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Malaria Hazard and Risk Analysis Using GIS and Remote Sensing in Korahey Zone of Somali Regional State, Eastern Ethiopia

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Abstract

Malaria is one of the killer human diseases caused by protozoan parasites from plasmodium family which foremost transmitted by the bite of the female Anopheles species of Mosquito. Ethiopian lowland areas are favorable for mosquito breeding and malaria transmission due to their tropical location and environmental factors. The current study was aimed to analyze the malaria hazard and risk areas in the case of Kebridahar and Sheykosh districts of Korahey zone by using GIS and RS technique. In order to achieve the study objective, different data's such as satellite images, digital elevation model, topographic map, study area shape file and the environmental factors like temperature, elevation, slope, soil, land use land cover and proximity to pond water site were used as an input data for the analysis. Weight was assigned for these parameters by pairwise comparison method and weighted overlay was used in Arc GIS spatial analyst tools to produce the final malaria hard and risk map of the study area. The hazard malaria prevalence was mapped based on the environmental factors, computed using Multi Criteria Decision Evaluation technique (MCDE).

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The result of this study revealed that, from the total areas of both districts, 41.6%, 42.2% are mapped as very high and high hazard zone, whereas, the remaining 16.2% is mapped as low level of malaria hazard. The result of the malaria risk map also shows that about, 4095 km^2 (23.7%), 12169.2 km^2 (70.5%) and 1010 km^2 (5.8%) of the study area were subjected to very high, high and low malaria risk level respectively. Generally, the result of this study revealed that large area (94.2%) is located in very high and high risk area toward the malaria hazard in Kebridahar and Sheykosh districts of Korahey Zone in Somali region. Therefore, it is recommended that all stakeholders especially health offices at district, zonal, regional and federal levels as well as NGOs should make awareness creation towards malaria prevention in the study area as special and in lowland areas as general.

Keywords: GIS; Remote Sensing; Malaria; MCDE; Risk map; weighted overly.

1. Introduction

Malaria is a life-threatening diseases caused by parasites that are transmitted to people through the bites of infected female Anopheles mosquitoes [20]. The transmission of malaria occurs primarily between dusk and dawn because of the nocturnal feeding habits of Female Anopheles mosquito species. According to [20], about 60 species of the genus Anopheles can transmit malaria. Malaria is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and development rates. The increase in malaria prevalence is determined by several factors: mosquito resistance to insecticides, parasite resistance to drugs, changes in land-use patterns, and reductions in funding and manpower dedicated to control activities [7]. As one of vector borne disease systems, malaria is caused by Plasmodium parasites that transmitted by Anopheles mosquito. Vectors (female Anopheles mosquitoes) require specific habitats with surface water for production, humidity for adult mosquito survival and the development rate of both vector and parasites are dependent on temperature [3]. Globally, about 3.3 billion of the world populations are at risk for malaria infection, and recent report indicate that in only in 2017, nearly half of the world's population was at risk to malaria hazard {[17,20]}. Most malaria cases and deaths occur in sub-Saharan Africa. However, the WHO regions of South-East Asia, Eastern Mediterranean, Western Pacific, and the Americas are also at risk. In 2017, 87 countries and areas had ongoing malaria transmission [20]. According to the latest World malaria report, released in November 2018, there were 219 million cases of malaria in 2017, up from 217 million cases in 2016. The estimated number of malaria deaths stood at 435 000 in 2017, a similar number to the previous year. The WHO African Region continues to carry a disproportionately high share of the global malaria burden. In 2017, the region was home to 92% of malaria cases and 93% of malaria deaths. In 2017, 5 countries accounted for nearly half of all malaria cases worldwide: Nigeria (25%), the Democratic Republic of the Congo (11%), Mozambique (5%), India (4%) and Uganda (4%). Children under 5 years of age are the most vulnerable group affected by malaria; in 2017, they accounted for 61% (266 000) of all malaria deaths worldwide [19]. Malaria is one of the greatest killers of the human beings, particularly in the Sub-Saharan countries because over one million cases in which its 80% happen in Sub-Saharan countries were reported in every year [19]. In Sub-Saharan countries there are 140 Anopheles species in which out of this 20 are known to transmit malaria parasites to human beings. From the recent health problems records in Ethiopia, malaria is the most health problems in which its cases are one of the highest and it is increasing in an alarming rate. Ethiopians live at altitudes ranging from −100 to >4220 m, the topography made a fertile ground for the reproduction of the epidemic. More than 50 million (68%) of the population live in areas below 2000 m above sea level are at risk of malaria. In general, the main reasons given for the increment are ecological and climatic changes. The peak of Malaria incidence follows the main rainfall season in July, August, September, October and November each year [20]. Because of its tropical area and accessibility of numerous streams and lakes, Ethiopia is suitable for breeding of plasmodium [21]. As a result, it is a major public health problem in Ethiopia [7]. Accordingly, its occurrence in most parts of the country is unstable mainly due to the country's topographical and climatic features. In order to reduce this impact of the epidemic disease, wide range of measures were taken by national and international organizations. Preventive measures are cost and time effective. One of the main agendas that need to be under consideration towards the malaria preventive is to work on the main factors contributing for the development and expansion of the problem. In this case, Geographic Information System (GIS) and Remote Sensing (RS) application can be the best tools to analyze the root problem of both spatial and temporal variation. In Korahey zone specially Kebridahar and Sheykosh districts malaria transmission is one of the community health problems. They are characterized by poor housing, lack of proper sanitation, poor drainage of surface water, weak health services and wide spread economic disparity, which independently or together pave the way for malaria transmission. In order to design and implement cost-effective approaches of malaria prevention we need to understand environmental factors that facilitate mosquito breeding and then develop malaria hazard and risk map. However, in the study area, the spatial variation of malaria risk level based on environmental factors, which could facilitate the malaria prevention and control activities are not researched yet. The current study intended to identify environmental factors facilitating conditions for mosquito breeding and its relationship with malaria hazard level as well as to develop a factor map in a relation to potential habitats for malaria risk and its degree of vulnerability and finally generate malaria hazard and risk map. This study applied GIS, RS and MCDE to identify and map, areas which is vulnerable to malaria epidemic in the study area. The results of this study will help policy makers, concerned government bodies, and NGOs to make cost and time efficient malaria prevention and control exercises.

2. Material and Methods

2.1. Description of the study area

The study was conducted in selected districts of korahe zone, Somali national regional state. It falls in two districts namely Kebridehar and Shekosh districts. Geographically, both are found between 6◦28′-7◦68′-N Latitude to 43◦53′-45◦oo′ E longitude and 6◦78′-7◦6′N Latitude to 43◦54′-44◦49′-E longitude respectively.

Both districts are found within southeastern lowlands of Ethiopia with altitude ranges from 456 to 1042 meters above sea level. The average elevations of both districts are 736 and 815 meters above sea level respectively. The lowest elevation of the study area is 456 meters above sea level, found along the Fafen River valley. The climate of the study area is found within the tropics and experiences high incoming solar insolation due to high angle of the solar rays. A vast area of both districts experiences high temperature and low precipitation with mean annual temperature ranges between 20.750c -31.250c. The annual rainfall of the districts varies between 295mm and 595.6 mm.

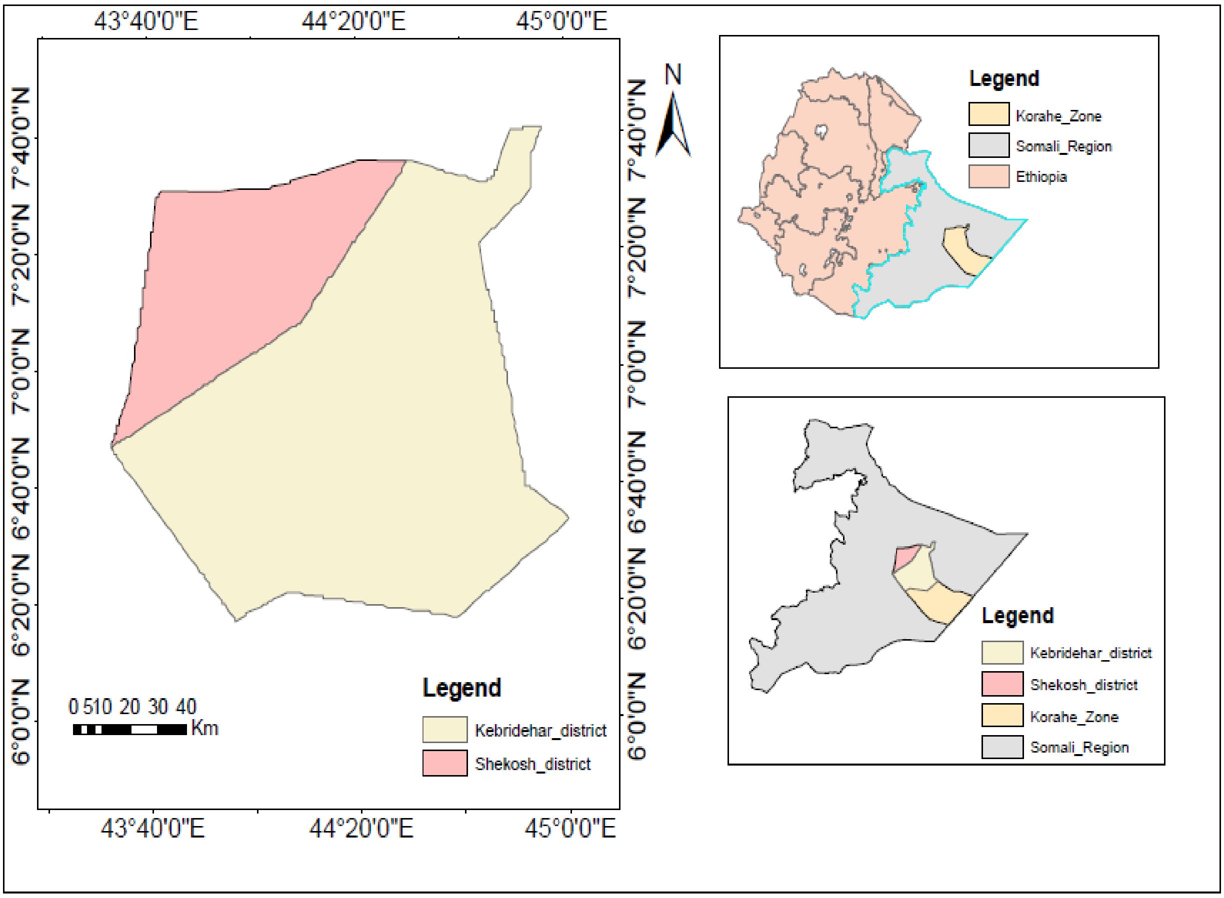

Figure 1: Map of the study area

According to [4], Kebridehar district has a total population of 136,142, of whom 77,685 are men and 58,457 women. While 29,241 or 21.48% are urban inhabitants, a further 50,361 or 36.99% are pastoralists, whereas Shekosh district has a total population of 107,590, of whom 67,376 are men and 34,214 women. While 4,924 or 8.55% are urban inhabitants, a further 36,969 or 64.19% are pastoralists. Based on the result of housing and population census of May, 2007, in 2017 the projected population of Kebridehar district is 176,494people, out of this 97,694 are males and 78,800 are females. Whereas the projected population of Shekosh district is 63,145 people, out of this 32,588 are males and 30,557 are females.

2.2. Data acquisition and analysis

Both primary and secondary data was used for the malaria hazard and risk mapping of the study area, which was obtained from field survey and concerned institutions. The data and materials which were used include satellite images, soil map, digital elevation, climatic data, topographic map and health centers point data of the study area. Types of data which was used and their sources are described in the following table.

Table 1: Source and types of data

Types of data	Source of data	Spatial resolution/scale
Landsat satellite image	USGS	30m
Topographic Map	Ethiopian mapping Authority	-
Digital elevation model	SRTM	30m
Clinical data(malaria case)	Districts health office	-
Rainfall and temperature	National meteorological services Agency	-
Soil map	FAO	-
GPS data points	Field survey	-
Study area boundary shape file	Central statistical Agency	-

2.3. Methods of Analysis of Environmental Factors

The environmental factors used to analyze malaria risk and hazard of the study area was selected based on model developed by [12] and depending on previous research works. According to this, elevation, temperature, slope, soil, land use land cove type and proximity to water bodies are selected as major environmental factors for malaria incidence. For each environmental factor, maps are generated and then reclassified depending on their suitability for mosquito breeding. These factors and their analysis techniques are described as follows.

Elevation: Elevation is a prominent factor for malaria transmission, this is because of elevation highly determines the amount of temperature, and temperature in turn affect mosquito breeding as the length of immature stage in life cycle. Elevation map of the study area was generated from SRTM 30-meter resolution Digital Elevation Model (DEM). The elevation map is reclassified on the basis of the relationship between elevation and malaria incidence that is based on previous research works and literatures. Malaria frequently occurs in areas below 2000 meters' elevation and the transmission is very intense in areas below 1500 meters of elevation. Hence, the elevation of the study area was classified in to five classes as 700m-1000m, 1000m-1300m, 1300- 1600, 1600-2000 and >2000m.Then new values were assigned for each class as 1, 2, 3, 4 and 5, respectively. Finally, elevation based malaria risk level was leveled as very high, high, moderate, low and very low respectively.

Slope: Slope map of the study area was generated from SRTM 30-meter resolution Digital Elevation Model. Previous studies showed that a slope below 5% has the highest number of malaria cases [10]. Accordingly, the slope of the study area was reclassified in to five groups based on suitability of the slope for mosquito breeding by using spatial analyst tools in Arc GIS. The reclassified slope raster layer sub groups were ranked accordingly to the degree of suitability for malaria incidence as: 0- 5, 5 – 11, 11 – 19, and 19 – 30 and >30%. The assigned new value was given as 1, 2, 3, 4, and 5 respectively. This described as very high, high, moderate, low and very low malaria area respectively. The steeper slope values are related to lesser malaria hazard and the gentler slope area have high susceptible for malaria incidences [13].

Distance from pond water sites: The pond waters in the study area are a tendency to create innumerable sites for malaria vector breeding. This condition can result the occurrence of abundance of mosquitoes found around rivers where there are still waters. The river network was digitized from 1:50,000 scale topographic map of the study area. Therefore, taking the heed of the maximum flying distance of anopheles' mosquito from the distance to stream is km as a basis for reclassification distance to the stream layer. This means areas out of the flaying distance threshold are considered as less malaria risk level. Then, Distance was computed from every river and new values were assigned as 1, 2, 3, 4, and 5 in order to show the relative hazard of the class ranges 0-500m, 500-1000m, 1000m-1500m, 1500m-2000m 2000m-2500m and > 2500m which is re assigned as very high, high, moderate, low, and very low malaria hazard layer respectively.

Soil: The types of soil in the study area were generated from FAO classification based on their ability to hold moisture and or being permeable or impermeable. Then after, the new values were assigned to chromic vertisols, calsic cambisols, Regosls, Lithosols and Yermosols respectively in order to show the relative permeability of the soil. Chromic Vertisols are very sticky, poorly drained soils and are found along tidal marshes and alluvial plains allow water stagnation, reclassified as very high malaria risk level and assigned new value 1. Calsic Cambisols, which have good water holding capacity reclassified as high risk level assigned new vale 2. Regosol is a deep, well drained, medium textured, have low water holding capacities and Lithosols which have good drainage reclassified as moderate and low risk level and assigned new value 3 and 4 respectively. Yermosols have high water drainage/percolation, reclassified as very low risk level and assigned new value 5.

Land use land cover factor: The land use land cover was taken as element at risk that affect by malaria incidence. Land use is the way in which and the purpose for which human beings employ the land and its resources. To identify the land use and land cover of the study area, Landsat 8 OLI (Operational Land Imager) was classified using a supervised classification method. A total of 4 classes were identified by this classification based on the order of susceptibility to be suitable breading site, source of food and use as a shelter from climatic condition for the vector mosquito. Based on the classification done, the study area has four major land use land cover types such as range land, bare land and bush land and settlement area. The type of land use land covers especially type of vegetation which surrounds the breeding sites basically supply sugar feeding for adult mosquitoes, and provided ideal sites for resting and protection from climatic conditions and enhance enhancing longevity of the vectors [22]. Therefore, Settlement area classified as very high risk, bush land as high risk, range land as moderate and bare land as low malaria risk level respectively. Finally, a new value assigned to these land use classes as 1, 2, 3, and 4 respectively.

Temperature: The temperature data of the study area from the last 20 years were retrieved from national meteorological agency. Then twenty years mean monthly maximum and mean monthly minimum temperature data of each station were analyzed in order to generate temperature map. From the mean monthly maximum and mean minimum temperature of the stations, mean monthly temperature of each station was calculated. Then, a single average value is computed for 20 years. Finally, a single average value of each station used for surface interpolation in Arc GIS spatial analyst tools using kriging interpolation technique. The principle of Kriging is to estimate values of a regionalized variable at a selected location based on the surrounding existing values.

According to [15], temperature above 30°C has negative impact on the survival of the vector. On the other hand, for temperature below 16°C, the development of Anopheles gambiae, the main malaria vector in most parts of Africa, is completely stopped, and the larvae die in wet temperature below 14°C. [1]. Accordingly, the study area temperature map was reclassified into four classes as <16oc, 16 - 18oc, 18-24oc and 24-30oc and assigned to new values 1,2,3,4 labeled as low, moderate, high and very high malaria risk level respectively.

2.4. Malaria vulnerability

Malaria vulnerability is the susceptibility to be affected by its causal agent (plasmodium sp.). According to [14], malaria vulnerability is influenced by demographic characteristics, access to health facilities and socioeconomic condition. The people that live far from health care facilities were identified as the most vulnerable to malaria in most sub- Saharan African countries [14]. Vulnerability (accessibility index) is prominent factor to malaria vulnerability. In this study, location of health station was digitized after georeferencing GPS field collected data on Topographic map in ArcGIS. Then, vulnerability map was developed and reclassified in to 5 sub class as: 1, 2, 3, 4, and 5. and the reclassified sub groups of vulnerability (accessibility index) raster layer were ranked as: very high, high, moderate, low and very low respectively. In this case very high indicates that area's far away from health stations are very high vulnerable to malaria. That means vulnerability increase with increasing distance from health stations.

2.5. The overall development of malaria hazard and risk

2.5.1. The development of malaria hazard

Hazard is the probability of the occurrence of mosquitoes infective with malaria in a certain area. It was approached by assessing the suitability of environmental condition for malaria transmission based on environmental and physical factors. Malaria hazard analysis was computed by weighted sum overlay of elevation, slope, distance from pond water sites, temperature and soil developed factors. The technique was implemented in IDRISI software and it is that of pair wise comparisons developed by [11] in the context of a decision-making process known as the Analytical Hierarchy Process (AHP) [6]. It is one of the multi-criteria decision-making techniques. In the procedure for Multi-Criteria Evaluation using a weighted linear combination, it is necessary that the weights sum to one. In Saaty's technique, weights of this nature can be derived by taking the principal Eigen Vector of a square reciprocal matrix of pair wise comparisons between the criteria. Eigen vectors are a special set of vectors associated with a linear system of equations (i.e., a matrix equation) that are sometimes also known as characteristic vectors, proper vectors, or latent vectors [8]. The standardized raster layers were weighted using Eigen Vector that is important to show the importance of each factor as compared to other in the contribution of flood hazard. Accordingly; the Eigen Vector of the weight of the factor was computed in IDRISI 32 Software in Analysis menu of the decision support/weight module based on the given pair-wise comparison. The weighted module was fed with the pair wise comparison 9 point continous scale. Then the principal Eigen Vector of the pair wise comparison matrix using the factors affecting flood hazard was calculated. A consistency ratio values less than 0.1 is acceptable. The consistency ratio of the calculated Eigen Vector was 0.02 that shows that the given pair-wise weights are accepted. The computed Eigen vector was used as a coefficient for the respective factor maps to be combined in weighted Overlay in the Arc

GIS environment using the following equation:

Malaria hazard= 0.45× [Elevation] +0.12× [Temperature] +0.10× [Slope]+0.04× [soil]+0.29× [distance from pond water sites].

Table 2: weighted malaria hazard ranking of the study area

Factors	Weight	Class	Rankings	Degree of vulnerability
Elevation	0.45	700-1000	5	Very high
		1000-1300	4	High
		1300-1600	3	Moderate
		1600-2000	2	Low
		≥ 2000	1	Very low
Temperature	0.12	24-30 ^{0}c	5	Very high
		18-24 ^{0}c	4	High
		16-18 ^{0}c	3	Moderate
		≤16 ^{0}c	2	Low
Slope	0.10	0-5	5	Very high
		5-11	4	High
		11-19	3	Moderate
		19-30	2	Low
		≥30	1	Very low
Soil	0.04	Poorly drained	5	Very high
		Moderate	4	High
		Rapid	3	Moderate
		Very rapid	2	Low
Distance from pond water sites	0.29	500-1000m	5	Very high
		1000-1500m	4	High
		1500-2000m	3	Moderate
		2000-2500m	2	Low
		≥2500m	1	Very low

A model builder in Arc GIS was used to facilitate the overall malaria hazard assessment by combining all impact factors. It is a visual programming language for building geo-processing workflows. Geo-processing models automate and document our spatial analysis and data management processes. The model was created and modified in Model Builder, where a model is represented as a diagram that chains together sequences of processes and geo-processing tools, using the output of one process as the input to another process.

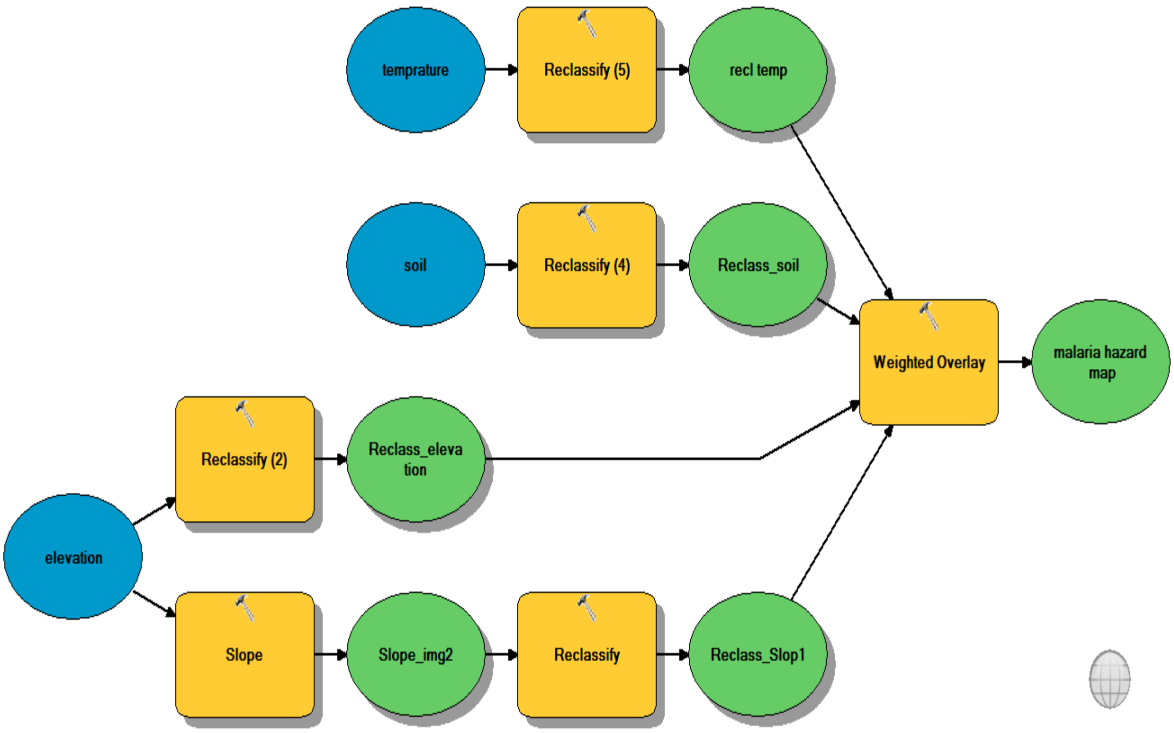

Figure 2: Malaria hazard analysis workflow using Model Builder in Arc GIS

2.5.2. Development of malaria risk

Risk (R) is the expected degree of loss due to a particular natural phenomenon. In other words, it is the probability of developing a given disease over a specified period of time [18]. Thus, Malaria risk is the probability that an individual will be attacked by malaria in a given interval of time and in a known area. Elements at risk indicators specify the amount of social, economic or ecological units which are at risk of being affected regarding all kinds of hazards in a specific area e.g. persons, economic production, buildings, public infrastructure, cultural assets, ecological species and landscapes located in a hazardous area on connected to it. Thus, Malaria risk assessment and mapping was done for the study area by taking population density, land use/cover, health center and road access elements that are at risk as well as socio-economic factors that determine the risk level combined with the degree of malaria hazards of the study area. Thus, the basis for the calculation of the map was the risk computation model (Risk = Hazard * Element at Risk * Vulnerability) developed by [12] as follows.

Malaria Risk =0.40 × [Malaria Hazard Level] +0.23× [Land use/cover] + 0.34× [Health Center].

Table 3: Weighted parameters for malaria risk map

Parameters	Weight	Class	Rankings	Degree of vulnerability
Elevation	0.43	Very high hazard areas	1	Very high
		High hazard areas	2	High
		Moderate hazard areas	3	Moderate
		Low hazard areas	4	Low
		Very low hazard areas	5	Very low
Land use/land cover	0.23	Settlement areas	1	Very high
		Bush land	2	High
		Range land	3	Moderate
		Bare land	4	Low
Distance from health station (km)	0.34	≥30km	1	Very high
		24-30km	2	High
		12-24km	3	Moderate
		6-12km	4	Low
		0-6km	5	Very low

Procedures that were used for malaria hazard mapping model in Arc map model builder were also applied for malaria risk mapping model builder.

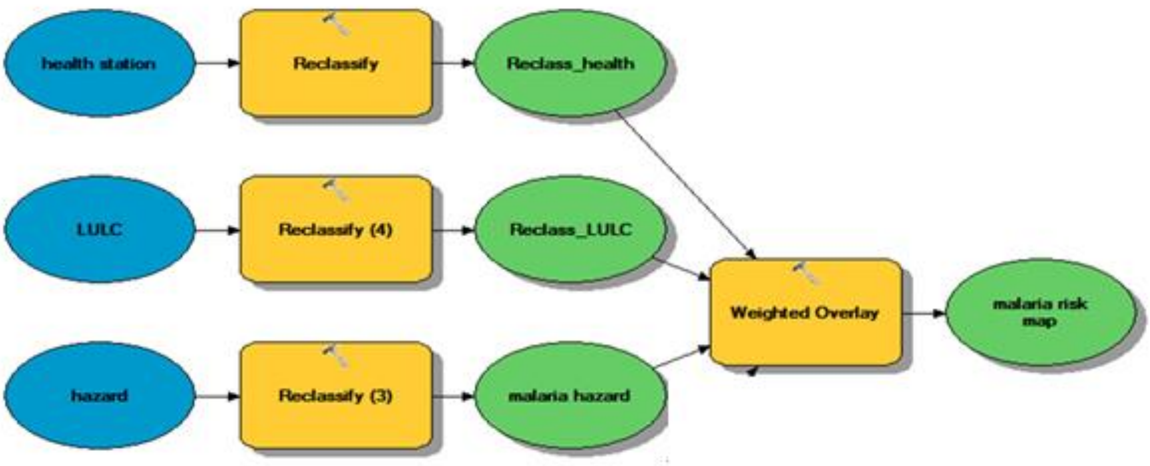

Figure 3: Malaria risk analysis workflow using Model Builder in Arc GIS

3. Results and Discussions

3.1. The relationship between environmental factors and malaria hazard level

3.1.1. Elevation and malaria hazard

According to the reclassified elevation map, it was estimated that 10883 km^2 (61.5%), and 6713.6 km^2 (38.5%), of the study area were subject to very high, and high malaria hazard area respectively. In relation to elevation, no areas of the study area are free from malaria, mainly due to suitability of its topographic features for mosquito breeding. From this, it is possible to understand that more than half of the study area is in the very high malaria hazard zone. Most studies in Ethiopia showed that malaria frequently occurs in areas with elevation below 2000 m and its transmission is extremely high in areas below 1500m. Thus, almost all areas of the study area are likely under the hazard of malaria prevalence since its elevation is below 1500m. This study in line with that of [2], which stated that various environmental and socioeconomic parameters were interrelated and influenced the malaria outbreak.

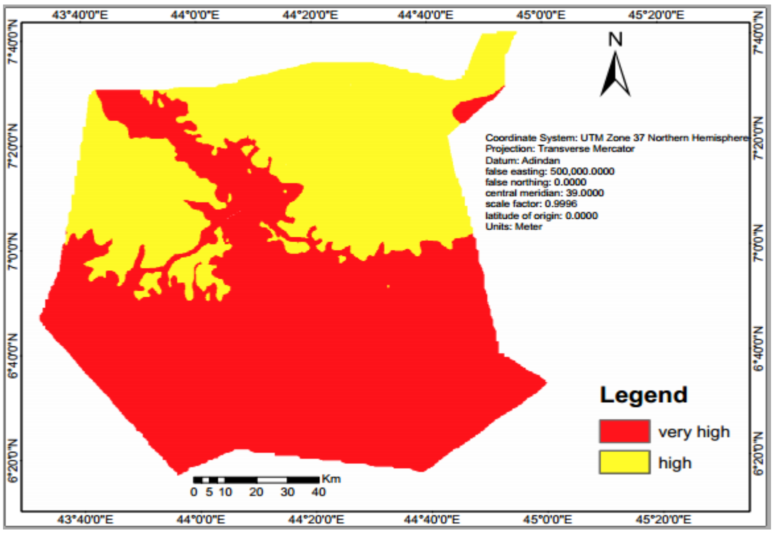

Figure 4: Reclassified elevation map vs malaria hazard

3.1.2. Slope and malaria hazard level

The reclassified slope map (figure 5) of the study area have five hazard levels with a new value of 1 to 5, where value 5 stands with very high hazard level and value1 to area which have very low malaria hazard level. Areas leveled as high and very high malaria hazard, have slope less than 0 – 5% and 5% – 11% that allow water stagnation and create suitable conditions for mosquito breeding. Accordingly, the reclassified slope map shows that, out of the total area, 16819km^2 (95.6%) is in a very high; 709.3 km^2 (4 %,) in high; 67km^2 (0.4%) in moderate; 1.5km^2 (0.008%) in low and 0.02 km2 (0.0001 %) is very low hazard of malaria incidence. From the total study area, over 98% is in high and very high malaria hazard while the remaining 2% of the total area is in moderate, low and very low malaria hazard. In areas with low slopes, water tends to be logged and such conditions accelerate chances for water stagnation, which in turn, encourages breeding and survival of mosquitoes.

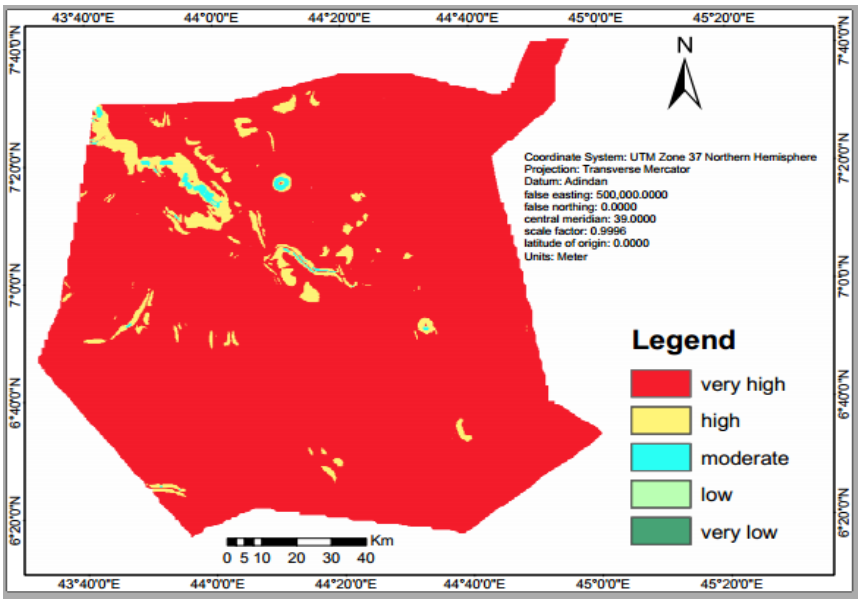

Figure 5: Reclassified slope map vs malaria hazard

3.1.3 Types of soil and malaria hazard level

An assessment made to identify suitable soil type for mosquito breeding reveals that, 3123.47 km^2 of the study area have very high malaria hazard; 8362.53 km^2 have high malaria hazard, 4251.65 km^2 moderate malaria hazard and 1560.4 km^2 areas have low malaria hazard, and 200.21 km^2 areas have very low malaria hazard.

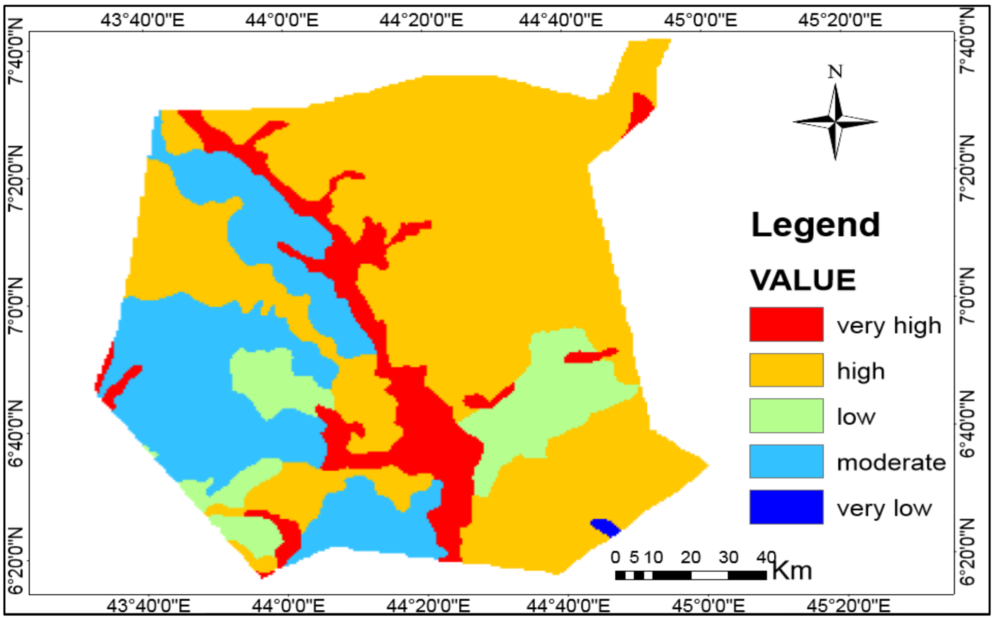

Figure 6: Soil type vs Malaria hazard

The reclassification was based on water storage capacity and permeability of soils characteristics [5], which determines their suitability for mosquito breeding. Accordingly, Chromic vertisols /stone surface soil/ and Calsic Cambisols represented as very high and high hazard level due to the fact that they allow water stagnation and typically impermeable or poorly drained soils. They account for 1861km^2 or 10.6% &10265.5 km^2 or 58.3% of the total area of the study area respectively. Regosols which was deep, well drained, medium textured, represented as moderate malaria hazard level and accounts for 1620.7 km^2 or 9.2% of total area. Lithosols and Yermosols which have good drainage are represented as low and very low malaria hazard with 3825.2 km^2 or 21.7% & 26 km$_2$ or 0.15% of total area respectively.

3.1.4. Proximity to pond water and malaria hazard level

The reclassified map of distance from pond water shows that very high and high malaria hazard area which accounts for 4640.7 km^2 (26.4%) and 8417.8km^2 (47.8%) respectively. Moderate and low malaria hazard area covers an area of 3827.1 km^2 (21.8%) and 695.6 km^2 (4%) respectively. Distribution of water bodies are an important factor influencing the occurrence and distribution of malaria cases and contributes as larval breeding sites for malaria vectors, thus, it is a major determinant of malaria risk incidence [22]. Thus, the reclassification of pond water site of the study area was based on flight range of mosquito, since mosquito can fly 2km from its origin, thus areas which located 0-0.5km ,0.5-1km, 1-1.5km and 1.5-2km were mapped as very high, high, moderate and low malaria hazard respectively.

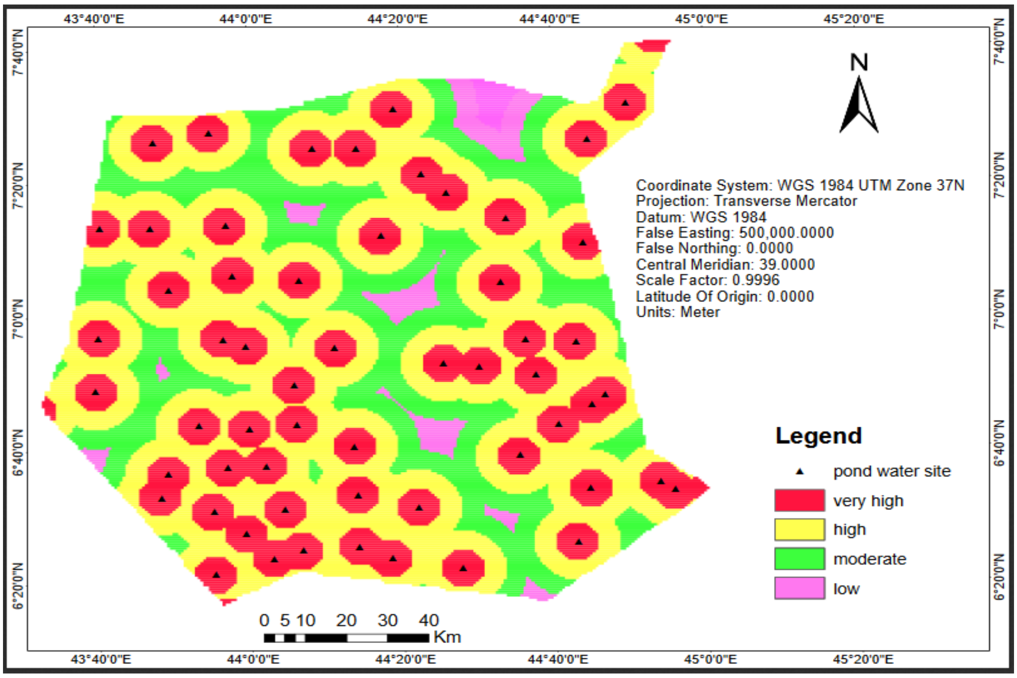

Figure 7: proximity to pond water vs malaria hazard

3.1.5. Temperature and malaria hazard

The temperature of the study area was classified into three malaria risk levels which is based on suitability of the amount of temperature for mosquito breeding. In the area where temperature below 16°C, the development of Anopheles gambiae, the main malaria vector in most parts of Africa, is completely stopped, and the larvae die in wet temperature below 14°C. On the other side, places with temperature amount >30°C are difficult for larval survivorship [1]. From this point of view, most of the study area is in the temperature range between 22.87°C to

26.72°C, which is suitable for mosquito breeding. Accordingly, 13.27%, 50.3%, 36.43 % of the study area is under low, high and very high malaria hazard level respectively. So the average temperature between 22.87°C to 26.72°C, is suitable for malaria incidence thus leveled as high and very high hazard level of malaria.

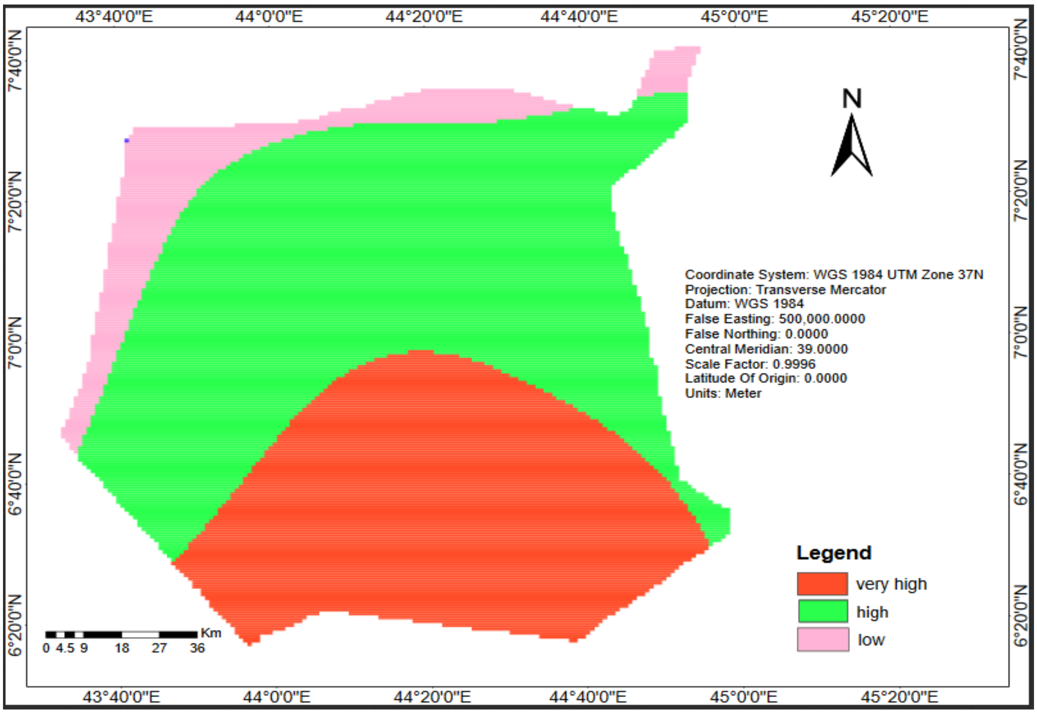

Figure 8: temperature vs malaria hazard

3.2. *Developed factor map of malaria risk and its degree of vulnerability*

3.2.1. Land use land cover and malaria risk level

The type of land use land covers especially type of vegetation which surrounds the breeding sites basically supply sugar feeding for adult mosquitoes, and provided ideal sites for resting and protection from climatic conditions and enhance enhancing longevity of the vectors [22]. Based on the classification done, the study area has four major land use land cover types such as range land, bare land, and bush land and settlement area. The land use/cover types of the study area were reclassified into a common scale in order of sensitivity for the malaria risk analysis. Accordingly, the reclassified land use land cover based malaria risk level of the study area is shown in the figure below. The result shows that, 358.6 km^2 or 2.1 % (settlement area) subjected to very high risk of malaria; 5062.6 km^2 or 29% (bush land) high risk of malaria, and about 8632 km^2 or 49.4 % (range land) and 3407.2 km^2 or 19.5% (bare land) was subjected to moderate and low malaria risk level respectively. Therefore, from the above figure, it is possible to understand that bush land and settlement area are high contributors of mosquito survival due to the fact that they contain more moisture content which is favorable for mosquito breeding than other land use available in the area. In contrary, bare land which lacks moisture content and food source for larva is leveled as low malaria risk level.

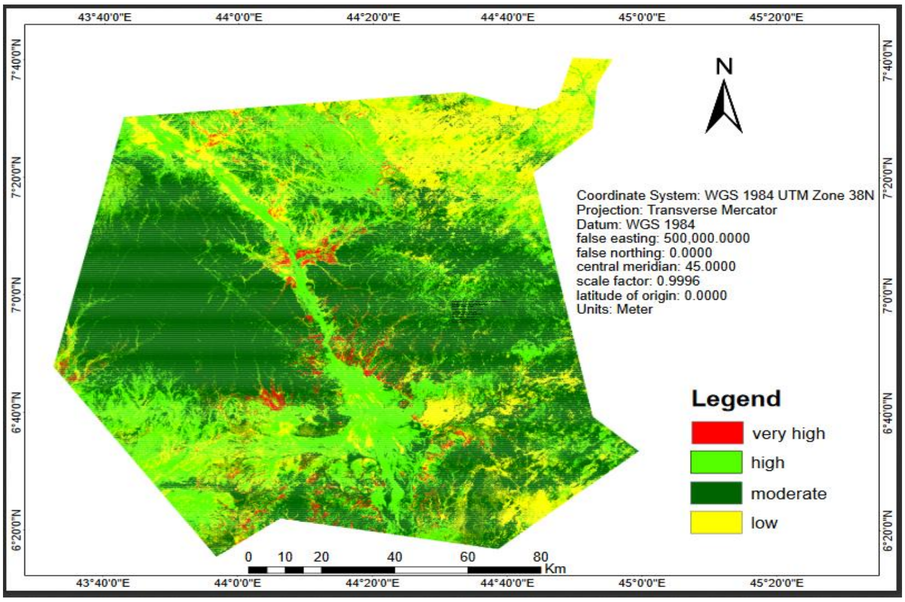

Figure 9: reclassified land use/land cover vs malaria risk

3.2.2 Distance from Health Station and Malaria Risk (Vulnerability)

Proximity of each health station were analyzed using distance module in spatial analyst in arc GIS. The WHO report shows that vulnerability to malaria incidence in developing countries assumed to be less vulnerable and easily accessible to the existing health when it is found within 3km radius. In addition, vulnerability increases beyond 3km radius from the existing health station due to distance limitation for health station services. Accordingly, in relation to health station, about 1407.4 km^2 (8.1%) of the study area is very highly vulnerable to malaria, 4536.8 km^2 (26%) is highly vulnerable and the rest 7665.8 km^2 (44%) and 3824 km^2 (21.9%) is moderate and low vulnerable to malaria.

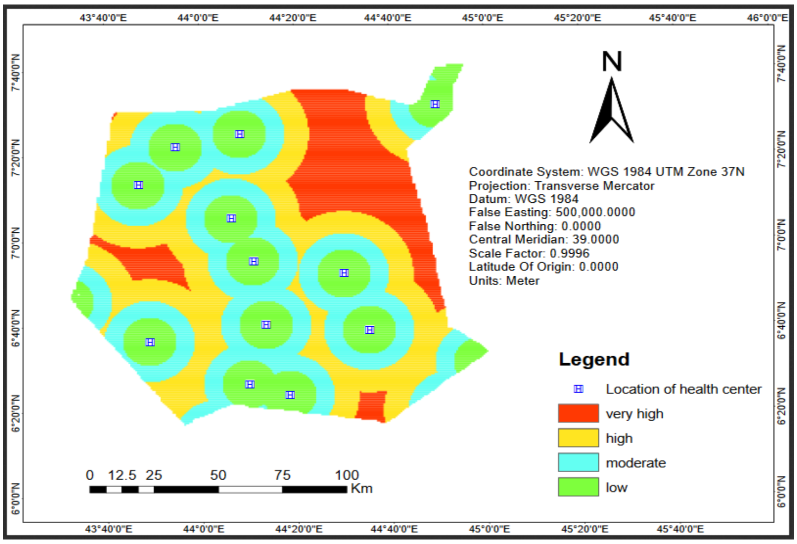

Figure 10: Location of health centers vs malaria risk

3.3. Identified Areas of Malaria Hazard and Risk

3.3.1. Identified Areas of Malaria Hazard

The malaria Hazard analysis of the study area was approached by assessing the suitability of environmental condition for malaria transmission based on environmental and physical factors. The study results shows that the existence and transmission of malaria incidence is determined by the environment with lower elevation (higher temperature), abundance of wet lands, occurrence of gentle slopes, availability of still waters around rivers, and areas of lower drainage density''. Similarly, in this study malaria hazard map was computed by overlaying all reclassified environmental and climatic factors mentioned above such as elevation, slope, types of soil, and distance from water bodies, and temperature. After the overlay analysis of those parameters, malaria hazard map was produced. According to reclassified malaria hazard map, it was estimated that about, 7286.4 km^2 (41.6%), 7390.15 km^2 (42.2%) and 2836 km^2 (16.2%) areas of the study area was mapped as very high, high and low hazard level respectively. The final Malaria Hazard map also revealed that elevation, temperature and proximity to pond water site are the most important factor for malaria hazard in the study area. While soil types and slope were identified as relatively the least important factors.

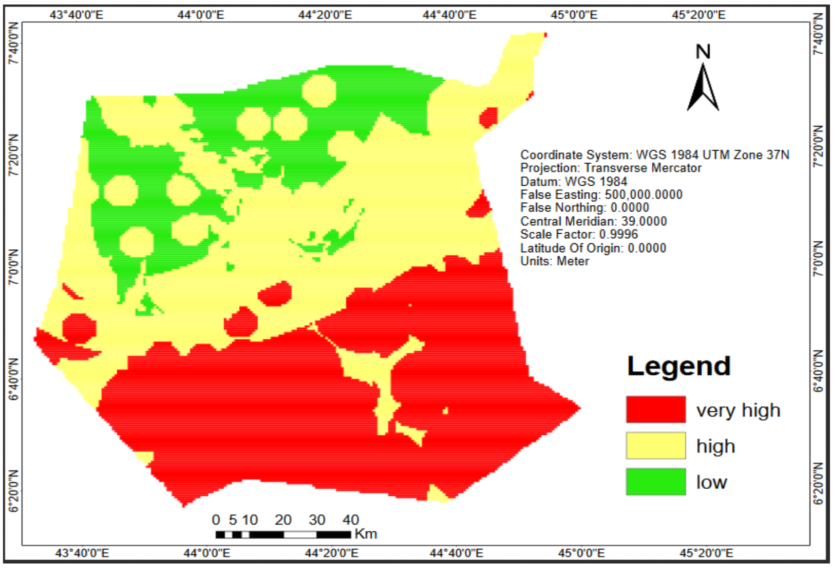

Figure 11: Final malaria hazard map

Table 4: Malaria risk level, Area coverage and percentage

Hazard level	Area (km^2)	Area (%)
Very high	7286.4	41.6
High	7390.15	42.2
Low	2836	16.2

3.3.2. Identified Areas of Malaria Risk

The basis for the calculation of the malaria risk map was the risk computation model (Risk = Hazard * Element at Risk * Vulnerability) developed by [12]. Elements at risk indicators specify the amount of social, economic or ecological units which are at risk of being affected regarding all kinds of hazards in a specific area e.g. persons, economic production, buildings, public infrastructure, cultural assets, ecological species and landscapes located in a hazardous area on connected to it. Thus, malaria risk mapping for the study area was done using the malaria hazard layer which is based solely on natural conditions and the elements at risk, namely land use/land cover and health services. The malaria hazard layers were computed by overlaying elevation, temperature, slope, rain fall, distance to streams and soil raster layers. The element at risk layer were developed by reclassifying land use/ land cover image file on the basis of malaria susceptibility of each land use/ cover classes and vulnerability layer was developed by computing distance on the existing health station distribution point data of the study area. According to the malaria risk map it was estimated that 4095 km^2 (23.7%), 12169.2 km^2 (70.5%) and 1010 km^2 (5.8%) of the study area were subjected to very high, high and low malaria risk level respectively. This shows majority of the study area fell in the high and very high risk level which occupies (94.2%). Low malaria risk zone covers small area, which accounted only 1010 km^2 (5.8%) of the total area. Hence, it is possible to conclude that most of the study area (over 90 percent) is under high and very high risk of malaria. This malaria risk level found by the study is among the highest, when it compared with different study conducted in different parts of Ethiopia. For instance, the risk level identified in this study was by far greater than the findings of the study conducted by [16], which discussed the majority of study area, fell in very high and high risk level 54.5 %. In general, the whole study area is in the high malaria risk zone, this is mainly because of its location and climate characteristics that facilitate suitable condition for mosquito breeding. Figure 12 below shows the final malaria risk map of the study area.

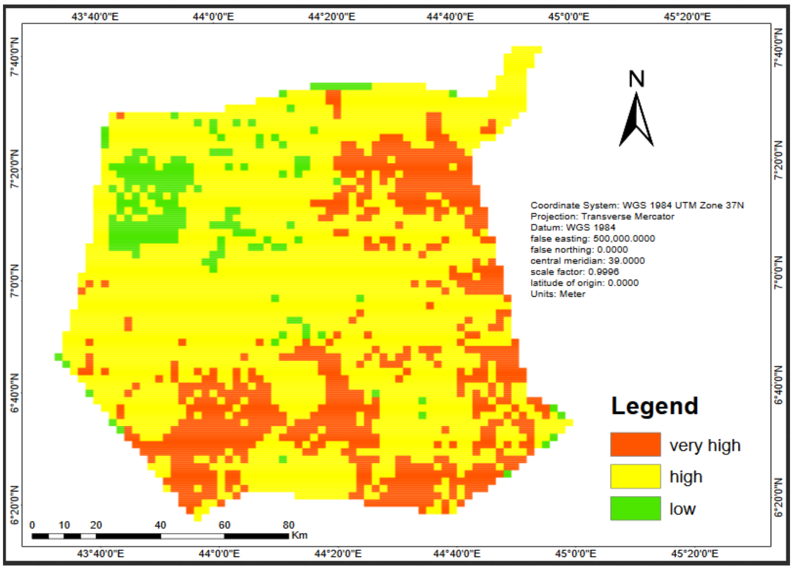

Figure 12: Final malaria risk map

Table 5: Malaria risk level, Area coverage and percentage

Risk level	Area (km^2)	Area (%)
Very high	4095	23.7
High	12169.2	70.5
Low	1010	5.8

Findings of the present study shows that, a model-based malaria-risk map can be developed by establishing the relationship of various parameters using remote sensing and geographic information system. It also reveals that remote sensing and GIS techniques can be effectively used in mosquito larval habitat identification and risk area mapping. The malaria-risk map developed can support decision makers to take precautions in space and time to control and manage malaria incidence.

4. Conclusion and Policy Implications

This study analyzed malaria hazard and risk areas in Korahey zone of Somali regional state, eastern Ethiopia. The malaria hazard analysis of Kebridahar and Sheykosh districts revealed that, from the total area, 41.6%, 42.2% is mapped as very high and high risk zone, whereas, the remaining 16.2% mapped as low level of malaria hazard. For the presence of high level malaria hazard, the existence of suitable climatic condition and topography particularly elevation for mosquito breeding plays major role. The result of the malaria risk map shows that about, 4095 km^2 (23.7%), 12169.2 km^2 (70.5%) and 1010 km^2 (5.8%) of the study areas were subjected to very high, high and low malaria risk level respectively. This shows the majority of study area fell in high and very high risk level which occupies (94.2%). Even though large areas of the study area are subjected to very high and high malaria hazard area, relatively less area of the districts is subjected to low malaria risk. The elements at risk particularly persons to malaria risk located in malaria hazardous areas or connected to it is relatively low as compare to the malaria hazard. This study confirm that GIS and RS are vital tools to identify malaria hazard and risk zone mapping using environmental factors, reclassifications and overlying. Based on the findings, the following policy implications were provided for stakeholders: First, the health office at the district should provide training in the awareness creation with respect to malaria prevention for local communities especially for those in high and very high areas. Second, regional office should provide anti-malaria drug provision, bed net distribution and house spraying by prioritizing based on the risk level with help of regional health office and NGOs. Third, proper data bases about detail patient data, the seasonal incidence of epidemics and about other related aspects of the malaria should be made with GPS Location. Fourth, to reduce the level of exposure to malaria in areas closer to swamps and other water bodies, the community and other concerned bodies should design appropriate facilities to drain swamps and stagnant water.

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References

[1]. Afrane, Y., Githeko, K., and Yan, G. (2011). Malaria transmission in the African highlands in a changing climate situation: Perspective from Kenyan highlands, global warming impacts: - case studies on the economy, human health, and on urban and natural environments, Stefano Casalegno (Ed.), DOI: 10.5772/24946

[2]. Ahmad, F., Goparaju, L. and Qayum, A. (2017). Studying Malaria Epidemic for Vulnerability Zones: Multi-Criteria Approach of Geospatial Tools. *Journal of Geoscience and Environment Protection*, 5, 30-53. DOI: https://doi.org/10.4236/gep.2017.55003

[3]. Ashenafi, M. (2003). Design and Water Management of Irrigation Systems to Control Breeding of Anopheles Mosquitoes. Case Study: Hara Irrigation Project, Arba Minch, Ethiopia. M.Sc. Thesis, Wageningen University, Wageningen, The Netherlands.

[4]. CSA, (2007). Summary and statistical report of population and housing census of Ethiopia. Central Statistical Agency, Addis Ababa

[5]. Stephen, J., Cechura, Lukas, Berhanu, and Adugna. (2011). BSE Disease Outbreaks, Structural Change and Market Power in the Canadian Beef Industry. Working Papers 114097, Structure and Performance of Agriculture and Agri-products Industry (SPAA), DOI: 10.22004/ag.econ.114097

[6]. Eastman,J.R.,(2001). IDRISI Guide to GIS and Image Processing. Volume 2, Clark University Version 32.20.Version 32.20. Clark University.

[7]. FMoH. (2009). National Strategic Plan for Malaria Prevention, Control and Elimination in Ethiopia 2010 – 2015. Federal Ministry of Health, Addis Ababa, Ethiopia Geosciences and Geometrics, Vol. 1, No. 1, pp.8-14.

[8]. Marcus, M. and H.Minc, (1988). Introduction to Linear Algebra. New York: Dover, p. 145.

[9]. Negassi, F. (2008). Identifying, Mapping and Evaluating Environmental Factors Affecting Malaria Transmission Using GIS and RS in Selected Kebeles of Adama district, Oromia Region. MSc Thesis, AAU.

[10]. Petrocelli, L.D., Camardiel, A., Aguilar, V.H., Martinez, N., Córdova,K., and Ramos's. (2011). Geospatial tools for the identification of a malaria corridor in Estado Sucre, a Venezuelan north-eastern state. Geospatial Health, 5(2), 169-176.

[11]. Saaty, T.L., (1977). A Scaling Method for Priorities in Hierarchical Structures. Journal of Math. Psychology, 15:234-281.

[12]. Shook, G. (1997). An assessment of disaster risk and its management in Thailand. Disasters, 21(1), 77-88.

[13]. Stephen, M. (2006). landscape determinants and remote sensing of mosquito larval habitats in the high land of Kenya. Malaria journal.

[14]. Stratton, L., O'Neill, M., Kruk, M and Bell.M. (2008).The persistent problem of malaria: addressing the fundamental causes of a global killer, Well Cornell medical college, New york, NY, USA.Socsci Med J 854-62.

[15]. Teklehaimanot,A., and Schwartz,J. (2004),Weather based prediction of Plasmodium falciparum malaria in epidemic-prone regions of Ethiopia I. Patterns of lagged weather effects reflect biological

mechanisms. Malaria Journal, 3, 41.

[16]. Tensaye, W. (2016). Geographic Information System and Remote Sensing Based Malaria Risk Mapping: A Case of shone town administration, Southern Nations Nationalities and Peoples' Regional State. MSc thesis. Addis Ababa University, Ethiopia.

[17]. WHO. (2011). World Malaria Report. Geneva: World Health Organization.

[18]. WHO. (2013). Global malaria situation. World Malaria Report /WMR/.

[19]. WHO. (2018). World Malaria Report. Geneva: World Health Organization

[20]. WHO. (2019). World Malaria Report. Geneva: World Health Organization

[21]. Woime, A.W. (2008). Changes in the spread of malaria in Ethiopia: case study from Awassa and Hossana area 2006-2007. Telemark University College, Norway. Master's thesis. Unpublished.

[22]. Zhou, G., Afrane, Y., Vardo, Z., Atieli, H., Zhong, D., and Wamae, P. (2012). Changing Patterns of Malaria Epidemiology between 2002 and 2010 in Western Kenya: The Fall and Rise.