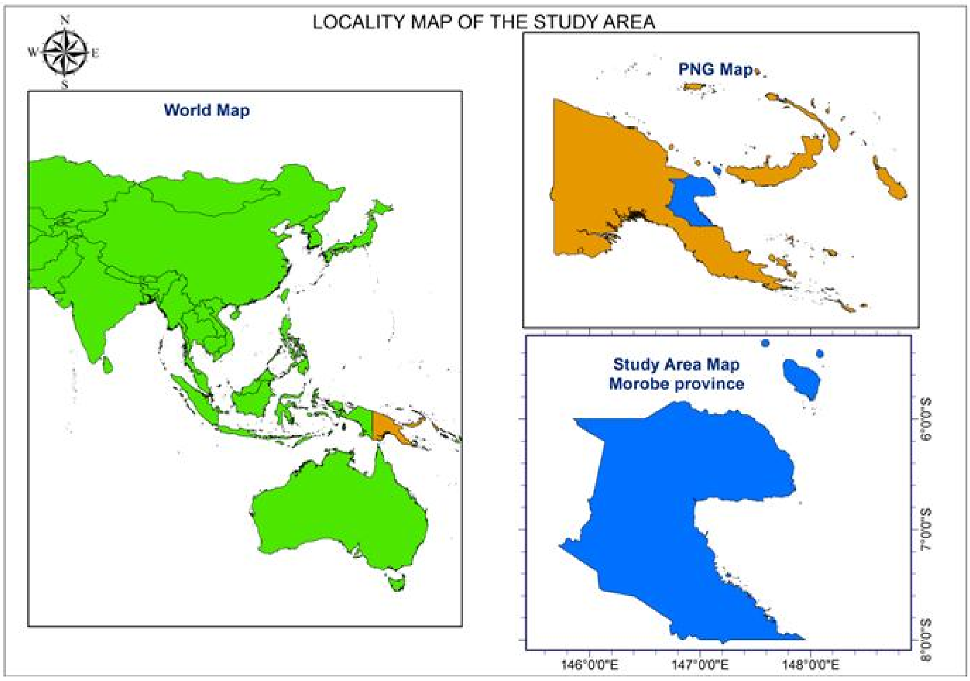

Figure 1. Study area map

Table 1. Data layers used

Data layers used	Description	Source
Slope factor	Extracted from SRTM DEM of PNG	PNG University of Technology
Land use Land cover factor/layer	Generated from Landsat 8 satellite image(30m spatial resolution)	PNG University of Technology
Elevation/altitude	Generate from SRTM DEM of PNG	PNG University of Technology
Accessibility index layer/factor	Generated by considering the buffer distance in km created for feeder roads and major health centres.	PNG University of Technology
Distance to breeding sites	Generated by considering the buffer distance in km created from each breeding sites	Lae city council department

Thus malaria hazard map/factor was prepared through Multi criteria evaluation (MCE) from the factors; elevation, slope and distance to breeding sites factor. The three factors here were ranked and their classes were weighted according to how effective was each in malaria contribution. Vulnerability index/factor or we can say accessibility index was prepared from considering the minimum distance in kilometre of each major health centres to the nearby population and also by considering the feeder road connection to the nearby major health centres.

Description and analysis of each Data layers or factors

Elevation/Altitude

Elevation is one of the prominent factors; that was used to assess malaria risk in the study area. It is the factor that contributes into preparation of malaria hazard in a study area. The whole idea into integrating elevation factor for assessing the malaria hazard or risk is that of temperature difference within coast areas and mountainous areas of the study area. The higher terrain or high mountains have low temperature compared to low land areas that do have high temperature.

Thus mosquito's habitats are well suited with low land areas, where the temperature is relatively higher. Communities living in highlands are subjected to fewer malaria incidence /hazard compared to communities living in low land areas where the chance of vector induced infections is high because most mosquitos' habitats are found in low lying areas. Higher altitude depicts less malaria hazard while low altitude depicts more malaria hazard problems based on high or low temperature. As was discussed, the higher weightage value was assigned to low altitude areas which reflects high incidence of Malaria and lower weightage was assigned to higher altitude, which reflects low Malaria incidence. Elevation factor map was prepared from SRTM DEM data of the study area. It was again reclassified according to its potential of malaria incidence or hazard. Figure 2(A) illustrate the Elevation factor map.

Slope

Slope is one of the environmental factors/topographical parameters that have a bearing in the incidence of malaria. It is vital to include slope factor with other parameters to assess for the malaria risk in community. This is because slope determines the mosquito's lava habitat formation. As stated by (Mushinzimana E.at.al, 2006), "Slope is other topographic parameter that may be associated with mosquito larval habitat formation, it is the measurement of the rate-change of the land per unit distance which may affect the stability of the aquatic habitat. If a particular area that composed of steepest slopes, then there will be no chance of mosquitoes' lava habitat formation, and hence area would have a restricted / negative influence to malaria incidence/hazard. If a particular area has a gentle slope, then mosquitos' lava formation is possible, hence leading to more positive bearing in malaria incidence. With respect to the slope importance in causing malaria hazard as explained above, the slope factor was generated and the weightage value was assigned. Slope factor was generated from the SRTM 30m DEM of PNG. The study area DEM was extracted using extraction tool in ArcGIS 10 and then slope factor was generated using slope tool in ArcGIS 10. Again according to its importance in mosquito's lava formation at each class level of the slope factor, the classes were reclassified using reclassify tool in ArcGIS and was weighted accordingly. Figure 2(B) illustrates the slope factor.

Distance to breeding sites

Distance to breeding sites was the one of the environmental factors which was developed. The breeding sites were extracted from the Landsat 8 LOI through doing Normalize Differential Vegetation Index (NDVI) and Normalize differential water index Calculation. After extraction of water logged areas, the buffer zones were created. As was stated by Hassan et.al (2014), NDVI is a widely used vegetation index for delineating vigor vegetation using near infrared (NIR) and RED band. NDVI is a non-linear function which ranges between -1 to +1 where water, rocks, and bare soils are indicated by values in -1 range and the vigor of vegetation is indicated by values near to +1. The formula used to calculate NDVI using ArcGIS 10 was; [NDVI = (NIR – RED) / (NIR + RED)]. After generating the NDVI, the water logged areas were extracted. To do a further verification and confirmation on water logged areas in a study area, the NDWI for surface water was calculated. As was stated by Hassan et.al (2014), the NDWI can be used to identify water logged areas using green and NIR channel. The NDWI has been developed to achieve the goal similar to NDVI, it produces -1 to +1 values. However, most of the water bodies are found in near to +1 value. The equation used to developed NDWI was; [NDWI = (GREEN - NIR) / (GREEN + NIR]. Thus the breeding sites are simply, lakes, stream, stagnant water, swamp, pool, etc.

The distance to breeding sites was one of the contributing factors used in developing malaria hazard of the study area. After extracting the breeding sites and having known there locations, the buffer zone was created to figure out the deviation in distance from the breeding sites to the nearby sites. The idea here is the distance from the breeding sites to the surrounding or nearby environment, that is household area/community area, villages, industries and factories etc. The lower weightage was given to buffer zones that are created further away from the breeding sites while higher weightage was assigned to the zones that are close which reflect maximum malaria incidence. This simply explains that, the closer the breeding sites, higher the malaria incidence and further away the breeding sites, lower the malaria incidence. Through knowing the distance to each location, malaria control can be effective, as was described by Saxane. R,*et al* 2009, "the applications of GIS-distance parameter have been substantiated by different examples depicting the growing importance of this parameter in malaria research and control. Figure 2(C) illustrates the distance to breeding sites factor map.

Accessibility Index Factor

Accessibility to the nearest clinic or health centres once infected by malaria is more important for the public to improve their awareness, apart from getting treatment on time. Some communities are located in the remote areas where government health services, road access have been rather meagre, so once infected, they have to travel long distance to hospital. If it is too costly for them to travel, they are forced to live without any medical treatment and struggle with the vector borne disease that might cost their life or might cause permanent damage to their body. In order to developed accessibility index factor, two factors were considered. the buffer zones were created where nearby surrounding population and features within the region were considered as target location from the feeder roads, the source. The buffer zones were created to identify the distance in kilometre between the source and the target. The lower weightage was assigned to zones that are close to the feeder road which

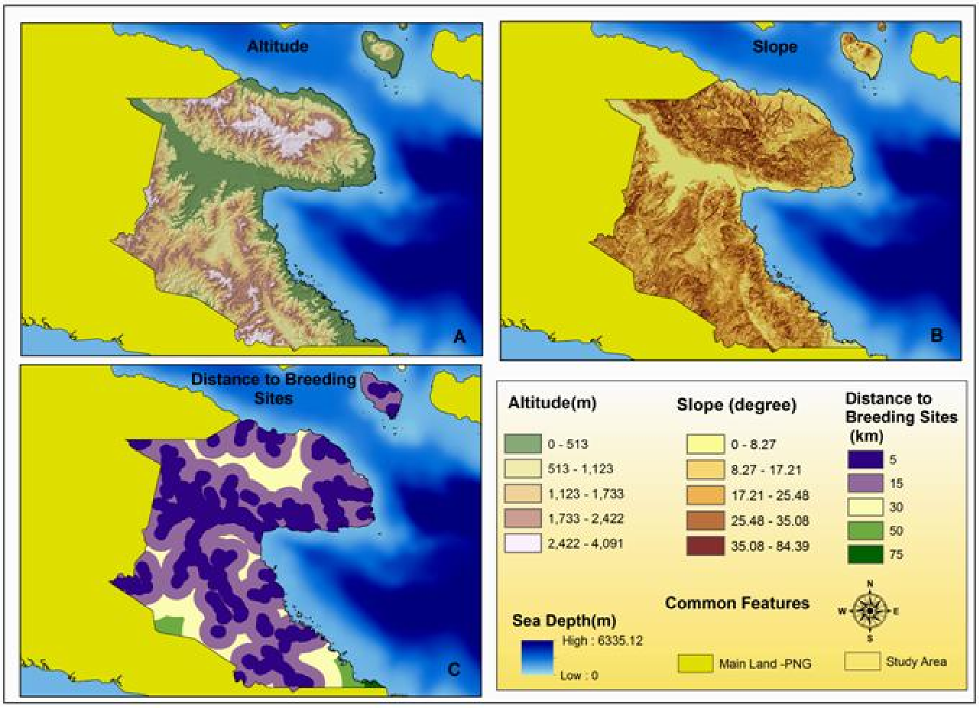

Figure 2. Factors Used for delineating Malaria Hazard Map

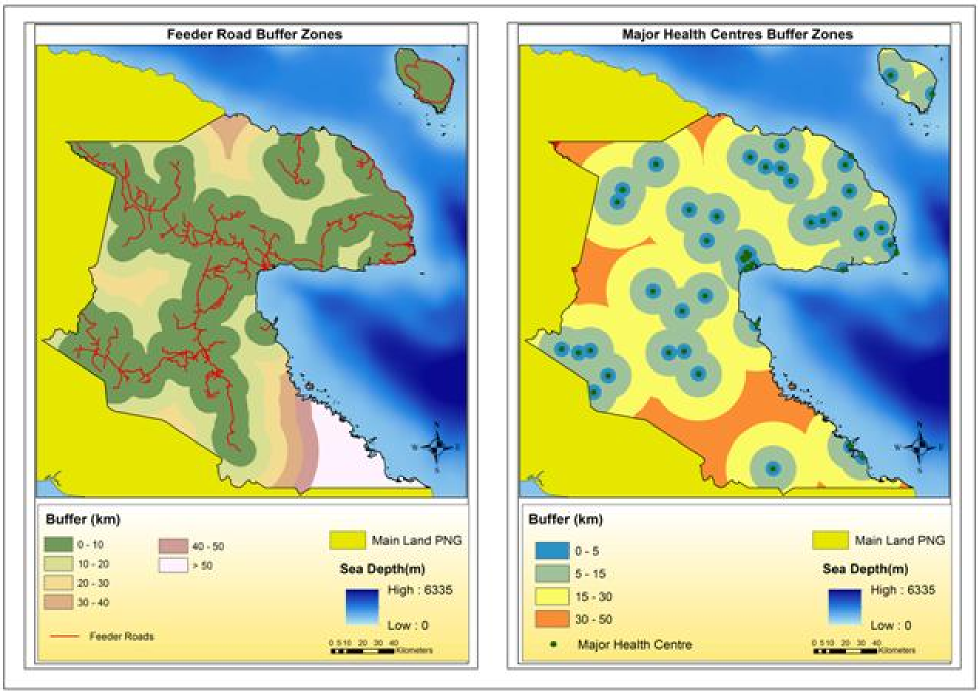

Figure 3. Factors Used for delineating Vulnerability/Accessibility Map

Delineation of Feeder road Buffer Zones

All the necessary feeder road connections within the study region (Morobe Province) was evaluated and identified. Then reflects minimum malaria incidence while higher weightage was assigned to zones that are further away from the source which reflects high malaria incidence.

Delineation of Major Health centres buffer Zones

Approximately total of 46 major health centres were considered within a study region. The buffer zones where created were source being the health centres and target being the surrounding population or environment as a whole like; villages, community, household, factories and industries, etc..... after the preparation of the buffer zones, higher weightage value was assigned the zones that are further away from the health centres which reflect high malaria incidence while lower weightage was assigned to closer zones which reflects low malaria incidence. After preparation of the two factors, the raster calculator in ArcGIS 10 was used to generate the accessibility factors. Figure 5(A) illustrates the accessibility index raster/factor layer.

Land Use Land Cover

Land use land cover is one of the prominent factors that were used in the assessment of malaria risk in Morobe province. The land use land cover was taken as element at risk (A. Ahmed, 2014). Thus the whole idea behind this is to identify which particular land use type or land cover types are more prone to be affected by malaria incidence or which land use land cover can exacerbate the incidence of malaria. As for example, increasing of more settlements in urban areas can leads to increase of malaria incidence. With that in mind land use land cover raster layer was developed from Landsat 8 satellite image at 30m spatial resolution. Each class was weighted/rank accordingly in order of susceptibility and suitability for malaria risk.

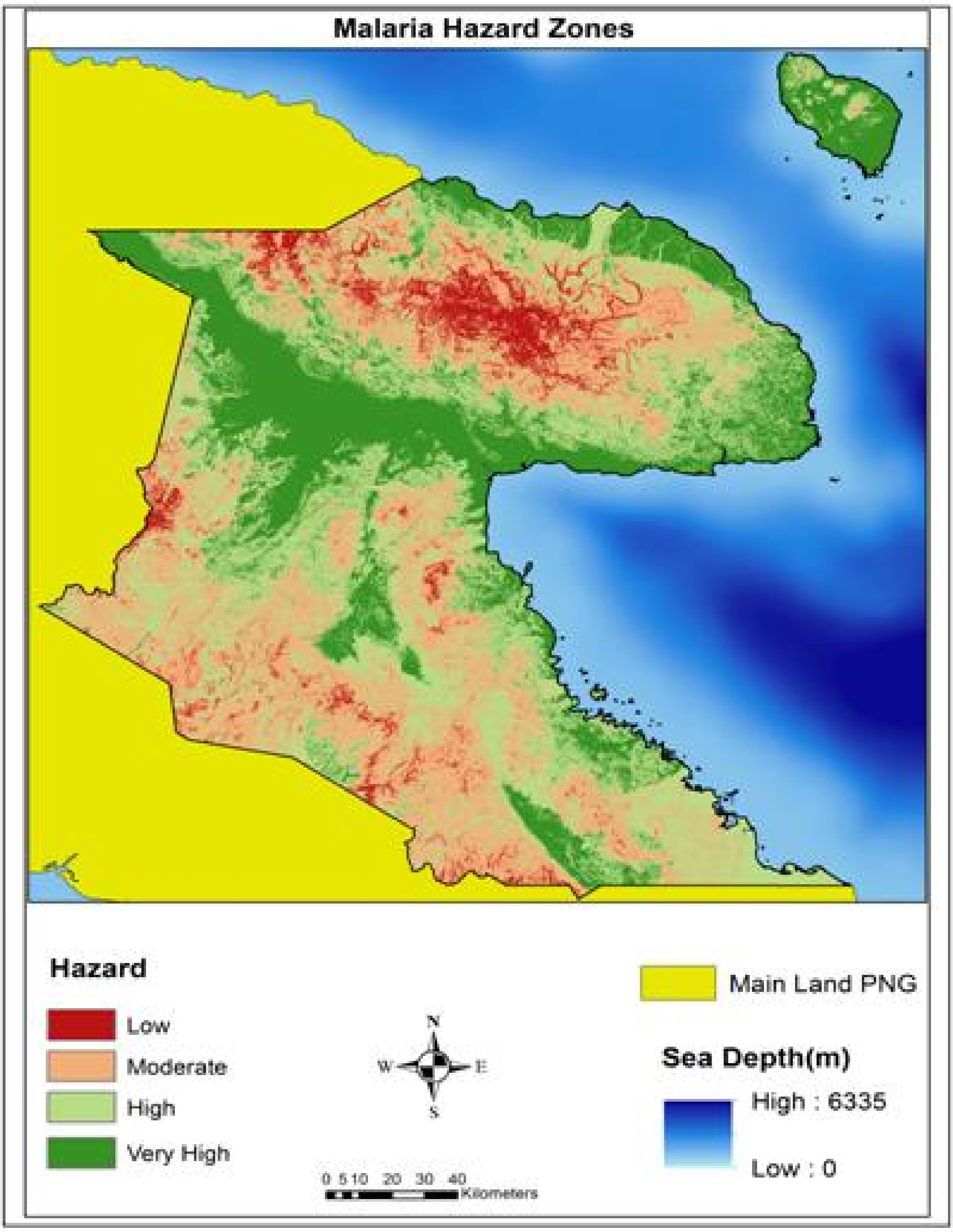

Figure 4. Malaria Hazard Factor prepared for contribution to risk factor delineation

Final output was used as factor involved in generating malaria risk map. Figure 5(B) illustrate the land use land cover raster/factor.

RESULTS AND DISCUSSION

Malaria Hazard investigation

The environment or geographical features or factors determine the probability of malaria vector born diseases in an area. This idea has lead to assessment of several geographical factors/parameters, namely; slope, elevation and distance to breeding sites to identify areas of malaria hazard. The malaria incidence and transmission requires the environment with lower elevation (higher temperature), abundance of wet lands/water logged areas, occurrence of gentle slopes, availability of still waters around rivers (Negasi, 2008). It determines number of occurrence of mosquitoes in an area, thus these leads to overlaying of each factors to establish and identify malaria hazard in an area. The malaria hazard map that was prepared was derived from several factors as shown in Figure 2. The three (3) factors prepared were ranked and weighted in GIS environment according to their relative importance in inducing malaria in an area. Due to different opinions and views in assigning rankings and weightings to each factors and their classes, the Analytical Hierarchy Process (AHP) was carried out to normalized all the weightage that was given this is to make sure that the decision made in assigning weightage and rankings is perfect and correctly judge. The final output after overlaying all these factors that was weighted and ranked in ArcGIS 10 software using overlay analysis tool, was the malaria hazard map shown in Figure 4.

Table 2. Malaria Hazardous Area in Percentage and Square Kilometre

SL No	classes	Area in Sq km	Area in percentage (%)
1	Very high	8732.50	25.96
2	high	12295.72	36.56
3	Moderate	10758.28	31.99
4	Low	1846.51	5.49

Vulnerability factor

Vulnerability factor is simply a accessibility factor. This simply means how are community, people or villagers having access to Health centres and getting cured quickly at a minimum time. The closer the community to the health centres, the more accessible it is to the health service. The travelling of infected people from their home land to the health centre is vital to be evaluate and consider because it is the main problem behind where many locals do face. Thus this leads to treatment delay and there dearth comes. Figure six (A) illustrates the accessibility map which was prepared through integrating feeder road buffer and major health centre buffer. The value 1 indicates community or people leaving at that particular zone are less accessible to the health service and to value 5 indicates community or people leaving at that particular zone are more accessible to health services

Element at risk factor

Element at Risk Factor was derive from LULC factor. It was one of the factor that was integrated with other two (2) factor to delineate Malaria Risk map of the study region that is shown in Figure 5B.

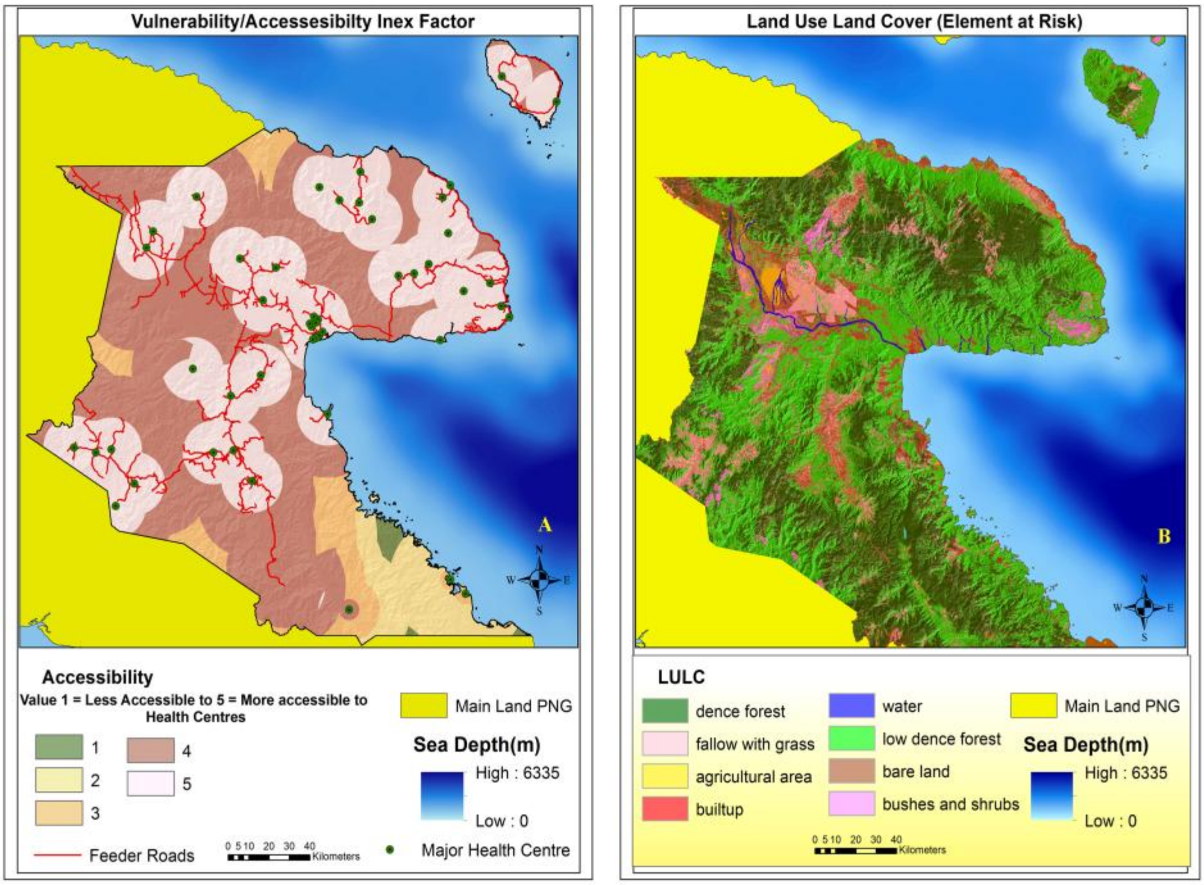

Figure 5. Vulnerability/Accessibility index factor (A) and Land use land cover factor (element at risk factor) (B)

LULC factor was used to identify the possible areas of mosquitoes breeding sites and areas where it is possible for mosquito to exist. there were about eight classes were delineated and was again reclassified or simplified to 5 classes where from their weightage were assigned to each classes according to how effective are each class for malaria contribution to the region. Figure five (B) illustrates the Element at risk factor.

Malaria risk investigation and analysis

Malaria risk investigation and analysis is a very important task to be carried out. Malaria infection is immensly dangerous to the community. The infection often leads to death and permanent damage to the body. Through investigation and identification of risky areas, the problems related to malaria infections can be reduced. To do analysis in to identifying malaria risk areas in an area, the point data or health centres data is needed with the road network. A Land use land cover factor is also needed.

Multiplying these two factors with the malaria hazard factor as discussed above using raster calculator tool in ArcGIS 10 software, the malaria risk area is likely to be identified in an area. The equation developed by Shook, 1999 was used to generate and identify malaria risk areas of Morobe province, that is;

Risk = Element at risk * hazard * vulnerability

The three (3) factors which were prepared and developed were fed into the ArcGIS raster calculator tool. The output layer was the indication, distribution or identification of malaria risk areas in Morobe province. It was again reclassified into five malaria risk levels as very high, high, moderate/average, low and very low. It was found out from the calculation that about 5.10% of area within a study region was identified as 'very high' risk areas for malaria, 15.71% for the class 'high', 28.58% for the 'moderate' risk class; 29.86% for the 'low' risk class; and 20.75% for the 'very low' risk class.

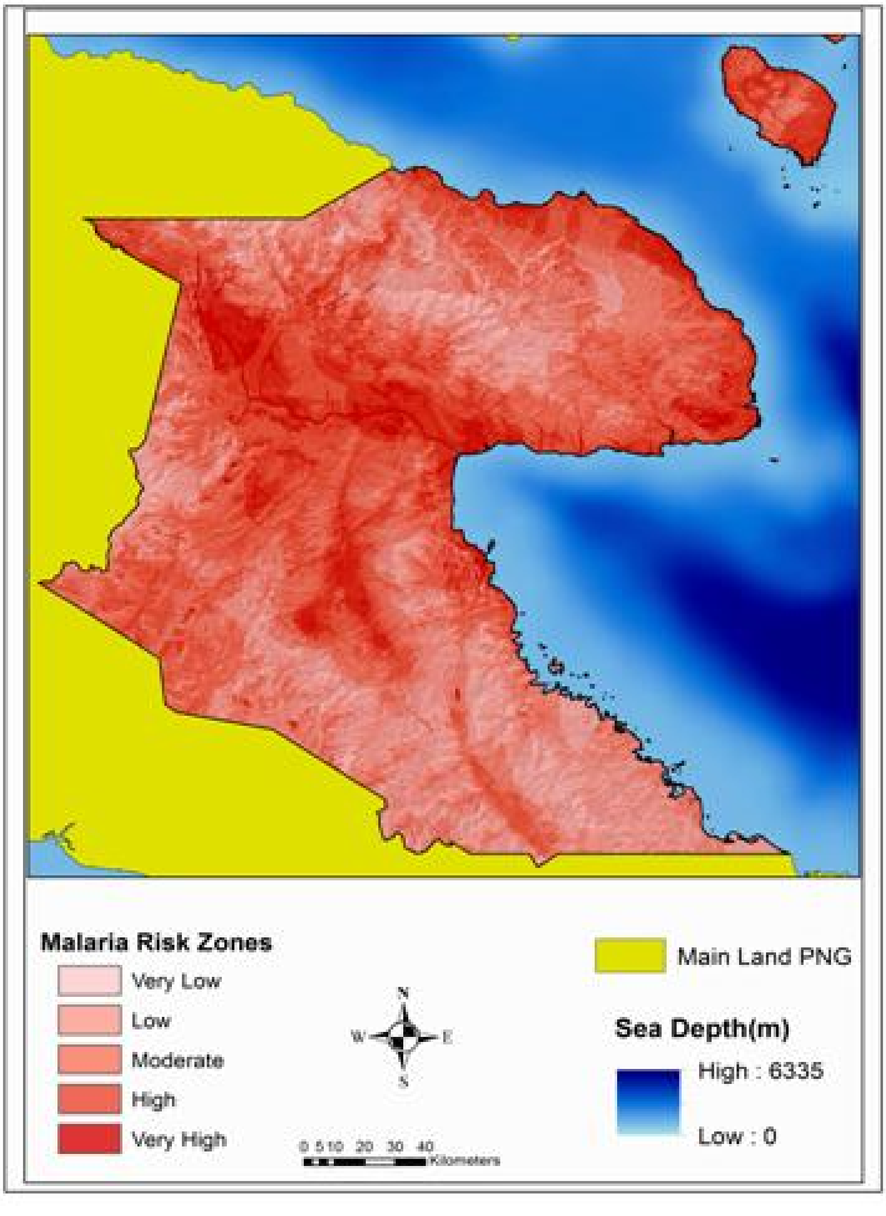

Figure 6. Malaria Risk Area Micro-Zonation

It was found out that the low altitude is more prone to malaria vector borne diseases. At the low altitude, the places can be suitable for water accumulation, infrastructure/household construction, high temperature that is suitable for mosquitoes breeding, also abetted by the agricultural activities like rice agriculture on standing water. In the field where rise is cultivated or even the other agricultural activities, the farmers create or make a small drains around their cultivated plants, when the rain water or natural water accumulate in those drains, the cultivated plants survive and grow well with the help of those stored water, however, on the other hand, the breeding sites for anopheles mosquitoes are created.

Table 3. Malaria risk area coverage in square kilometre(km^2) and percentage(%)

SL No	classes	Area in Sq km	Area in percentage (%)
1	Very high	1716.57	5.10
2	high	5284.12	15.71
3	Moderate	9611.39	28.58
4	low	10042.61	29.86
5	Very low	6977.32	20.75

Conclusion

Tropical countries receive higher rainfall and at the same time get high solar isolation and hence the climate. The anopheles mosquitoes are adapted to this hot humid climate for their survival. The vectors find this climate very conducive to breeding. As long as anopheles mosquitoes are adapted to this climate, the chance of malaria vector borne diseases in the area shall remain very high. The major contribution to increasing of malarial vector comes from environmental factors or parameters, for example wetness type of a particular land area, agricultural area (rice cultivation), lakes and ponds, etc.... Remote sensing and GIS technologies were adopted to find issues abetting malaria vector born diseases. Through applying these technologies, the environmental parameters are assessed and analysed in order to find out the hazardous areas and risk areas of malaria vector borne diseases within the community. The development of risk map establishes the base line to estimate the risk within the areas. Thus this has profound effect on mitigation or control on such vector borne diseases as also identifies the environmental parameters that are capable for increasing the probabilities of being infected with malaria. Prioritizing the geographical parameters can be possible after knowing its capabilities in inducing/increasing the malaria risk. The multi criteria evaluation with AHP performed in GIS environment, that is overlay and weighted normalizing analysis and techniques was shown to be more useful in identifying malaria hazard areas and malaria risk areas where NGOs and health workers have to adapt to this technology in order to reduce malaria incidence within the community.

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