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Malaria prone area analysis and mapping using geospatial tools: The case of Amibara and Gewane Woreda, afar region, Ethiopia

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Malaria is one of the most killer diseases in our planet earth. It is the primary cause of patient talks, admissions and demise every year in Ethiopia. It is important to reduce the transmission and effects of the problem identifying and mapping the malaria risk area using geospatial technologies. The general objective of the study is to analyze and map malaria prone areas using geospatial tools in Amibara and Gewanie Woredas of Afar Region. The specific objectives are to identify parameters that contribute to malaria hazard in the study area and to classify and map areas at risk of malaria. To achieve the stated objectives, the researchers employed spatial modeling technique particularly Weighted Overlay Analysis (WOA). Climatic data, topographical data and infrastructural data are the major data of the study. These data were processed and analyzed by ArcGIS, Erdas imagine, Idrisi, 3DEM terrain visualization and global mapper software. The result showed that the area is suitable moderately and marginally for malaria. From the total area of the study, 35 and 65% were moderately and marginally suitable for the occurrence of malaria respectively. Therefore, as malaria is one of the killer diseases the concerned bodies should use the technologies to prevent and control the transmission of malaria in the study area and there should be health package to prevent the diseases.

Key words: Malaria mapping, geospatial tools.

INTRODUCTION

Background and justification of the study

Malaria is one vector borne diseases that affect huge number of people in the world. Globally, in 2011 there were 243 million estimated cases of malaria disease. The vast common cases stayed in African Region with 85%, tailed by the South-East Asia with 10% and Eastern Mediterranean Regions 4% (WHO, 2016). Malaria is the 5th leading source of passing from infectious diseases in low-income countries and a worldwide community health

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problem. The public showed signs of malaria from one to two weeks later being chomped by an infected mosquito In Ethiopia, it remains the main public health problems; every year it is the foremost origin of outpatient discussions, charges and death. In most parts of the country its occurrence is seasonal, with uneven spread which advances it to the outbreak of epidemics. According to many researchers including FMOH (2013a) report, the broadcast patterns and strength vary significantly due to the large multiplicity in altitude, rainfall, and population movement within the areas below 2,000 m. Those areas are home to nearly 68% (52 million) of the country's population and conceal almost 75% of the landmass. In 2015, malaria was still the first leading cause of health problem accounting for 48% of outpatient consultation, 20% admissions and 24.9% inpatient deaths. The influence of malaria, in addition to its health, concerns a noteworthy barrier to communal and fiscal growth of the country. The disease causes debilitating damage to work force, reduction of income as well as school absenteeism for both the sick and family members who serve as care takers (FMOH, 2013b).

The transmission and spatial spreading of malaria in Ethiopia is mostly determined by the various eco-climatic settings. The most important climatic features that influence malaria transmission are temperature, rainfall, and humidity along with altitude, which is the most important variable. The chief malaria broadcast period in the country is from September to December, succeeding to the main rainy season from June/ July to September (FMOH, 2013a,b). As part of Ethiopia, Afar region is an area where malaria affects the lives and livelihoods of the pastoral and agro-pastoral communities. The problem is aggravated due to the various characteristics of the area. The temperature of Amibara and Gewanie woredas is favorable for the occurrence of malaria.

According to Amibara and Gewane Health Office (2015) malaria was the top disease responsible for high morbidity and mortality in the Woreda. Seasonal rain, over flow of Awash River during high rainy season, impounded water and geographic location which is typical for the breeding of mosquito contributed a lot to the prevalence of malaria. Presence of large and small scale irrigation schemes and presence of swampy area favor breeding of mosquito which will aggravate malaria prevalence in the area. Severity of malaria increases at the rainy seasons putting higher pressure on the activity of the local people whose livelihood is totally dependent on crop production and livestock rearing. It reduces labor, time for on farm follow up, livestock supervision and children school attendance.

Numerous studies used satellite imagery and GIS techniques to plot the scattering of vector species in diverse spatial scales such as the entire world, continent, national, regional, and even at small village level.

According to Gujju et al. (2017), in widespread areas, mostly in tropical and subtropical regions, this vector plotting is designed to improve vector control. As this study showed, remote sensing and geographic information system (GIS) are used to plot the dissemination of vectors at different spatial scale. Therefore, this study was able to identify and map the malaria risk areas by considering many geographical and environmental factors that make condition suitable for breeding site of mosquito in the study areas.

Climatic and topographic issues, particularly precipitation, temperature, altitude, and slope remain recognized to have a resilient effect on the ecology of this insect. GIS and remote sensing can be used to associate such variables with the dissemination of mosquito which is accountable for malaria. Therefore, GIS and remote sensing are the appropriate tools that aid malaria control and prevention system through assessing potential malaria risk level of an area (Karen et al., 2015).

Objectives of the study

General objectives

The overall objective of the study is to analyze and develop map of malaria prone areas using Geospatial tools in Amibara and Gewanie Woredas of Afara Regional State, Northeast Ethiopia.

Specific objectives

(1) To identify the parameters that contributes to malaria hazard in the study area
(2) To classify and map areas at risk of malaria in Amibara and Gewanie areas
(3) To evaluate the suitability of an area for the occurrence of malaria.

LITERATURE REVIEW

Theory of malaria

In prehistoric Rome, as a moderate climate, mosquitos are seen in marshes and swamplands. People accused the unhealthiness in the parts of deterioration and decay that wafted out on the foul air. Hereafter, the name is derived from the Italian word, "malaria," or bad air. In 1880, inventors revealed that the real cause of malaria is this climatic condition. The naked organism is transmitted from person to person through the bite of a female Anopheles mosquito, which necessitates blood to nurture eggs. There are around 400 dissimilar species of Anopheles mosquitoes throughout the world, but only 60 of these are vectors of malaria under natural conditions,

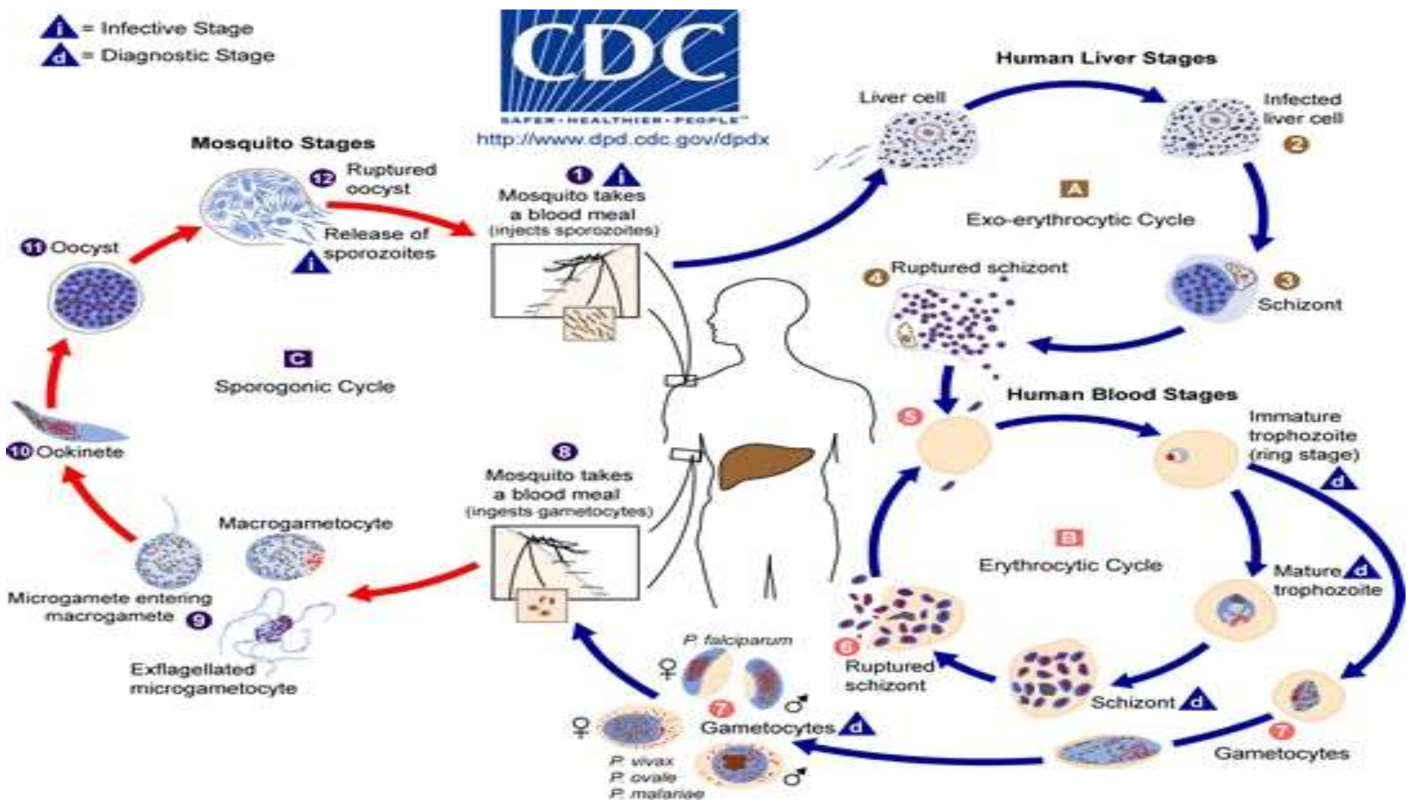

Figure 1. Stages of anopheles mosquito.
Source: Hubs for disease control and prevention, malaria life cycle (Grace, 2011).

and only 30 are vectors of major importance (Sivani, 2010; Abdulhakim, 2014) (Figure 1).

Global distribution of malaria

Regular decisive features of mosquitoes and their vector-borne diseases remain establish throughout the world, except in areas that are always frozen over. Roughly 75% of all mosquito species exist in in the world's steamy and subtropical regions (Gujju et al., 2017).

Causes of malaria

Malaria is introduced by a single-celled parasite from the genus *Plasmodium*. They yield malaria in various types of faunas and birdies, as well as in humans. The four *Plasmodium* species that contaminate persons are *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale and Plasmodium malaria*. Every bloodsucker has a unique presence under the optical microscope, and creates a different form of indications. *P. falciparum* is accountable for maximum malaria deaths, particularly in Africa. A person that is asymptomatic (no symptoms) for *Plasmodium malaria* can poison others, either through lifeblood gift or mosquito bites (WHO, 2016).

Factors determining the occurrence of malaria

Climatic factors

Climatic differences and extreme weather events have a reflective influence on infectious disease. Among the features studied, temperature and rainfall have a sturdiest association with malaria occurrence. Temperature, elevation and rainfall pattern remain easy to forecast and analyze malaria. The minimum threshold temperatures for organism growth of *P. falciparum* and P. *vivax* are 18 and 15°C, respectively (Sadie et al., 2015).

Terrain factors

Topographic factors are largely altitude, slope, and aspect. The way topographic issues impact vector-borne disease reclined through providing confident habitats appropriate for certain vectors. For example, grass land, is appropriate for mice, vector of plague, and whereas wetlands are fit for snails and mosquitoes. Topographic patterns affect the spatial distribution of mosquitoes and susceptibility level of human immune system (Mahmoud et al., 2017; Gómez-Barroso et al., 2017).

Anthropogenic factors

Communicable diseases, like malaria, can appear from natural or human made changes to the environment. Outside the regular environmental causes, anthropogenic factors can impact the spreading of the disease by directly adjusting the behavior and geographical dissemination of the anopheles mosquitoes. Before the past two centuries, anthropogenic aspects like agriculture, irrigation, increase in population size, migration, and war have all influenced the spatial circulation pattern of malaria (Gómez-Barroso et al., 2017).

The role of remote sensing and GIS on malaria risk mapping

In the Global Malaria Eradication Programme "geographical reconnaissance" entailed the detailed and manual mapping of malaria vector breeding places unaided by computers implementation and monitoring operations. Since then, spatial technology has advanced greatly in parallel with progress in information technology to the extent that it is now possible to capture and manipulate an array of complex spatial information with relative ease and in real time (Saxena et al., 2009; Abiodun et al., 2015). The relevance of GIS technologies to malaria control lies in the fact that the global spectrum of malaria epidemiology is broad, and varies as the natural diversity of the parasite. The disease varies in its prevalence, intensity, seasonality and clinical features depending on a multitude of local determinants such as the prevalence, location and nature of water bodies. These in turn are affected by environmental factors such as climate, surface water distribution, elevation and prevailing flora and fauna in the area. Therefore, geographical, climatological and landscape aspects of a locality become significant factors of malaria distribution. However, with GIS tools it is possible to overlay accurate spatial maps of an area to examine the relationship between the parameters and aggregating them in order to enable new and critical insights to be made to the disease and its transmission localities (Abiodun et al., 2015; Gómez-Barroso et al., 2017). Plotting the worldwide spreading of malaria is inspired to outline populations at risk for fitting resource allocation to fight the disease. Currently, managing malaria is easier with the support of the malaria risk maps representing hot areas with threat factors. Generally, integration of geospatial tools with remote sensing imageries helps in the identification, depiction, observation and investigation of breeding habitats and mapping of malaria risk areas (Karen et al., 2015; Sadie et al., 2015).

Description and research method of the study

Description of the study area

The study was investigated in Amibara and Gewane woreda's of Middle Awash River in Afar National Regional State of Ethiopia. The area is found between 08°49'00" and 140°30' 00''N latitude and 39°34' 00" and 42°28' 00" E longitude. Geographic location of the study is seen in Figure 2.

Geographical setting

The study area is found in the middle awash valleys, where sugarcane and cotton farmstead have been proven by the government of Ethiopia. It is characterized by high temperature, from 25 to 35°C. Typically, the mean annual rainfall is less than 600 mm whereas May and June is the driest period of the year. The highest raining season accounts for 60% of the yearly total rainfall from July to September whereas slight rainy season appears in March and April which account for 20% of the total rain fall. From the total land area of the region, 826,573 ha and 294,106 ha areas are covered by Gewane and Amibara woreda respectively. Similarly from the total state plantation in the region, the study area constitutes 10, 608 ha of land, which is about 18% of the total state plantations in the region.

Vegetation types

The woods and bush vegetation type was found along the major perennial rivers. Gewane woreda constitutes riverine bush land. It is evergreen due to continuous water supply from the Awash River and browsed by the livestock during the dry season. Grazing and browsing of livestock in Amibara woreda is bush land. The study area covers a total of 64,087 ha, which is about 68% of the total open bush land cover in the region.

Population statistics

According to CSA (2008), the population of the region is 1,406, 383 of which 745, 839 are males and 661, 544 are females. Similarly, Amibara has a total population of 40,175 and Gewane has a population of 28,144.

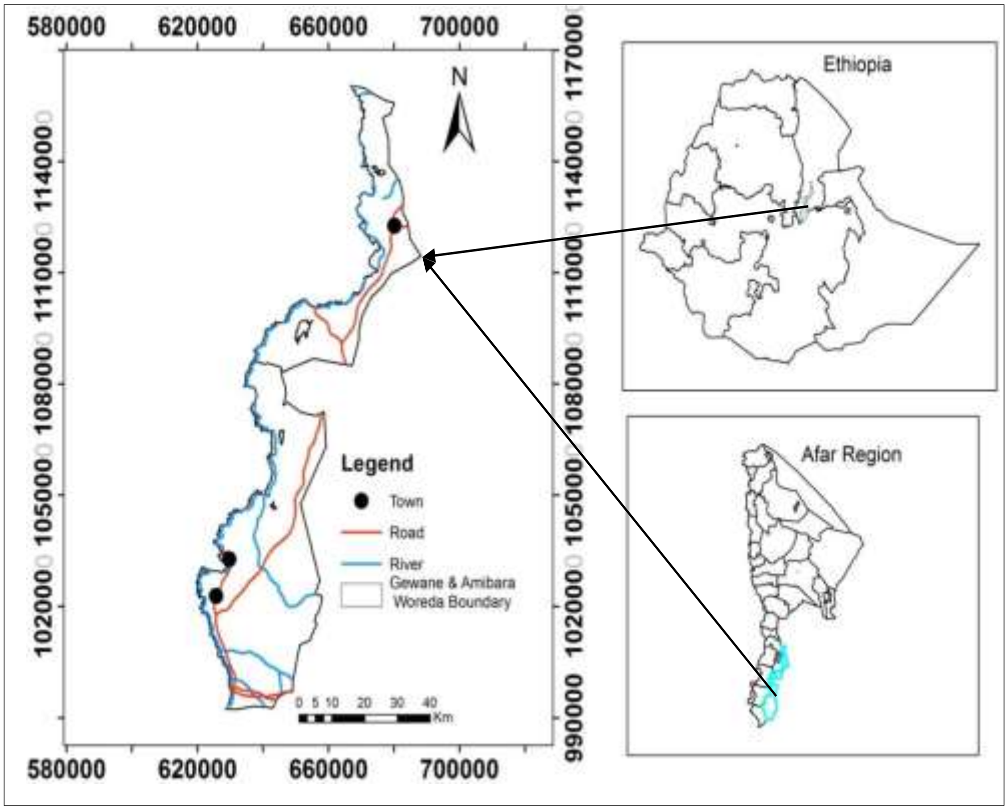

Figure 2. Study area map of Gewane and Amibara Woreda.

Socio- economic infrastructure development

Education

According to ANRSEB (2016), the schooling facilities in the state are normally insufficient and unevenly dispersed among zones. The majority of the straightforward schools and all of the senior secondary schools are located in zones 1 and 3. However, the participation level of the people is very minimal.

Health services

A health facility existing in the area is low in the country. There are 49 health posts, and 2 hospitals with 65 beds in the region. However, the supply of health facility in the region is not justifiable.

METHODOLOGY

Methods of data processing and analysis

The study used both remote sensing data and geospatial tools to process and analyze the parameters of the study. ArcGIS10.3, Erdas Imagine 14, DEM, Global Mapper and Idrisi32 tools are used. The final method of the data analysis used for the accomplishment of the research was weighted overlay analysis (WOA). However, factors ready for final overlay processing were applied. Before WOA application, reclassification and weight derivation were the main steps. Mathematically, the WOA used the summation of criterion cell values multiplied by their respective weight or percent of influence. The process is illustrated in detail in Figure 3.

RESULTS AND DISCUSSION

Factors of malaria risk

Different reasons exposed people to malaria. The spread of malaria varies due to temperature, river or water availability, elevation and slope. The criteria considered in this research are climate related (Rainfall and Temperature) and topographic related (elevation and slope). The maps of all parameters remained an input data for producing the final malaria risk maps of the study. Therefore, initial stage of the analysis was preparation of each criterion maps. Then the criteria were reclassified into three classes to map the most risk areas to the transmission of malaria.

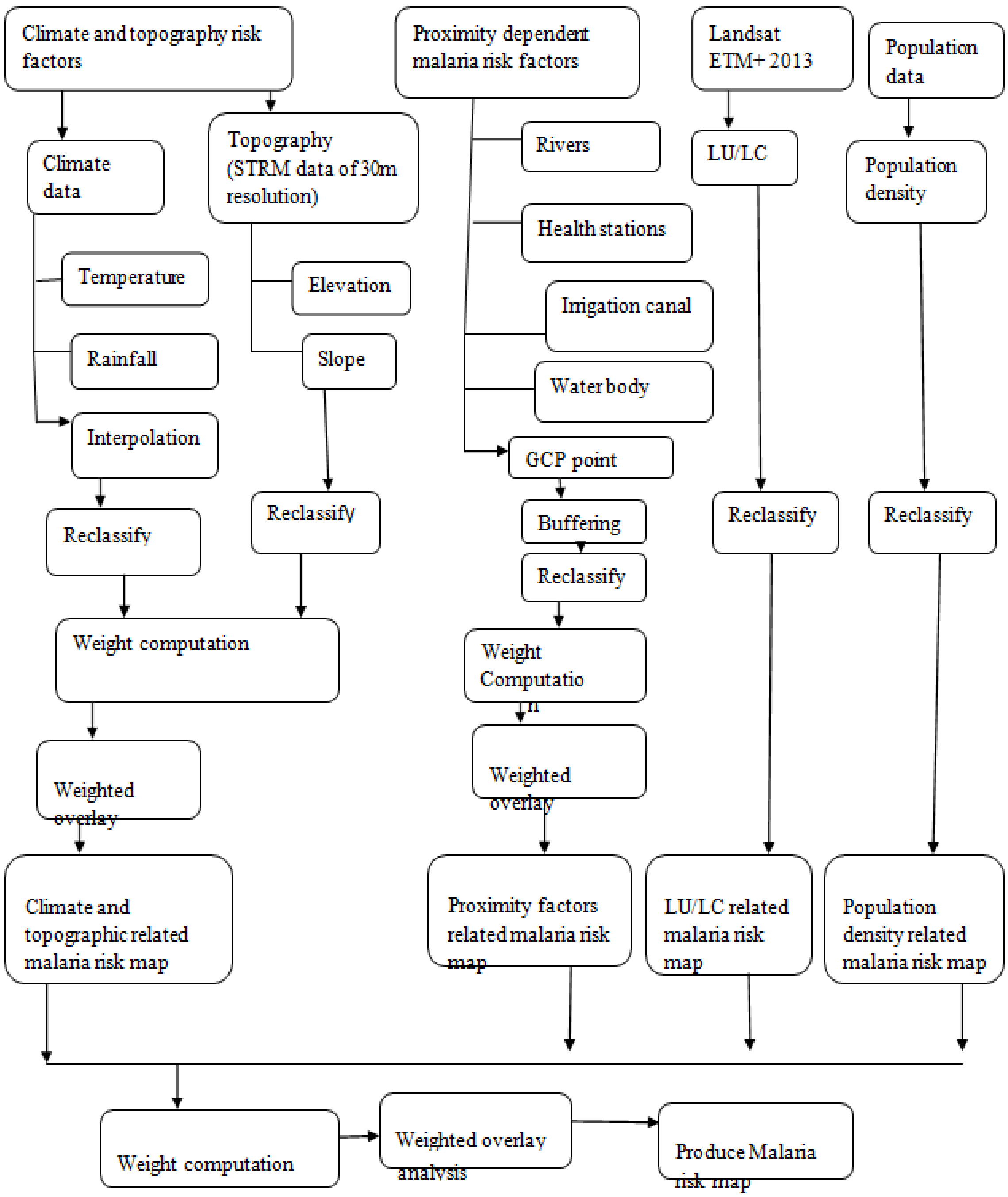

Figure 3. Work flow of the study.

Climate related risk of malaria

Climatic data of the study area were produced from gridded meteorological data. The gridded meteorological data are better than the interpolated meteorological data. This is because the gridded data are calibrated by the truth station and satellite data to reduce error.

Temperature related risk of malaria

The parasite plasmodium does not survive well below 15°C and in this case, it cannot transmit the disease due to dormancy of the parasite. As the temperature increases above 15°C up to 20°C the parasite starts to multiply slowly. Mosquito and plasmodium parasite starts

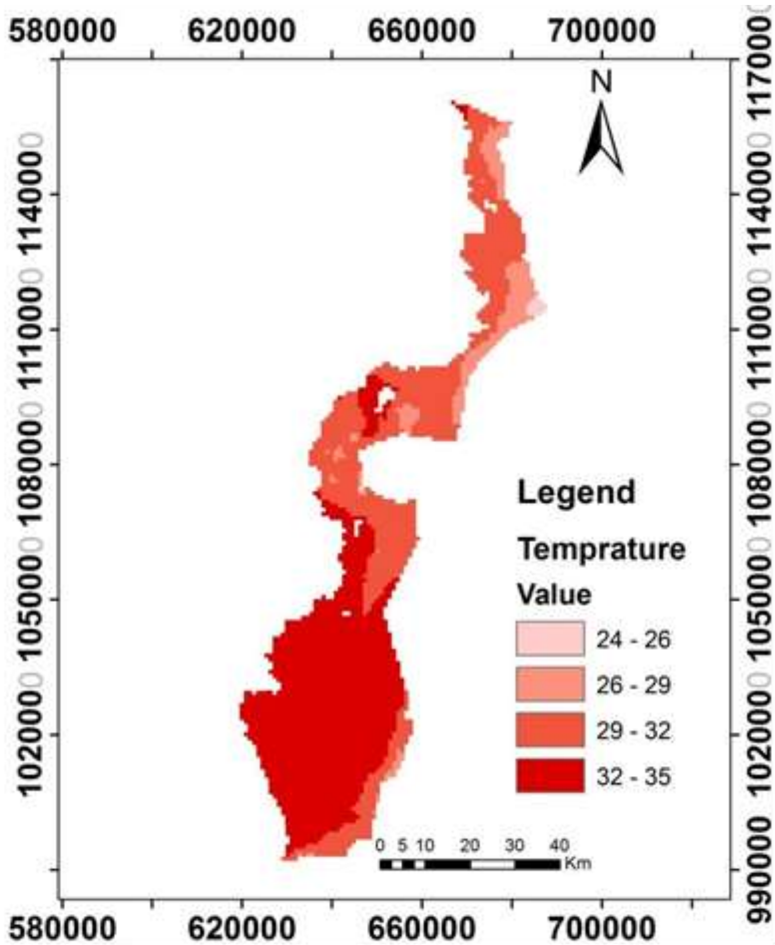

Figure 4. Temperature map of the study area.

to multiply at moderate, high and very high rate at 20 to 23°C, 23 to 25°C and 25 to 27°C respectively. However, as the temperature increases further, mosquito and parasite development starts to decline. Similarly, temperature values of 27 to 32°C and >32°C were associated with temperature related malaria risk levels of high and low respectively. As described in Figure 4, the temperature of the study area was from 25 to 35°C. These indicated that in the area there was malaria existence.

Rainfall related risk of malaria

Water bodies from rainfall, canals, rivers and other sources are important for mosquito to lay their eggs for breeding. Therefore, areas with high source of water are more suitable for mosquito breeding and the areas are under suitable condition. Even though an increase in temperature and rainfall increase mosquito breeding, it should be known that this is up to some maximum limit beyond which the relationship could be reversed. High rainfall destroys mosquito larvae from its stable habit. Accordingly, rainfall amounts of < 550, 550 to 700 mm and 700 to 1000 mm, respectively were seen (Figure 5).

Topography related risk of malaria

Topography of an area determines the elevation and slope of a particular area. This is turn determines the type of biological organisms and physical characteristics prevailing in that particular area. It also determines the prevailing microclimate. These factors together are helpful indicators for diseases causing vectors are prevailing in the area based on their natural requirement for their existence.

Elevation related risk of malaria

Elevation of the study area is derived from STRM data of

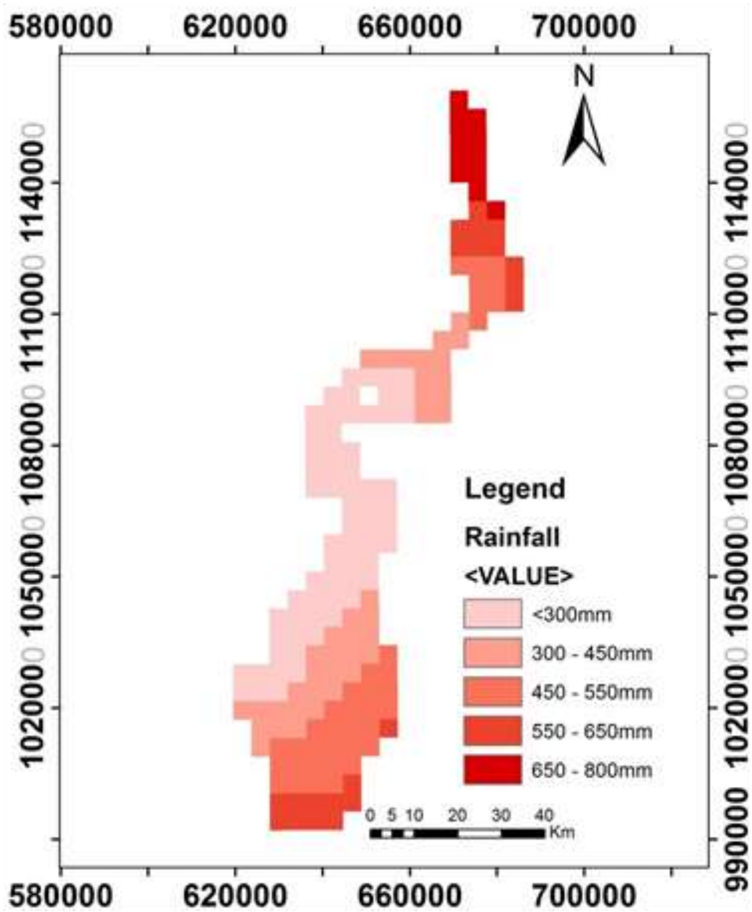

Figure 5. Rainfall map of the study area.

30m resolution. This is classified into four classes of 700 to 850m, 850 to 1000 m and 1000 to 1500 m above sea level. An elevation from 1000 to 1500 m was a safe area for malaria whereas in an area above 1500m it was decreasing (Figure 6).

Slop related risk of malaria

Slope of an area describes the relative verticality of a particular area. Area with higher slope is usually a typical characteristics of fragile, mountainous, and unstable physical area of the earth. This affects mosquito breeding in two ways: It does not support varieties of vegetation and animal population so that there could be low factors to favor mosquito breeding.

Secondly, unstable slope does not hold water at a particular place. But mosquitoes need still water to lay their eggs and progress to the next development cycle. Therefore, plain and gentle slopes favor mosquito breeding than sloppy areas. According to FAO (1976) and malaria experts of the study area, slope classes 0 to 5%, 5 to 8%, 8 to 15%, 15 to 30% and >30% are the appropriate classes to indicate the level of existence of watery body or marshy area and vegetation within a particular area. Accordingly, areas with 0 to 5% slopes have high probability to have water bodies and marshy areas and vegetation whereas as the slope increases this starts to decline. Therefore, areas with low and high slope classes are with high and low slope related malaria risk levels respectively. Based on this fact, slope classes 0 to 5%, 5 to 8%, 8 to 15%, 15 to 30% and >30% were seen associated with slope malaria risk levels of very high, high, medium, low and very low suitable respectively. The result showed that the area has a slope of 0 to 15% (Figure 7).

Reclassification of climatic factors

To know the suitability of an area for mosquito in terms of temperature, reclassification of the temperature values

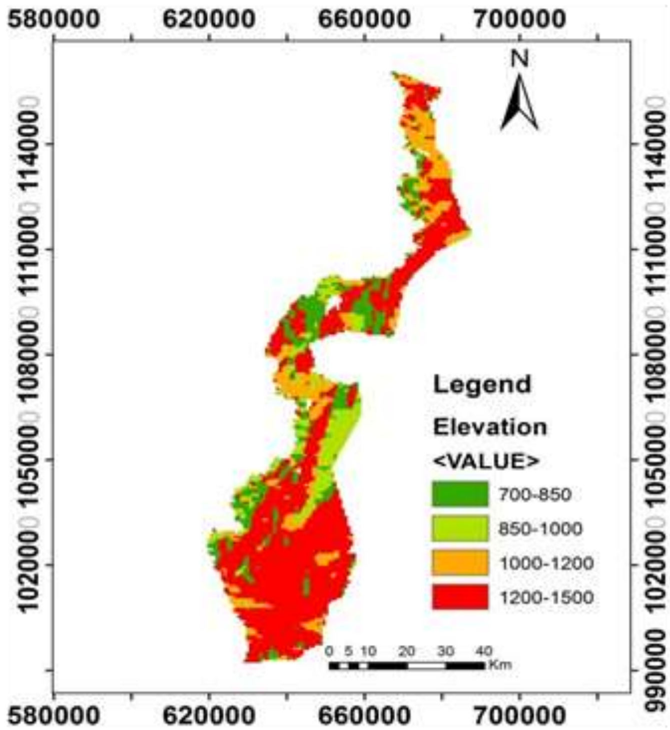

Figure 6. Elevation map of the study area.

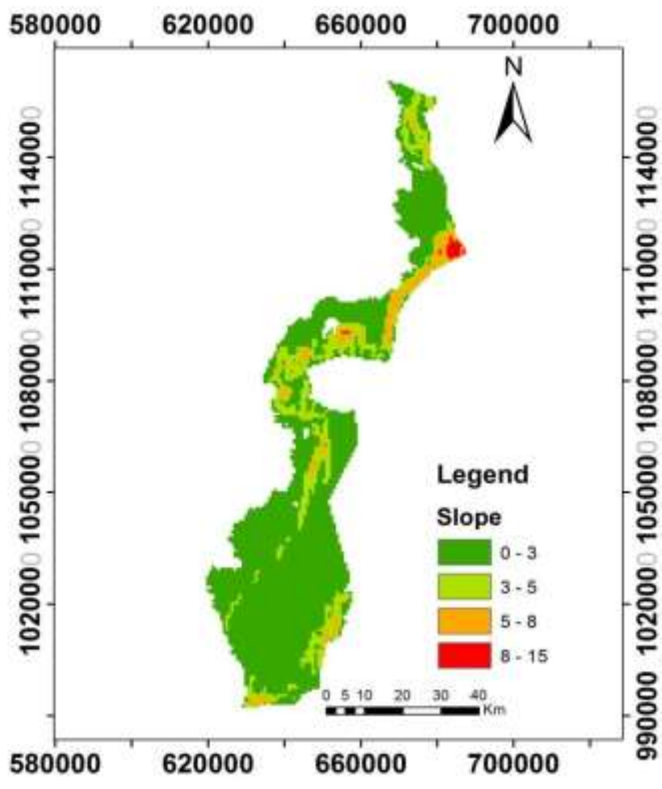

Figure 7. Slope map of the study area.

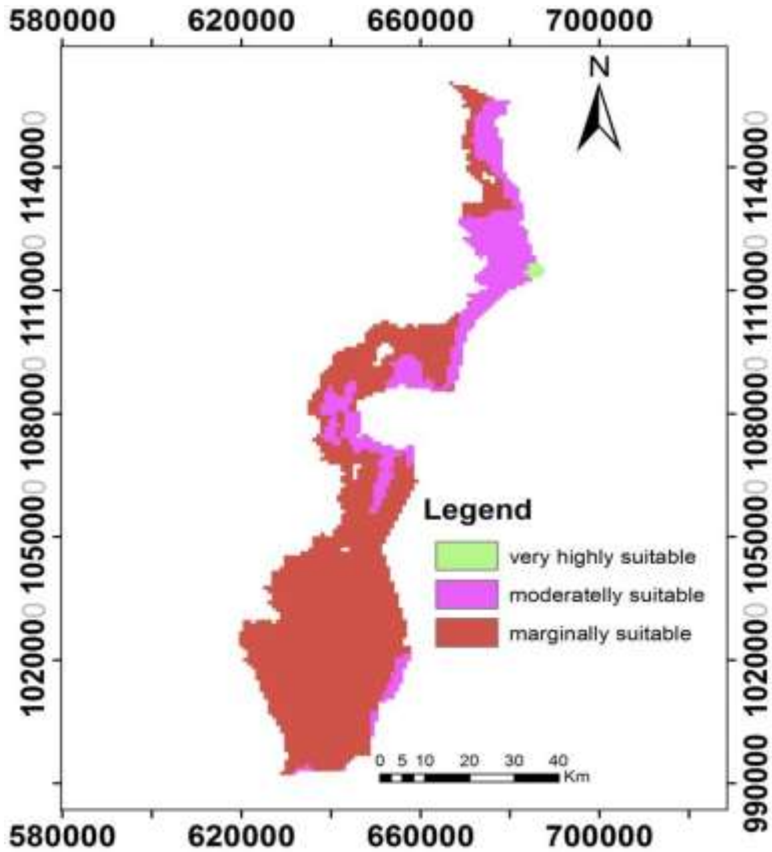

Figure 8. Reclassification of temperature map.

based on internationally recognized standards would be done (Figure 8). Figure 8 showed that most parts of the study area are marginally and moderately suitable whereas very small part of the area is very highly suitable for malaria in terms of temperature only. The temperature of the study area is very hot and difficult to duplicate themselves (Figure 9). Figure 9 illustrates that most of the areas are marginally and moderately appropriate for malaria production in terms of rainfall. The malaria reproduces itself in the area by the water comes from highland areas through flood in the area.

Reclassification of topographic factors

The area is moderately and highly suitable for malaria reproduction in terms of elevation point of view (Figures 10 and 11).

Proximity related malaria risk factors

Distance from rivers

Breeding of mosquito is related with different water sources. River is one among several of these. Mosquito requires still or slow moving water to lay its eggs and to complete its life cycle to be an adult. But river is not conducive for this since it disturbs and destroys the eggs and larvae during its movement with pressure in need of its stability. Water diverted from rivers for different purposes and in case of over flow becomes still and favors mosquito egg lying. This influences the particular area with increased mosquito breeding and malaria prevalence (Figure 12). Malaria risk availability of the area decreases as we go far from the rivers or water bodies since the existence of water body accelerates the reproduction of malaria in the area. This is shown in Figure 13.

Weighted overlay analysis

Malaria risk map of the study area illustrated in Figure 12 described that there is no malaria free in the area. The majority of the study areas fell in the marginal (65%) risk level. Moderate risk level covered about 35% of the study area. However, a small shift in one or more factors could lead from moderate to marginal malaria risk level.

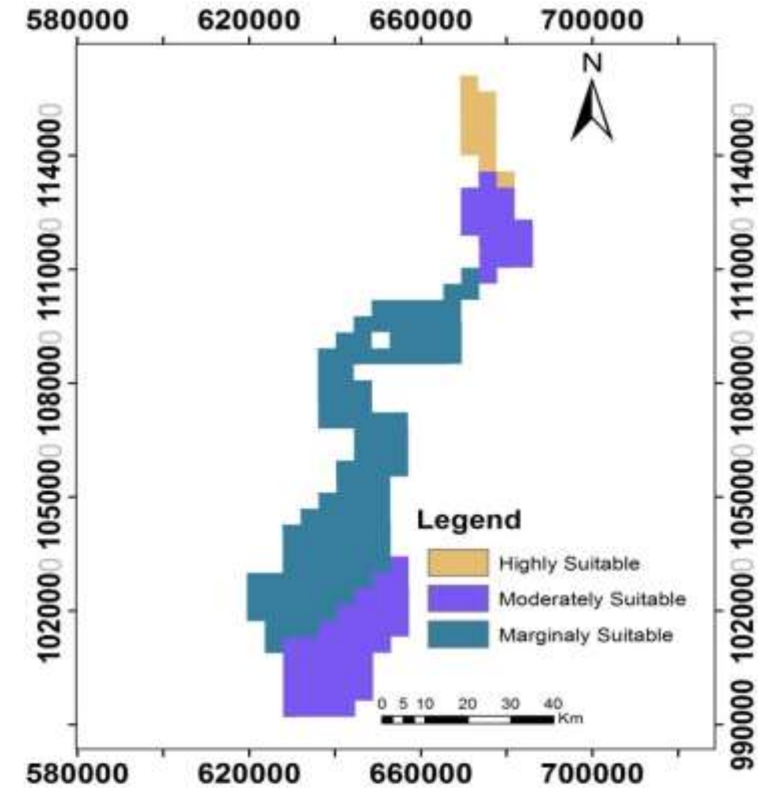

Figure 9. Reclassification of rainfall map.

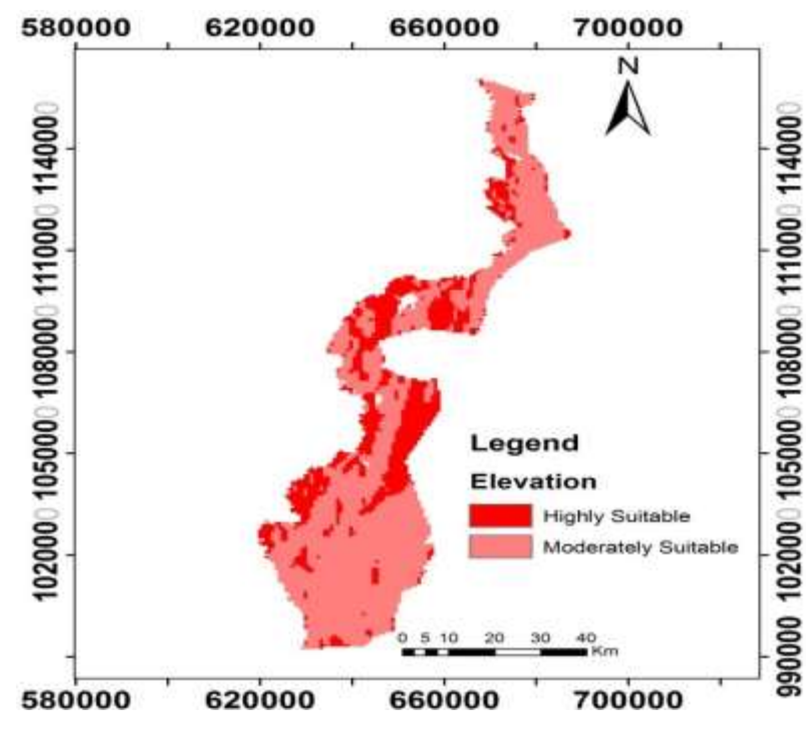

Figure 10. Reclassification of elevation map.

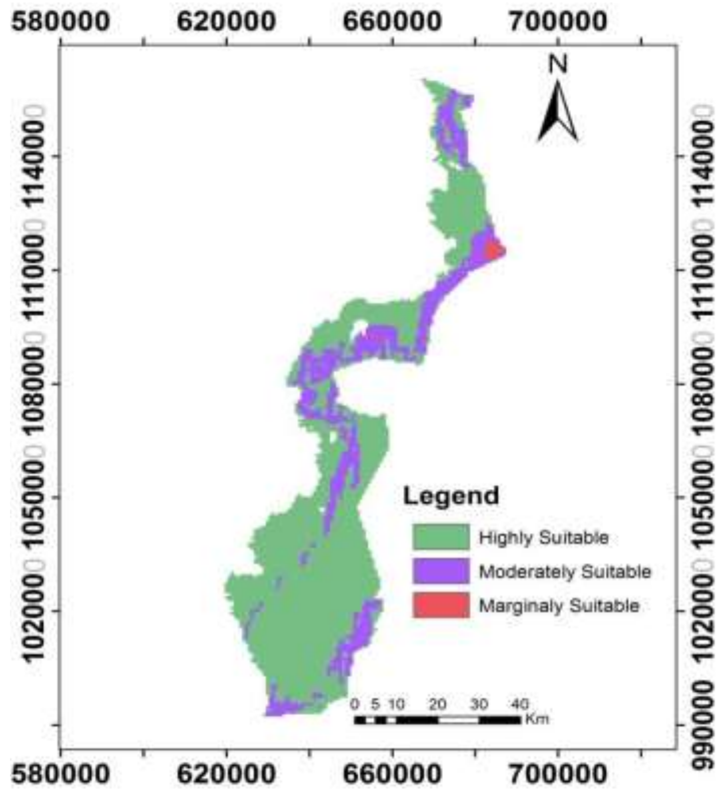

Figure 11. Reclassification of slope map.

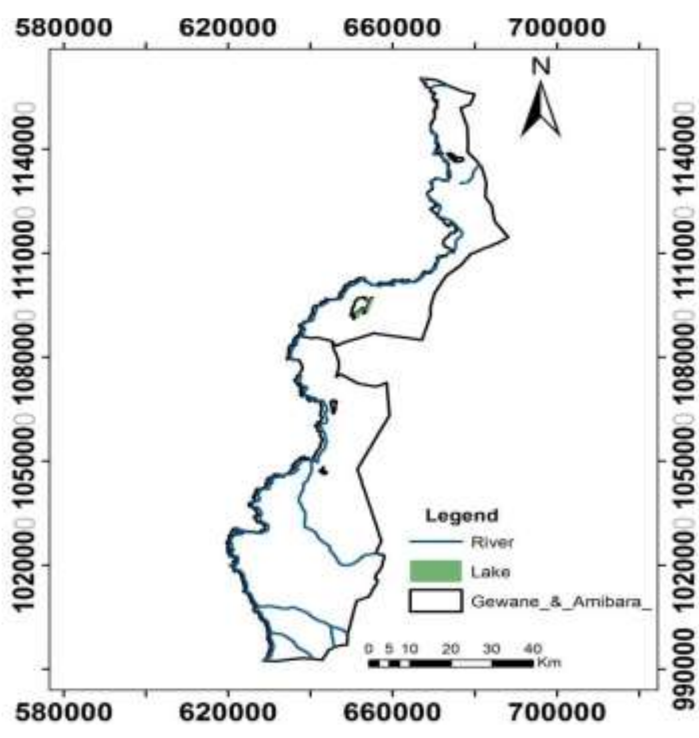

Figure 12. Water resource map of the study.

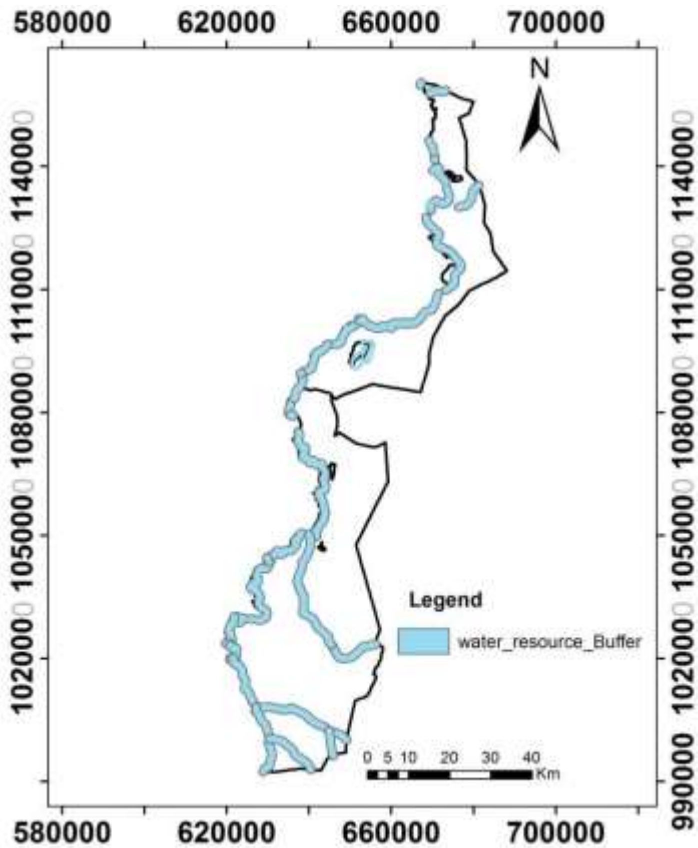

Figure 13. Water resource buffering of the study.

Therefore, these risk levels should not be ignored as it may happen based on some shift of conditions in favor of the risk factors (Figure 14). As Figure 14 weighted overlay analysis indicates most of the areas of the two woredas are marginally suitable for the occurrence of malaria and the remaining areas are moderately suitable. Therefore, the concerned bodies should give emphasis to prevent the occurrence of the diseases in the study areas.

Conclusion

In this study, geospatial data were used for identification, association, characterization, and final malaria risk map production for the study area. Accordingly, climatic and topographic factors, and proximity factors malaria risk level were come together to examine for their aggregate impact on malaria prevalence of the study area. Climate and topography factors of malaria risk mapping of the study area indicated that majority of the area fell under moderate malaria risk level. Proximity factors related malaria risk level is important indicator of malaria risk of a particular area. Related with this, high, medium and marginal risk levels were observed in the study area. Those areas, the rural parts, which are scarcely populated, take low risk level with regard to population density malaria risk. Malaria risk map of the study area showed that there is no area within Amibara and Gewane with malaria free risk level. Most areas fell under malaria risk level of high and medium with 7 and 93% of the total study area respectively. Low risk level is observed in negligible part. Kebele wise about 81% of the area which constitute about 17 kebeles fell in moderate malaria risk level. The other 19% occupied by 4 kebeles showed largely high malaria risk level with moderate risk level prevailing over smaller parts of them. Generally, GIS and remote sensing based malaria risk mapping consider appropriate mosquito harboring factors is a worthwhile technique to know the risk level and to enables public health officers in space and time to control and predict malaria spread over extensive areas. Moreover, the risk map can be valuable for public warning and awareness.

Recommendations

The researcher forwarded the following recommendations from the finding:

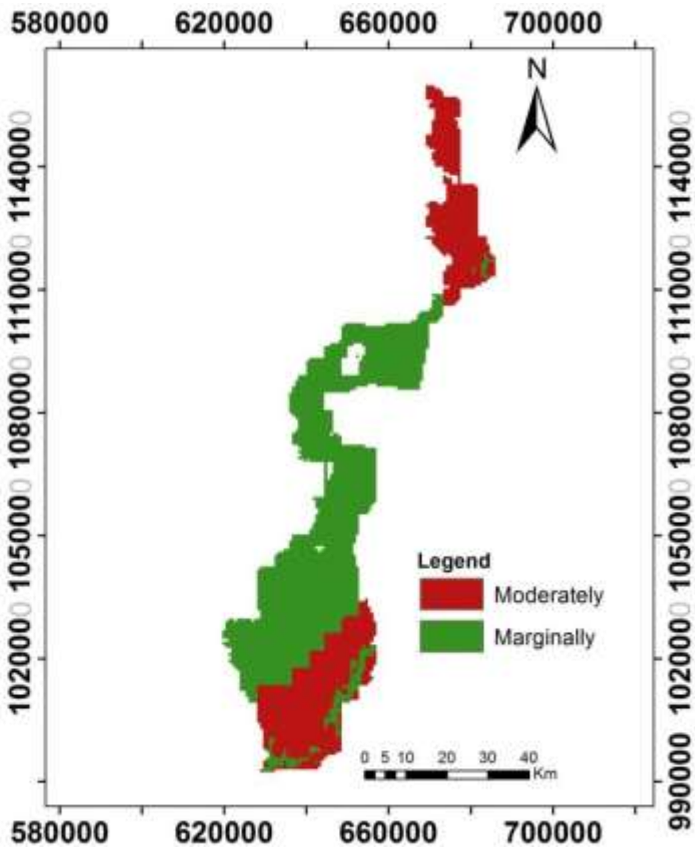

Figure 14. Malaria risk map.

(1) Malaria risk map of the study area indicated that most of the areas in this Woreda are with risk level of high and medium. But increases or decrease in value of one or more factors shift the situation to very high or other risk levels. Therefore, to make the information up to date, GIS and remote sensing based monitoring and early warning system should be integrated in malaria control and prevention activities in order to easily manage each activity towards alleviating malaria from the area.

(2) In connection with the newly developing canals for irrigation based agriculture purpose, there should be health packages to be served to the local community as part of the main project to prevent mosquito breeding and malaria prevalence. This could be through service delivery for the malaria victims, awareness creation on malaria prevention and control, and insecticide treated net delivery.

(3) Beyond the parameters used for malaria risk analysis in this study, other variables which can contribute to malaria prevalence like income level of the household, housing type, awareness level of the population and others can affect malaria prevalence. Therefore, it is better to integrate these factors with the already used parameters for better exactness.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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