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Identifying Malaria Epidemic Prone Area Hotspot Map by Using Geospatial Technologies and Spatial Multi Criteria Evaluation Techniques: The Case of Majang Zone, Gambella Region, Ethiopia

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Abstract: Malaria is one of the worlds serious and complex public health problems and it remains one of the greatest killers of human beings in developing countries. Due to its tropical location and other environmental, socio economic and epidemiological factors, southwestern part of Ethiopia where Majang zone is located is favorable for mosquito breeding and malaria transmission. The objective of this research was identifying malaria epidemic prone areas (hotspot) map using Geographical Information System and Spatial Melti-Criteria Evaluation techniques in the case of Majang Zone, Gambella Regional State, Ethiopia. To identify malaria epidemic prone areas, three parameters (environmental, socio economic and epidemiological) were selected depending on previous works and based on discussion made with malaria experts. Environmental parameters include wetness, elevation, drainage buffer, slope, aspect, forest cover, rainfall data, and temperature and water body buffer while socio economic parameters were categorized population and proximity to hospital. An annual parasitic incident case was classified as epidemiological parameters. Rasterization and reclassification process was done using GIS and remote sensing environments for the sake of weighted overlay analysis. Accordingly, weight was assigned for each parameter by pair wise comparison method and weighted overlay was used in Arc GIS spatial analyst tools to produce the final malaria epidemic prone area (hotspot) map of the study area. The final malaria risk map of the study area shows that from the total area, 16.8 % was mapped in very high, 42.3% in high, 27.6% in moderate and 13.3 % in low level of malaria risk. The majority of study area fall in high risk level (42.3 %) which is followed by moderate risk level (27.6%). The study proved that, seven kebeles seven from Godere woreda and four from Mengesh woreda were subjected very high risk for malaria. On the other hand, five kebeles, three from Godere woreda and two from Mengesh woreda were classified as high-risk level; whereas five from Mengesh woreda and two from Godere woreda were considered as moderately risk in malaria in the case study area.

Key words: GIS, ArcGIS, Remote Sensing, weighted overlay, pair wise comparison.

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I. INTRODUCTION

Ethiopia, one of the sub-Saharan countries in Africa is the victim of malaria epidemic and it's far reaching negative impacts. It is one of the main health problems in the country in which its cases are one of the highest and increasing in an alarming rate. However, exposure to malaria varies markedly by location and season. Ethiopians live at altitudes ranging from −100 to >4220 m, the topography made a fertile ground for the reproduction of the epidemic. Based on (MOH, 2008) studies, more than 50 million (68%) of the population live in areas below 2000 m above sea level are at risk of malaria. with consequent variation in minimum and maximum temperatures. In general, the main reasons given for the increment are ecological and climatic changes. According to (Negassi F., 2008) stated that, the peak of malaria incidence follows the main rainfall season in July, August, September, October and November each year. In general, the main reasons given for the increment are ecological and climatic changes. Moreover, climatic as well as landscape and land cover factors greatly influence malaria incidence and the diseases they transmit (Van der Hoek *et al.,* 2003). It is widely acknowledged that, the malaria transmission dynamics are closely related to socioeconomic, climatic and environmental factors; the latter including altitude, precipitation, temperature and land use and land cover (Craig *et al.,* 2004; Mboera *et al.,* 2010). Malaria has, therefore, been defined as an environmental disease (Hay *et al.,* 2000; Craig *et al.,* 2004; Raso *et al.,* 2012). About 70-90% of the risk of malaria is considered due to environmental factors which in turn influence the abundance and survival of the vectors (Smith *et al*., 2004; Ye *et al*., 2007). Hence, a deeper knowledge of environmental variables, conducive to mosquito vector life cycle, is important to target control interventions. Modeling environmental variables using GIS and Remote sensing techniques are very valuable in defining foci of malaria transmission. The development of spatial analytical techniques has created an avenue to evaluate environmental variables are generated by remote sensing satellite sensors and captured by Geographic Information Systems (GIS) for spatial and temporal environmental analysis (Tanser *et al*., 2002). These technologies provide tools for identification and quantification of the population at risk of parasite infections in endemic communities (Riedel *et al.,* 2010). In the case of malaria in Africa, these tools have been used to model and develop malaria risk maps at different spatial scales. Spatial technologies, i.e. GIS, RS and GPS offer an opportunity for rapid assessment of malaria endemic areas. These technologies coupled with prevalence/incidence data from health center can provide reliable estimates of population at risk, predict disease distributions in areas that lack baseline data and provide guidance for intervention strategies, so that, scarce resources can be allocated in a cost-effective manner. ((Rincon-Romero *et al*.2009). These research study focus on, mapping malaria incidence and prevalence, assessing the relationship between malaria and environmental variables as well as identify population at risk.

II. OBJECTIVE

The objective of the study was identifying malaria epidemic prone areas hotspot risk map using GIS and Spatial Multi-Criteria Evaluation Technique for the betterment of malaria intervention and control program service in the case of Majang zone.

III. DESCRIPTION OF THE STUDY AREA

The Majang Zone is one of the three zones of the Ethiopian Region of Gambela; is named for one of the three largest indigenous groups in Gambela, the Majangir. The Southern Nations, Nationalities and Peoples Region (SNNPR) border this zone on the south and east, on the west by the Anuak Zone, and on the north by the Oromia Region. The zones capital was called Meti. The area of the Majang Zone lies to the east of the escarpment, which borders the edge of the lowlands, which define the majority of the area of the Gambela Region. This Zone covers the extent of the original special woreda of Godere, which was made part of the Administrative Zone between 1994 and 2001. Subsequently, before 2007, a number of kebeles were split off to create Mengesh and both Woredas became the Majang zone formerly Mezhenger Zone.

According to the Atlas of the Ethiopian Rural Economy published by the Central Statistical Agency (CSA, 2007), over 40% of the Zone is forest. The Area has an altitude of about 1800 m above the sea, and the relatively flat, dry eastern parts (between 750-1800m in altitude). According to (FMOH, 2008) explanation in Ethiopia more than 50 million (68%) of the population live in areas below 2000 m above sea level are at risk of malaria. The Zone have 29 kebeles, 2 woredas and 1 administrative town which is called Meti. Based on the above reference Majang zone is at malaria risk. The rain that falls on the study area were usually not seasonal, where it stagnates creating pools of standing water suitable for mosquito breeding because of the flat terrain and high temperatures in this dry zone.The area of Majang zone is 225, 464.93 ha.

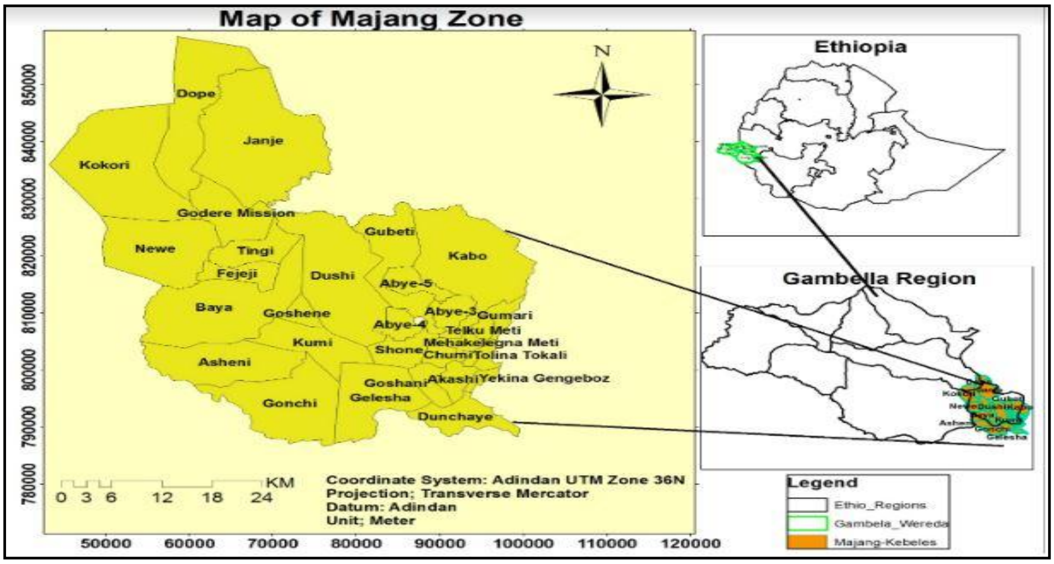

Figure 1: location map of the study area

According to the statistical abstract of the (FDRECSA, 2011), Majang zone has the population of 87,374. Out of this, 67,931 rural dwellers and 19,443 urban dwellers were found, i.e. 78 % and 22 % respectively.

Accordingly, out of the total population (87374) of the zone, 41,940 representing 48% was classified as female and 52%, which accounts 45,434, was categorized as male in the case study area. According to census done by (MOA, 2008 E.C) cited from Majang zone health department annual report (2009 E.C) almost all parts of the zone was considered as vulnerable for malaria parasite breeding. Based on the above information about 87374 people were at risk.

IV. MATERIALS AND METHODOLOGY

The design and the setting of the study were based on the combination of geographical models of the human population density with the clinical incidence of malaria, which allows an estimate of the spatial distribution of malaria cases and an estimation of how many malaria cases covered by the healthcare facility and where a large number of people affected by malaria do not have immediate access to healthcare facilities.

GIS was then used to evaluate the feasibility of medical GIS as part of anti-malaria strategies. GIS software to overlay and analyze different geographical datasets and to produce significant maps and outputs. Both spatial data and attribute data made it possible to display and examine both types of data simultaneously. Data input screens were designed to facilitate easy and accurate data entry. These use drop-down lists of permissible data values, and, when possible, data were derived automatically from values previously entered. Data were also validated and edited as they were entered. A set of standard queries and reports, developed in accordance with management's requirements, was also included in the system to allow for easy analysis and to provide timely feedback to local health staff. ArcGIS software (version 10.5, ESRI) run on a Pentium 4 processor with 4 Gigabytes of random access memory, a hard drive with 500 Gigabytes capacity, and a standard color printer were used. Commercially available digital map data sets of the entire study area at various scales were acquired from Ethiopia mapping agency. Orthography, three-dimensional displays of geographical areas, prepared by using satellite images particularly Landsat 8 found in USGS and provided baseline spatial data of the area. Global Positioning System required collecting control points accurate to less than a meter was used to correct the images for inclusion in the geographical information system. Maps were produced with delineated residential, commercial, recreational, public utility, villages, and other administrative boundaries including Study area boundary.

The researchers have used both primary and secondary sources of data. Primary data were collected through GPS, structured questionnaires of open and close ended type of questions for sample residents, and direct observation. This data helped to obtain extra information where swampy area found and how the residents are controlling it. Secondary data were also collected through patients' data from health centers, previous maps and satellite images.

Firstly, three parameters (environmental, socio economic and epidemiological parameters) were identified. Environmental parameters include wetness, elevation, drainage buffer, slope, aspect, forest cover, rainfall data and water body buffer while socio economic parameters were categorized as population at risk, i.e. according to (MOE,2009) almost all population at majang were at risk. Average API cases of 2008, 2009 & 2010 were classified as epidemiological parameters. Secondly, ArcGIS 10.5 by ESRI and ERDAS Imagine were used for all data extraction, editing, management and analysis. All raster and vector data types were converted into a common coordinate system which is the Universal Transverse Mercator (UTM) projection zone 36 N. Thirdly, all the three parameters used in the analysis would be geo-referenced, digitized, buffered and converted in to raster format, and reclassified according to their vulnerability classes in Arc GIS environment. After the reclassification process, weights are assigned for each criterion based on AHP model using pair wise comparison matrix.

Finally, prone area (hotspot) map of the study area was prepared as shown the model of the methodology in figure 2.

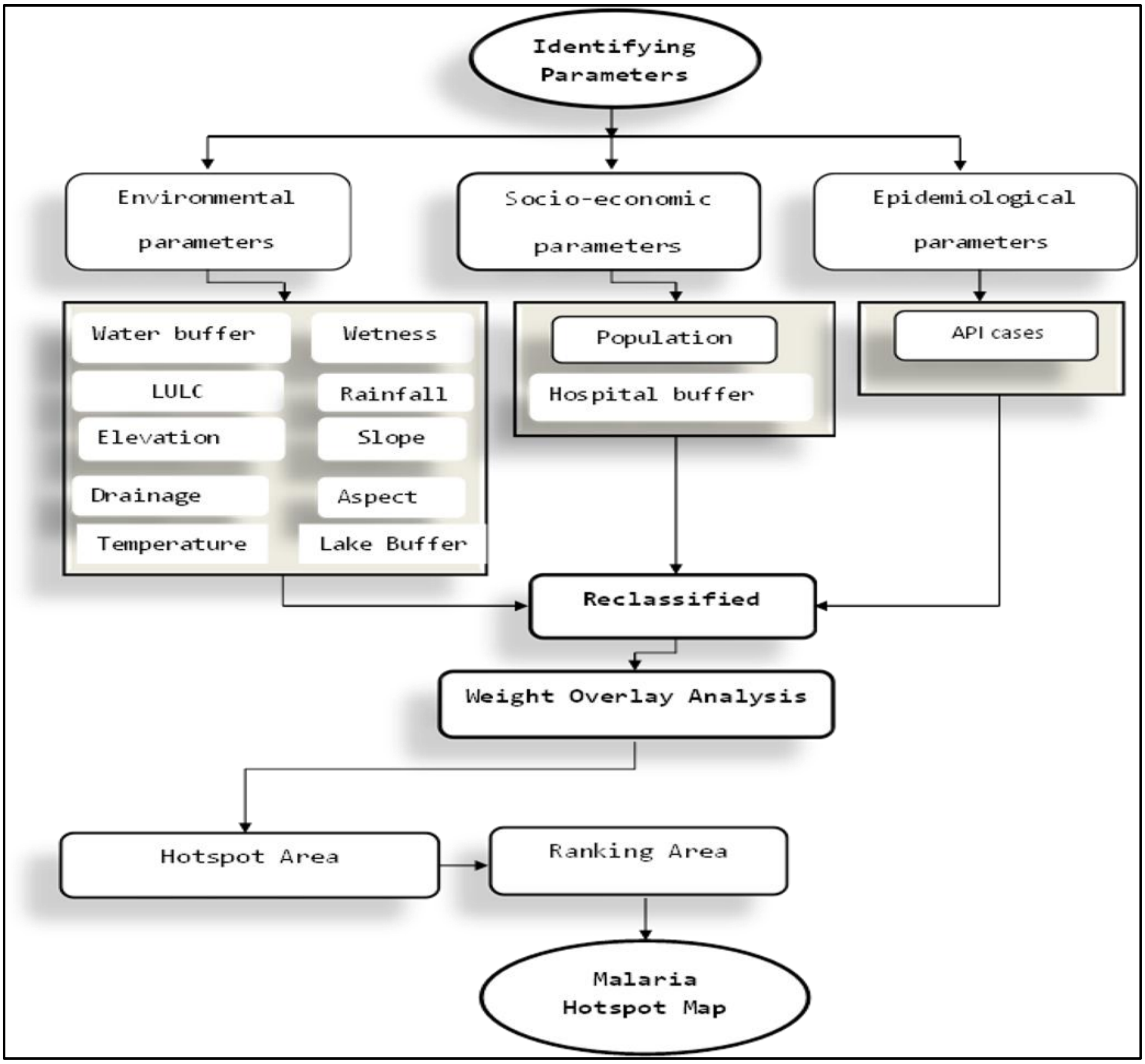

Figure 2: Technological schemes of Hotspot Map of the study area

V. DATA ANALYSIS, RESULT AND DISCUSSION

All factor maps/criteria used in the analysis would be geo-referenced, converted in to raster format, and reclassified according to their risk classes in Arc GIS environment. After the reclassification process, weights were assigned for each criterion based on AHP model using pair wise comparison matrix. Finally, all standardized criteria would be combined to perform weighted overlay analysis to obtain the malaria risk site and to produce the thematic map of the most hazard sites for malaria epidemic site in majang zone.

5.1. Land use land cover

Table and figure below shows that, densely forest coverage had a total land area of 1241.24 km^2 (48.6%), open forest coverage 845.37 km^2 (33.1%), agricultural land coverage 168.56 km^2 (6.6%) and settlement 298.81 km^2 (11. 7%). Accordingly areas around settlement were very high vulnerable for breeding of female anopheles' mosquito. Because, in that area there was condensed settlement pattern, small agricultural activities which create small ponds and both solid and liquid wastes around settlement area make this land use types most vulnerable for malaria transmissions (Zhou et al., 2007) and open forest was the second most vulnerable area for malaria. Agricultural field and dense forest followed moderate and low vulnerable respectively for malaria transmission in the study area.

Table 1: Forest coverage types & area Coverage

Class	Degree of vulnerable	Ranking	Area in km^2	Percentage
Dense forest	Low	1	1241.24	48.6

Open forest	High	2	845.37	33.1
Agricultural field	Moderate	3	168.56	6.6
Settlement	Very high	4	298.81	11.7
		Total	2254	100

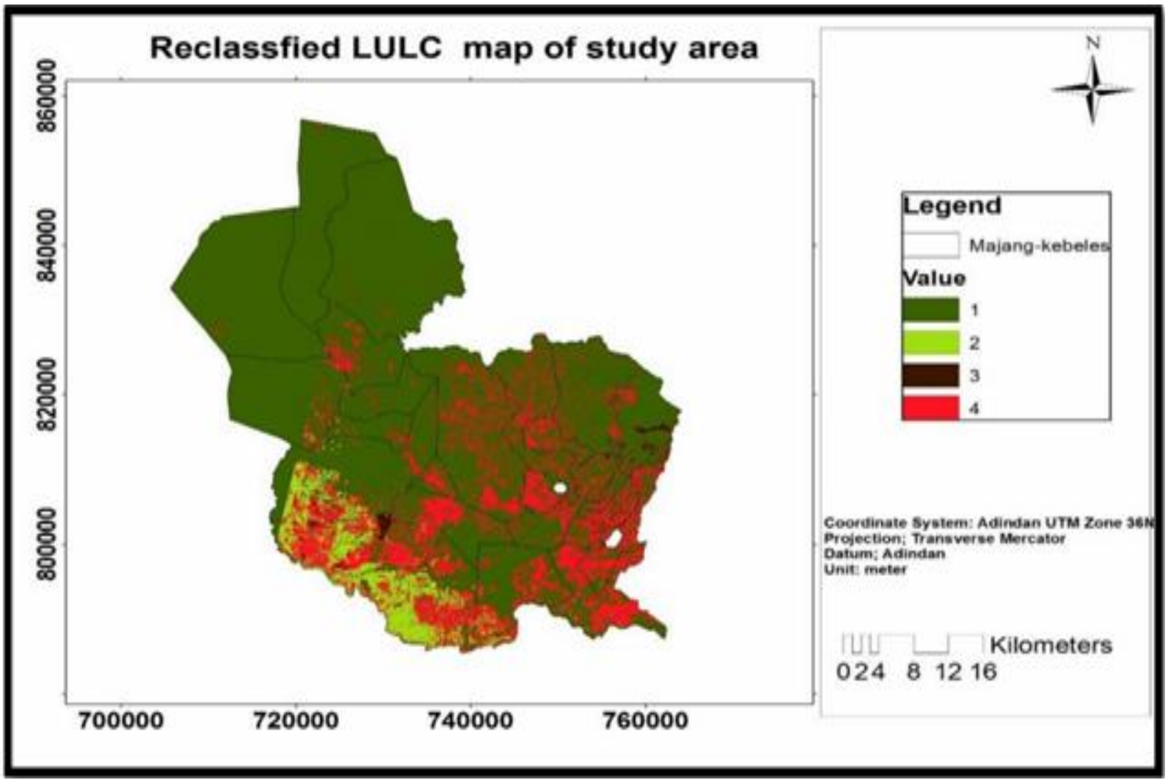

Figure 3: Land Use Land Cover Map of the Study Area

5.3. Proximity to River

The closeness of the populated area to drainage system is an important parameter for malaria vector breeding source in malaria risky areas (Kumar et al., 2012). Female anopheles' mosquito can able to fly maximum of 2km per day, so areas closer to river have high possibilities to be infected by malaria.

Accordingly, proximity distance to river less than 1000m that covers a total land area of 373.90 km^2 (14.64 %) was identified as very high vulnerable for malaria transmission and ranked as 5. However, proximity distance to river ranges from 4000-5000m of a total land area of 601.97 km^2 (23.57%) was classified as very low vulnerable for malaria transmission.

Table 2: River classification and area coverage

Class interval in (m)	Degree of vulnerability	Ranking	Area in km^2	percentage
0 – 1000	Very high	5	373.90	14.64
1000 - 2000	High	4	438.77	17.18
2000 - 3000	Moderate	3	524.08	20.52
3000 - 4000	Low	2	614.49	24.06
4000 - 5000	Very low	1	601.97	23.57
		Total	**2554**	**100**

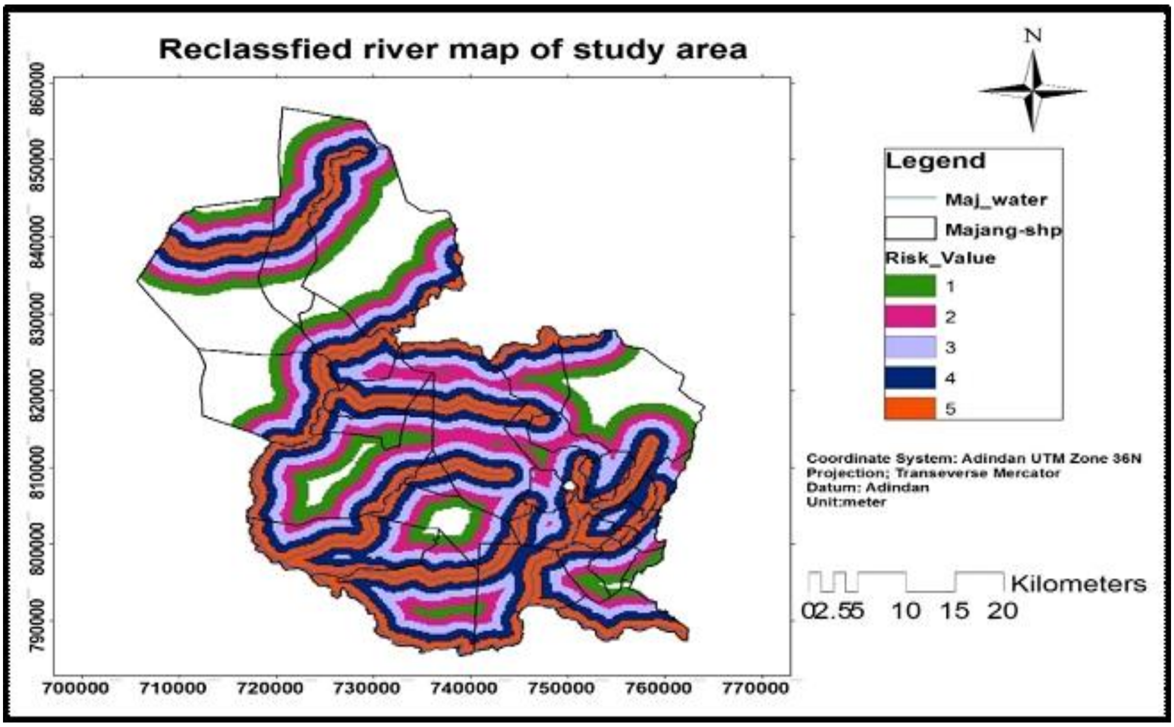

Figure 4: River Map of the Study Area

5.5. Hospital proximity

In majang zone there was one government hospital, which found in *kumi* kebele. As information obtained from majang zone health department, this hospital is the only hospital in the zone, which gives service for about 87,342 populations. Therefore, proximity to the hospital, i.e. nearness or farness can have significant influence to treat and care about malaria patients. Proximity factors (distance to hospital) are related to economic and physical capability of patient to reach and obtain necessary service from hospital. For this project, with in 1500m the study area was divided in to five classes.

Table 6 below indicates that, hospital proximity and its area statistics proximity distance was less than 15,000m from hospital covers a total land area of 772.32 km^2 (30.24%) was identified as very low vulnerable for malaria transmission in the case study area. whereas buffer distance greater than 55,000m from hospital was classified as very high vulnerable and representing a total land area of 117.73 km^2 (4.61%).

Table 3: Hospital buffer distance classification and area coverage

Class interval in (m)	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval in (m)
0 – 15000	Very Low	1	772.32	30.24	0 – 15000
15000-25000	Low	2	879.08	34.42	15000-25000
25000-35000	Moderate	3	433.41	16.97	25000-35000
35000-45000	High	4	351.17	13.75	35000-45000
≥55000	Very high	5	117.73	4.61	≥55000
		Total	2554	100	

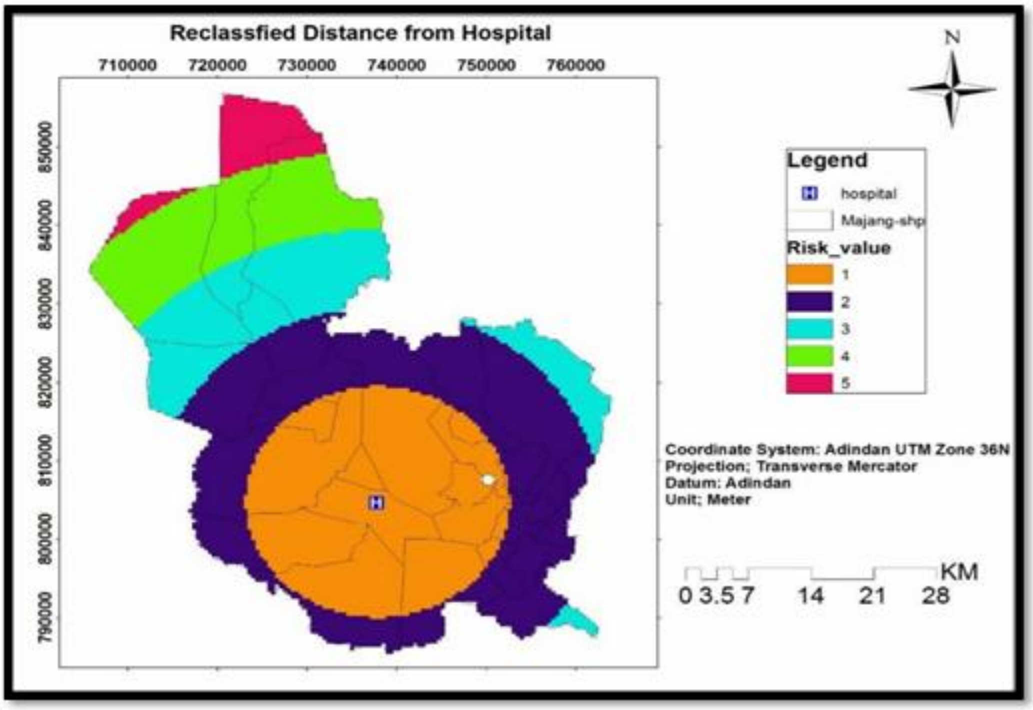

Figure 5: Reclassified hospital proximity Map of the Study Area

5.7. Proximity to Lake

Most lakes of Ethiopia are found in the rift valley area, where the temperature is high throughout the year. Both rural and urban populations occupy these regions, and high numbers of people are vulnerable to the disease like malaria (Woime, 2008). Accordingly, proximity distance to lake less than 500 m was identified as very high vulnerable for malaria breeding and representing a total land area of 152.98 km^2 (5.99 %) whereas proximity distance to lake between 2000-2500m of a total land area of 647.94 km^2 (25.37 %)was classified as very low vulnerable for malaria transmission in Majang zone.

Table 4: Proximity to Lake and area coverage

Class interval in(m)	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval in (m)
0 – 500	Very high	5	152.98	5.99	0 – 500
500 – 1000	High	4	118.50	4.64	500 – 1000
1000 – 1500	Moderate	3	940.38	36.82	1000 – 1500
1500 – 2000	Low	2	693.92	27.17	1500 – 2000
2000 – 2500	Very low	1	647.94	25.37	2000 – 2500
		Total	2554	100	

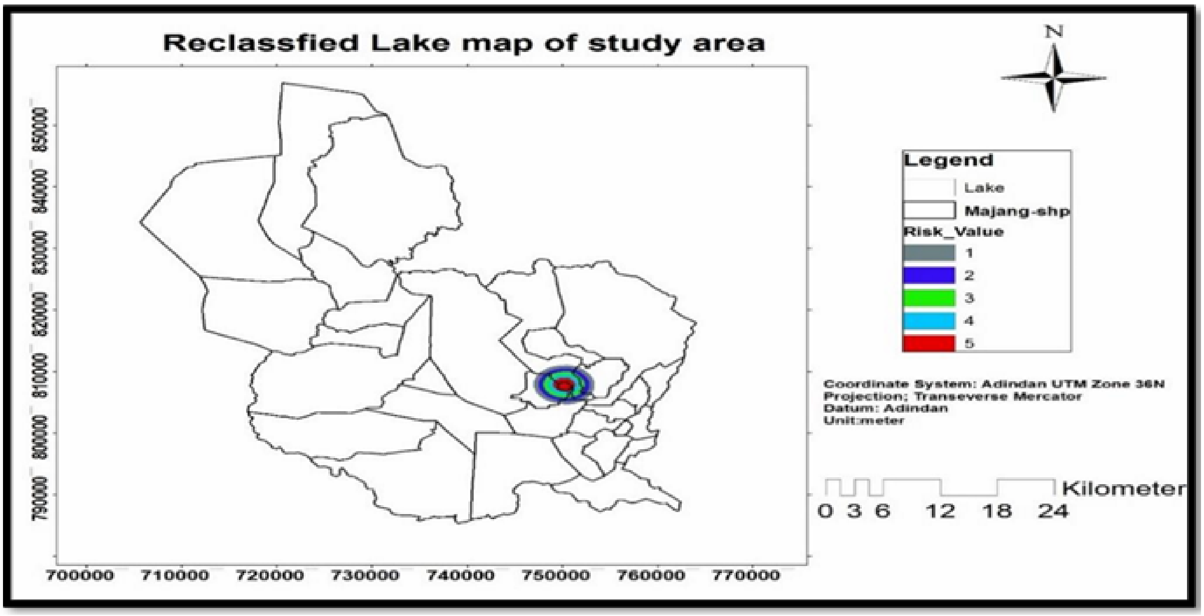

Figure 6: Proximity Lake Map of the Study Area

Table 5 below indicates the reclassified wetness index of the study area and area statistics. Class interval ranges from -1-7.5 which accounts an area of 116.46 km^2 (4.56 %) was classified as very low degree of vulnerability for malaria epidemic prone areas whereas class interval ranges from 44.5-53.6 of a total land area of 1566.36km^2 (61.33%) was considered as very high vulnerable for malaria transmission.

Table 5: Reclassified wetness index and area statistics

Class interval	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval
-1 – 7.5	Very low	1	116.46	4.56	-1 – 7.5
7.5 – 18.1	Low	2	616.53	24.14	7.5 – 18.1
18.1 – 26.7	Moderate	3	164.98	6.46	18.1 – 26.7
26.7 – 44.5	High	4	88.87	3.48	26.7 – 44.5
44.5 - 53.6	Very high	5	1566.36	61.33	44.5 - 53.6
		Total	2554	100	

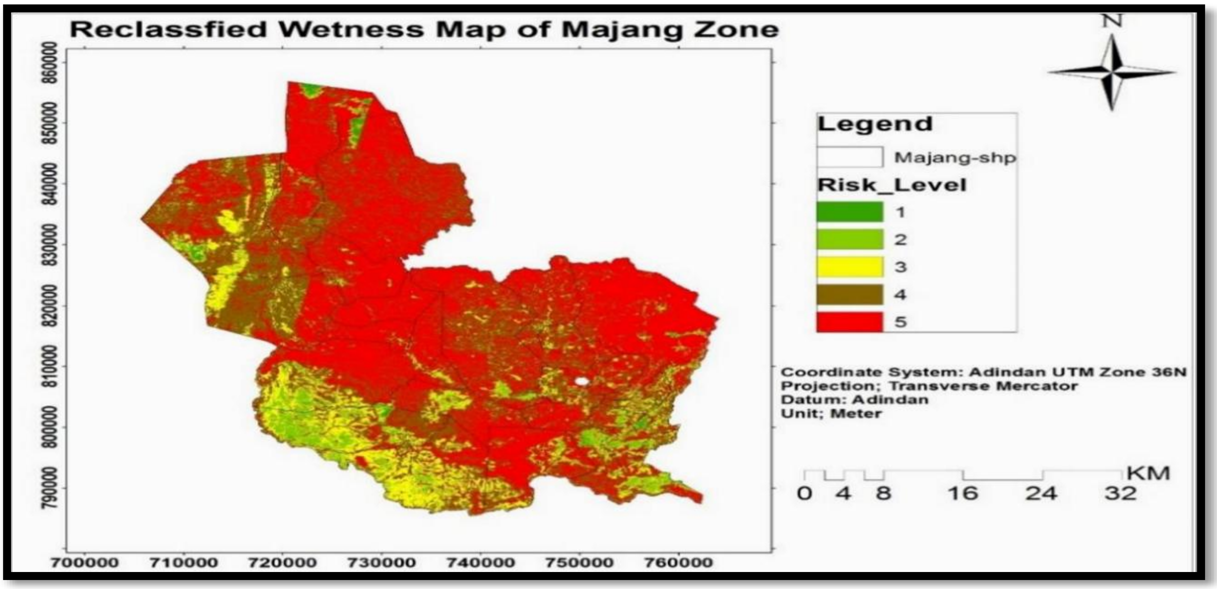

Figure 7: Wetness index Map of the Study Area

5.9. Rainfall

According to (Kumar et al.,2012) described that, rainfall is considered as the most important malaria triggering parameter and its spatial variation shows a heavy positive correlation with malaria incidence. Because high amount of rainfall causes flood; leads high amount of runoff which disturbs the breeding site of anopheles mosquito.

As indicated in table 3.10 below, rainfall class interval ranges from 126.96 – 134.14 mm which is covered a total land area of 367.26 km^2 (14.38%) was classified as very high vulnerable for malaria transmission. While rainfall class interval ranges from 152-159.1 mm representing a total area of 461.50 km^{2,} (18.07%) was considered as very low vulnerable for malaria risk in the case study area.

Table 6: Reclassified rainfall factor and area coverage

Class interval in(mm)	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval in (mm)
126.96 – 134.14	Very High	5	367.26	14.38	126.96 – 134.14
134.14 – 139.5	High	4	760.58	29.78	134.14 – 139.5
139.5 - 145.4	Moderate	3	541.70	21.21	139.5 - 145.4
145.4 - 152	Low	2	422.68	16.55	145.4 - 152
152 - 159.1	Very Low	1	461.50	18.07	152 - 159.1
Total			2554	100	

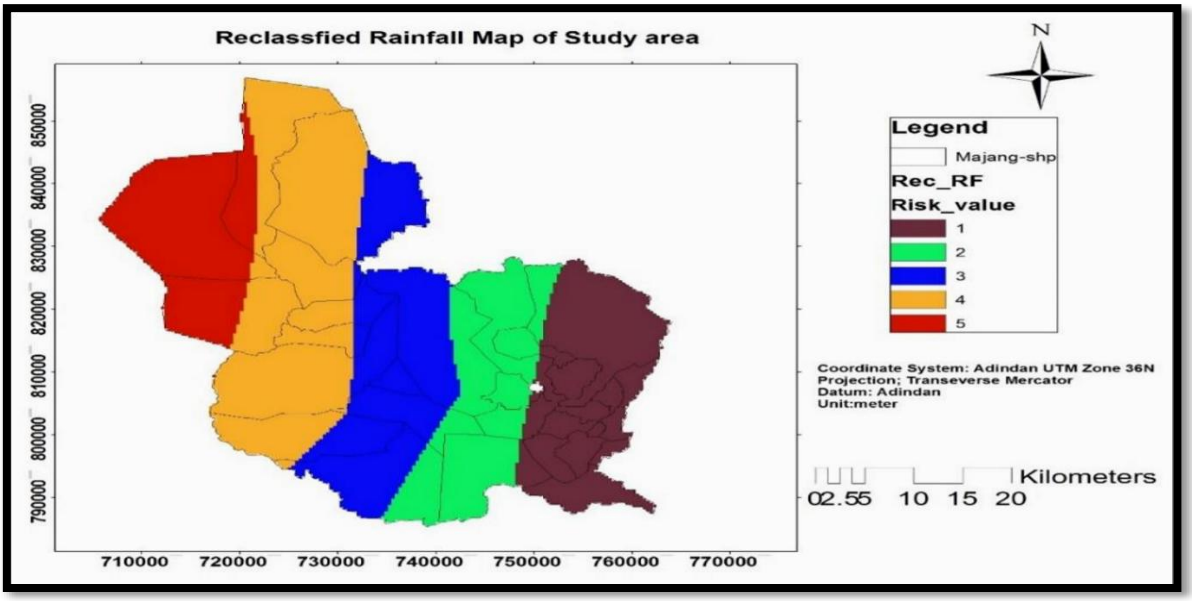

Figure 8: Reclassified Rainfall Map of the Study Area

5.11. Temperature

As stated in literature review temperature has significant influences on mosquito density, breeding and malaria transmission. Climate variability, specifically temperature has great impacts on incubation rate and breeding activity of certain species of mosquitoes and is considered as one of the key environmental contributors to mosquito propagation (Wilder, 2007). The development rate of immature mosquitoes is very much dependent on maximum temperature. As shown in the table 3.12, the average annual temperature of four consecutive years were collected, interpolated and reclassified in to five classes, which ranges from 24.7 up to 35.9 degree Celsius.

Table 7 below generated from interpolated temperature values from station indicates that, temperature class interval ranges from 24.7 – 27.6 ^{o}C and a total land area of 267.91 km^2 representing 10.49 % was subjected to very low vulnerability for malaria transmission and ranked one. However, a total land area of 478.61 km^2 (18.74 %) of class interval ranges from 32.7 – 35.9 ^{o}C was classified as very high vulnerable for malaria transmission in the case study area (Majang Zone) and ranked five.

Table 7: Reclassified temperature factor and area coverage

Class interval in °c	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval in °c
24.7 – 27.6	Very low	1	267.91	10.49	24.7 – 27.6
27.6 – 29.6	Low	2	329.72	12.91	27.6 – 29.6
29.6 – 31.2	Moderate	3	583.84	22.86	29.6 – 31.2
31.2 – 32.7	High	4	893.38	34.98	31.2 – 32.7
32.7 – 35.9	Very high	5	478.61	18.74	32.7 – 35.9
		Total	2554	100	

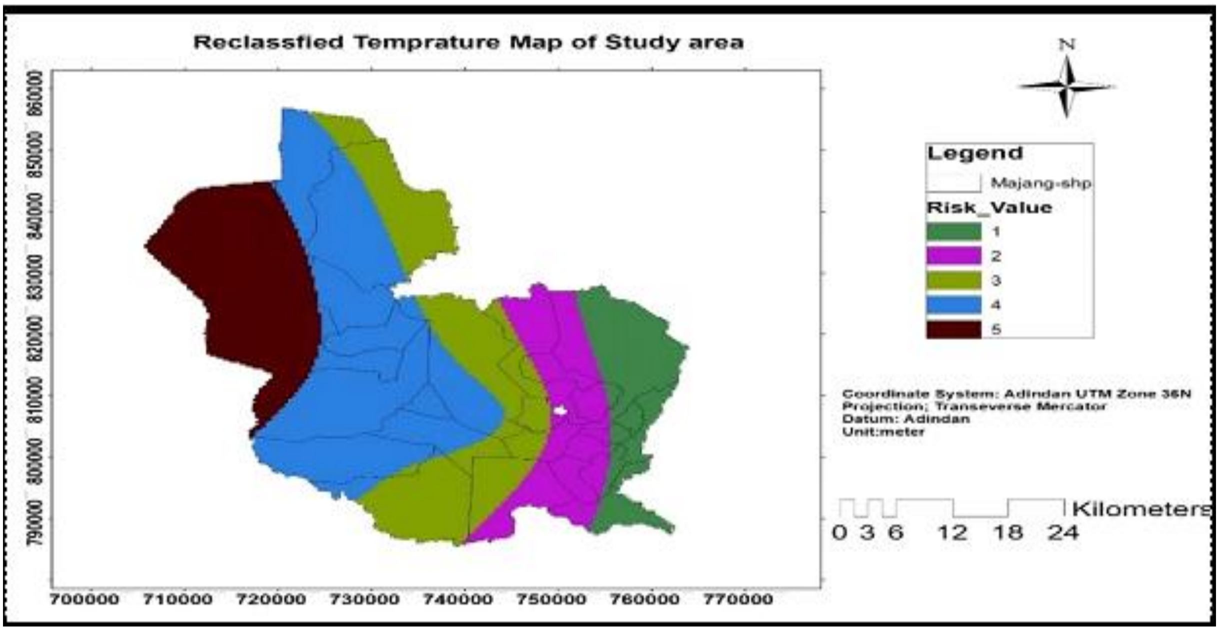

Figure 9: Reclassified Temperature Map of the Study Area

5. 13. Drainage

Drainage may affect availability of the aquatic habitat and was calculated as the distance from a grid cell moving downstream to a stream grid cell defined by the Stream Raster grid. The advantage of using flow distance to-stream rather than simple distance-to-stream is that flow distance takes flow direction and landscape profile into consideration (Stephen, 2000). The Flow distance to stream (drainage pattern) raster layer was generated from the DEM of Majang zone using (terrain analysis using Digital Elevation Model) specialized grid analysis/Flow Distance to Stream module. Taking need of the maximum flying distance of anopheles' mosquito from the distance to stream is 2 km as a basis for reclassification distance to the stream layer.

Accordingly, buffer distance less than 500m from drainage representing 819.83 km^2 (32.10%) was identified very high vulnerable in the study area. Class interval ranges from 2000-2500m buffer distance which is covered a total land area of 411.70 km^2 (16.12%) was classified as very low vulnerable for malaria epidemic prone area in the case study area.

Table 8: Reclassified drainage factor and area coverage

Class interval in (m)	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval in(m)
0 – 500	Very high	5	819.83	32.10	0 – 500
500 – 1000	High	4	718.44	28.13	500 – 1000
1000 – 1500	Moderate	3	603.51	23.63	1000 – 1500
1500 – 2000	Low	2	509.01	19.93	1500 – 2000
2000 – 2500	Very low	1	411.70	16.12	2000 – 2500
		Total	2554	100	

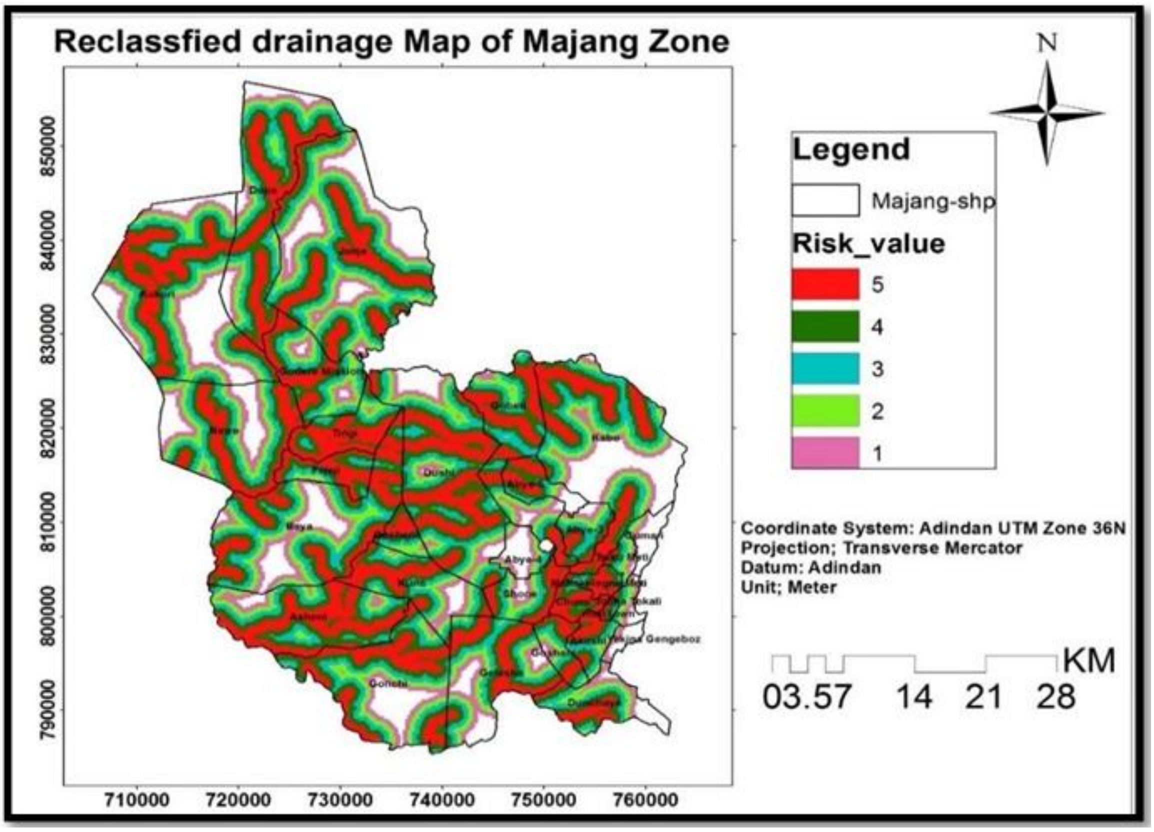

Figure 10: Reclassified Drainage Map of the Study Area

API class interval less than 500 which is covered a total land area of 683.45 km^2 (26.76%) was classified as very low for malaria transmission whereas class interval ranges from 200-2500 of a total land area 343.25 km^2 (13.44%) was considered as very high for malaria epidemic prone area.

Table 9: Reclassified API and area coverage

Class interval	Degree of vulnerability	Ranking	Area in km^2	percentage	Class interval
0 – 500	Very low	1	683.45	26.76	0 – 500
500 – 1000	Low	2	599.16	23.46	500 – 1000
1000 – 1500	Moderate	3	503.39	19.71	1000 – 1500
1500 – 2000	High	4	424.47	16.62	1500 – 2000
2000 – 2500	Very high	5	343.25	13.44	2000 – 2500
		Total	2554	100	

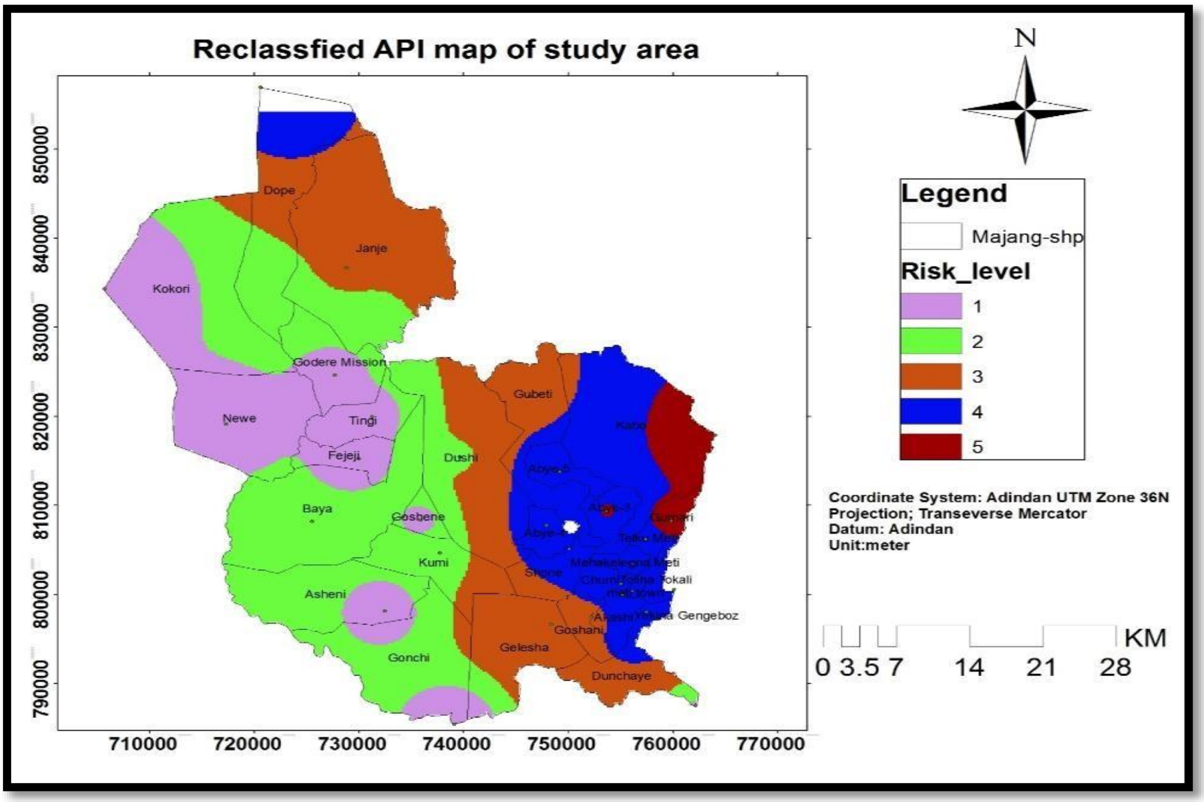

Figure 11: Reclassified API Map of the Study Area

5.15. Malaria Risk Map

Various environmental and socioeconomic parameters are interrelated and influence the possibility of malaria outbreak (Ahmed, A. 2014). All such environmental parameters were incorporated in the present study to delineate areas suitable for mosquito growth. The result obtained was classified into four-malaria hotspot rating:

Very high: most part of the areas was found to be in Godere woreda of majang zone. From Godere woreda: Meti Town, centeral parts of Dunchay, Mehakelegna Meti, Southern & Northern part of Kabo, North western part of Tolina Tokali, Eastern part of Chumi and Eastern part of Akashi. This part of the study area highly dominated by Crowded population pattern comparative to High and moderate risk areas, high amount of API was recorded, high wetness, high rainfall with lot of perennial streams with gentle slope and moderate to low elevation provide most conducive environment for grow of malaria parasite. Mengesh woreda 4 kebeles were included such as; parts of Abiye 5, Abiye 3, Dope and Southwestern part of Asheni. An area in very high risk surrounds 16.8% of total area amounting to 429.07 km^2.

High: The area was dominated with little bit sparse population covered with dense to medium forest, moderate wetness, medium rainfall with streams with moderate to gentle slope and high to low elevation provides moderate favorable conditions for the parasite growth and accounted for 42.3% of total area (1080.34 km^2). Majority of area found in mengesh woreda such as Gubeti, and Northern parts of Kokori.

Moderate: This area covered with Dense to open forest, moderate wetness, low to moderate rainfall, high to moderate slope and moderate to high elevation provides moderate favorable condition for the parasite growth. Parts of kebele from mengesh woreda, which fall in this category, are; Northwestern and Southeastern part of Janjie, Centeral part of Kumi, Godere mission, Gonchi, Tingi and Baya. This category accounts for 27.6% of total area (704.90 km^2).

Low: Low priority areas were found to be more in north to central part of the study area (concentration is more in the north-west) with low population in general and low to sparse population. It is covered with open forest to dense forest, low wetness, low rainfall, high slope and high elevation, which provides less favorable condition for the malaria parasite to grow. Kebeles fall in this category are: Central parts of (Kabo, Kumi, Gonchi, Baya,Janjie), Southern part of Kokori, Northern Part of Newe, Gumari, yekina Gongeboz. It accounts for 13.3% of total area (339.68 km^2).

Table 10: Malaria hotspot rating of study area with area statistics

Malaria hotspot rating	Area in km^2	Area in %
Very high	429.07	16.8
High	1080.34	42.3
Moderate	704.90	27.6
Low	339.68	13.3
Total	2554	100

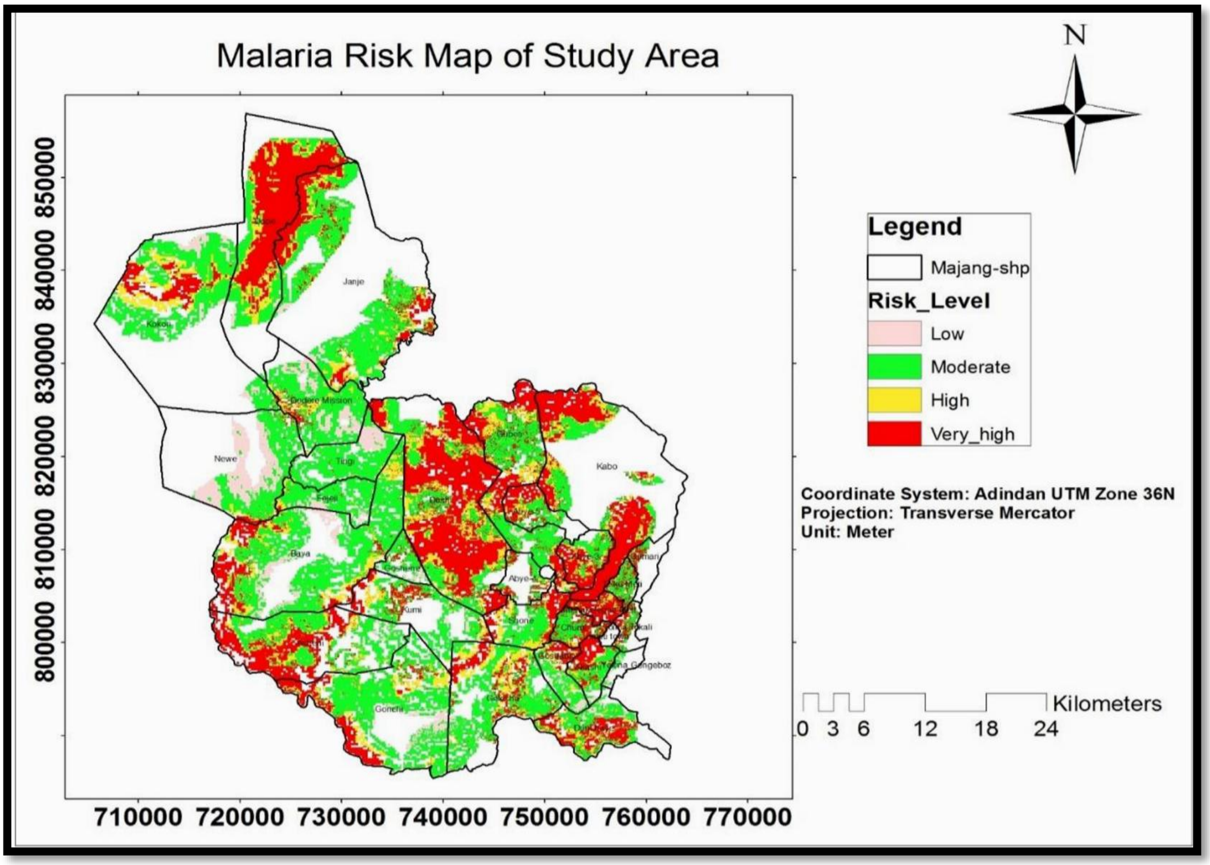

Figure 12: Malaria Risk Map of the Study Area

VI. CONCLUSION

According to the result of the findings and assessment made in some selected kebeles after the completion of project, large area of the zone is found on risk area for malaria. In this study pair wise comparison method of malaria hazard map generation is a good approach to deduce a sound decision for a future malaria disaster. This research justified that by combining GIS with Multi-criteria Evaluation was capable to integrate all the malaria hazard causative factors and the components of malaria risk as well. One of the Multi Criteria Evaluation techniques, which were known as Weighted Overlay and Weighted sum in GIS environment, was shown to be useful for delineating areas at different rating in terms of malaria hazard and malaria risk. Moreover, Assigning weights and its computation in AHP module, that is developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated, has generated valuable information.

Three parameters (environmental, socio economic and epidemiological parameters) were used to generate malaria epidemic prone areas (hotspot) map of the study area. Environmental parameters include wetness, elevation, drainage buffer, slope, aspect, land use land cover, temperature, rainfall data and water body buffer while socio economic parameters were categorized population and proximity to hospital. Maps were generated for all factors and then reclassified based on their vulnerability for mosquito breeding and malaria incidence. Depending on the influence of factors, weight was computed by using pairwise comparison matrix using IDRISI32 software. Then weighted overlay was undertaken to produce the final malaria risk map. The final malaria risk map of the study area shows that from the total area, 16.8 % was mapped in very high, 42.3%

in high, 27.6% in moderate and 13.3 % in low level of malaria risk. The majority of study area fall in high risk level (42.3 %) which is followed by moderate risk level (27.6%).

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