American Journal of Earth Science and Engineering
2020; 3(1): 1-7
http://www.aascit.org/journal/ajese

American Association for Science and Technology

Application of Analytical Hierarchy Process Techniques in Assessing Malaria Risk Transmission Areas in Gombe Metropolis, Gombe State, Nigeria

Yila Caiaphas Makadi[*], Samuel Sulei, Elnafaty Aliyu

Department of Geography, Gombe State University, Gombe, Nigeria

Email address
ycaiaphas@gmail.com (Y. C. Makadi)
[*]Corresponding author

Citation
Yila Caiaphas Makadi, Samuel Sulei, Elnafaty Aliyu. Application of Analytical Hierarchy Process Techniques in Assessing Malaria Risk Transmission Areas in Gombe Metropolis, Gombe State, Nigeria. *American Journal of Earth Science and Engineering*. Vol. 3, No. 1, 2020, pp. 1-7.

Received: November 26, 2019; **Accepted**: January 4, 2020; **Published**: February 3, 2020

Abstract: The research focused on the application of AHP method in assessing malaria risk transmission areas in Gombe metropolis, Gombe State Nigeria. The integrated Geospatial and Multi-Criteria Evaluation (AHP) technique was used to determine malaria risk zones. The influences of physical environmental factors viz., drainage, elevation, and slope were utilized in scoring their shares in the evaluation of risk condition. This was synthesized on the basis of preference over each factor and the total weights of each data and data layer were computed and visualized. A model builder in Arc GIS and AHP Khaskia Software were used to facilitate the overall malaria risk assessment of the factors involved. The study revealed that there are three zones: high, moderate and low malaria risk transmission areas. It was observed too that that a geographical area of 1201.10 hectares having 22% fall is the high risk zone comprising Arawa, Nasarawo and Herwa Gana; 3031.84 hectares with 57% made up the moderate zone and consisted of Shamaki, Pantami and GRA while 1124.9 hectares with 21% and was the low risk zone of Tunfure, Federal Lowcost and New GRA). The risk zones identified on the basis of these parameters and assigned weights shows a close resemblance with ground condition. The study demonstrates the significance and prospect of integrating Geospatial tools and Analytical Hierarchy Process for malaria risk zones and dynamics of malaria transmission. The research recommends the consideration of the geographic variation of malaria risk in Gombe metropolis for government efforts and the design of interventions vital for reducing this menace.

Keywords: Malaria Risk, GIS, ArcMap Model Builder, Spatial Multicriteria Evaluation Technique

1. Introduction

Despite recent progress in reducing malaria morbidity and mortality as a result of the expansion and intensification of malaria control programs, approximately half of the world remains at risk of contracting the disease and in 2012 about 207 million cases and 627,000 malaria-related deaths were observed currently, most strategies for malaria prevention and control tend to concentrate on reducing exposure to mosquitos or treating infections [3] (Bates I, Fenton C, et al. 2004). While these strategies do provide tangible health benefits, integrative approaches (accounting for socioeconomic, cultural, behavioral, environmental, and political aspects) that also aim at reducing individual vulnerabilities to the disease, are needed as countries achieve very low levels of transmission [12]. (Singer BH, Castro MC. 2011). In recent years, a range of malaria risk assessments have been carried out, focusing on (i) malaria transmission risk (ii) malaria risk factors [6]. (Gahutu JB, Steininger C, et al 2011), (iii) the links between climate change and malaria risk [8]. (Gething PW, Smith DL et al, 2010), and (iv) spatial population datasets for mapping populations at risk [9]. (Hay SI, Guerra CA, 2004).

The World Health Organization (WHO) estimates show that over 80% of clinical cases of malaria occur in Africa south of the Sahara. Malaria is transmitted by anopheles mosquitoes which breed in surface water pools where environmental conditions are suitable their development [13, 14]. (WHO, 2005, 2006). These risk factors are proximity to water body, vegetation cover, temperature, rainfall and altitude [7]. (Gunawardena et al., 1994; Henri et al., 2010). In

Nigeria, malaria infection and distribution by mosquito vectors vary across the different ecological zones of the country [1]. Yet not much study has been carried out to ascertain factors favorable to their survivals [1]. (Akpama, 2010). Malaria risk assessments focus on the probability of harmful consequences resulting from interactions between the hazard (or the disease; measured by the entomological inoculation rate [EIR]) and the vulnerability of the exposed population; thus, they are commonly carried out once the hazard is prevalent. Vulnerability assessments focus on identifying and analyzing a wide range of socioeconomic, demographic, biological, cultural, and governance-related factors that can potentially impact human susceptibility and lack of resilience to the disease.

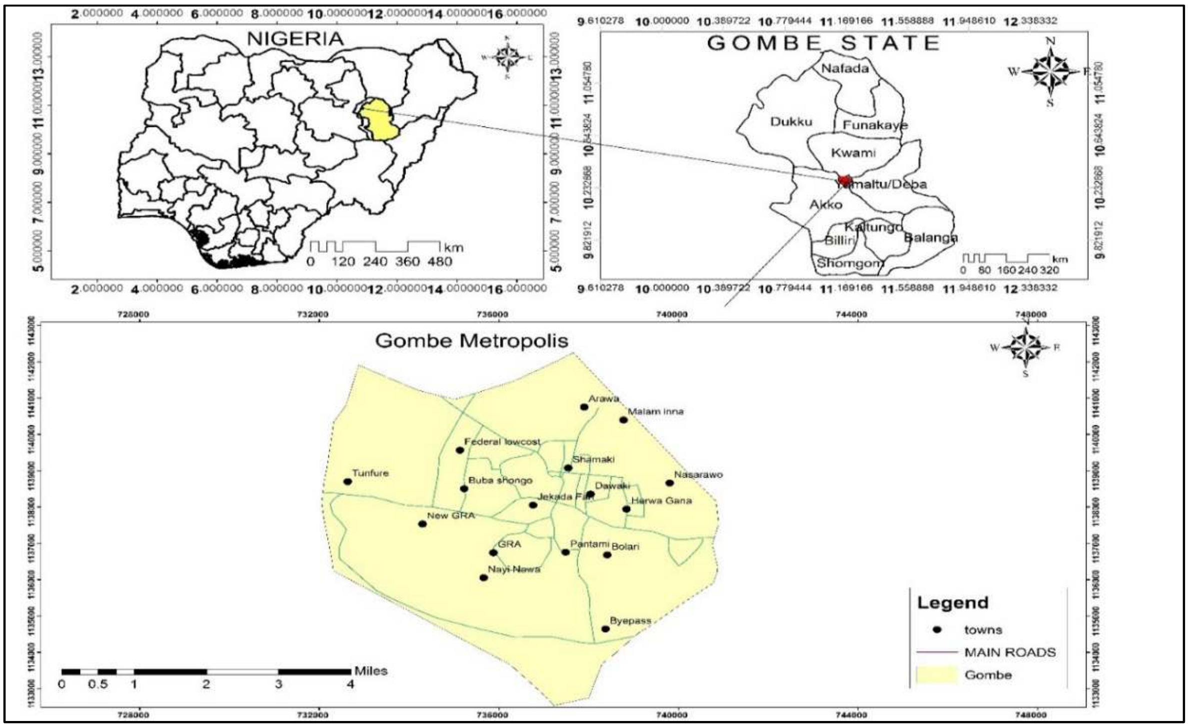
Therefore, mapping vulnerability and integrating the results in a spatial explicit risk assessment can provide evidence for planning preventative interventions, by targeting factors that can reduce susceptibility and increase resilience. Although the focus on malaria risk and vulnerability is increasingly gaining ground in the malaria literature [10]. [Ribera JM, Hausmann-Muela S 2011], little emphasis has been given to integrating spatial explicit information on prevailing vulnerabilities into malaria risk assessments. Thus, it is against this background that this research is conducted to assess malaria risk transmission areas in Gombe metropolis using analytical hierarchy process techniques.

2. Materials and Methods

2.1. Study Area Description

Gombe metropolis is a centrally located within the state on latitude 10°16'59.94"N and longitude 11° 9'55.55"E. It has an average altitude of about 500m above sea level and covers an area of 175.94km^2. Gombe metropolis is well linked by road to other regional centers like Biu (Borno State) to the east, Potiskum (Yobe States) to the north, Bauchi (Bauchi State) to the west, and Jalingo (Taraba State) to its south. A large part of existing town is at the foot of the Akko escarpment and on a shallow dish-like site.

Gombe State, "Jewel in the Savannah," was created on 1st October, 1996 by the General Sani Abacha administration. Its creation was a fulfilment of the aspirations of the people who, for long, yearned for a state of their own out of the then Bauchi State. The genesis of the struggle dates back to 1979. Since its creation, the state has been growing fast, blessed with abundant physical, human and economic resources which confirms its economic viability for state creation-Gombe metropolis id indeed the hub of economic activities in the North East Geopolitical Zone given its nodal location.



Source: Authors Analysis (2019)

Figure 1. *Study area (Nigeria-Gombe state-Gombe metropolis).*

2.2. Methods

Malaria transmission is strongly associated with environmental conditions, which control mosquito maturity and parasite development. Accordingly distance from water bodies, slope, and elevation are listed in order of importance. To assess malaria risk of Gombe using GIS and Remote Sensing, Multi-Criteria Evaluation was used. SMCE is a procedure which needs several criteria to be evaluated to meet a specific objective [11]. (Saaty, T. L., 1977)

Table 1. *Pairwise Comparison Scale.*

Definition	Intensity of importance
Extremely important	9 8
Very Strongly more important	7 6
Strongly more important	5 4
Moderately more important	3 2
Equally important	1

Source: Satty L. Thomas (1980)

Table 2. *Pairwise comparison matrix: comparison matrix with intensity judgments.*

	WATER BODIES	ELEVATION	SLOPE
A	1	7	3
B	1/7	1	1/3
C	1/3	3	1

Table 3. *Column addition:*

	WATER BODIES	ELEVATION	SLOPE
A	1.00	7.00	3.00
B	0.143	1.00	0.33
C	0.33	3.00	1.00
TOTAL	1.48	11.00	4.33

Source: AHP Khaskia Software

Table 4. *Nominalize matrix:*

	WATER BODIES	ELEVATION	SLOPE	CW
A	0.669	0.636	0.692	0.669
B	0.97	0.087	0.77	0.087
C	0.23	0.27	0.242	0.242

Source: AHP Khaskia Software

Calculation of λmax:

λmax =>(1.48 * 0.67) + (11 * 0.09) + (4.33 * 0.24) =3.001

Calculation of Consistency:

Consistency index (CI):

$$CI = (\lambda max - n)/(n - 1)$$

Where n is the number of compared elements (n = 3).

Therefore,

CI =>(3.01-3) / (3-1) =0.004

Now we can calculate the consistency ratio, defined as:

CR=CI/RI=> 0/0.58=0.007

CI is the consistency index calculated in the previous step with a value of 0.004.

RI is the consistency index of a randomly generated comparison matrix In other words, RI is the consistency index that would be obtained if the assigned judgment values were totally random. The value of RI depends on the number of items (n) that are being compared It can be seen that for n = 3, RI = 0.58. Using these values for CI and RI, it can be calculated as

CR=0.004/0.58=0.007 (AHP Khaskia Software) [4].

In practice, a CR of 0.1 or below is considered acceptable. Any higher value at any level indicates that the judgments warrant reexamination. Thus, CR reflects the consistency of one's judgment. If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment. (Satty, 1980), [11]. In this study, a consistency ratio of 0.01 is obtained which is less than 0.10, the ratio indicate a reasonable level of consistency in the pair-wise comparisons. Since, CR < 0.1, the judgments are acceptable. The value of CR=0.01 is acceptable suggesting judgment of parameters weight in identifying risk zones for malaria is agreeable.

2.3. Factor Development

A. Distance from Water Bodies Factor:

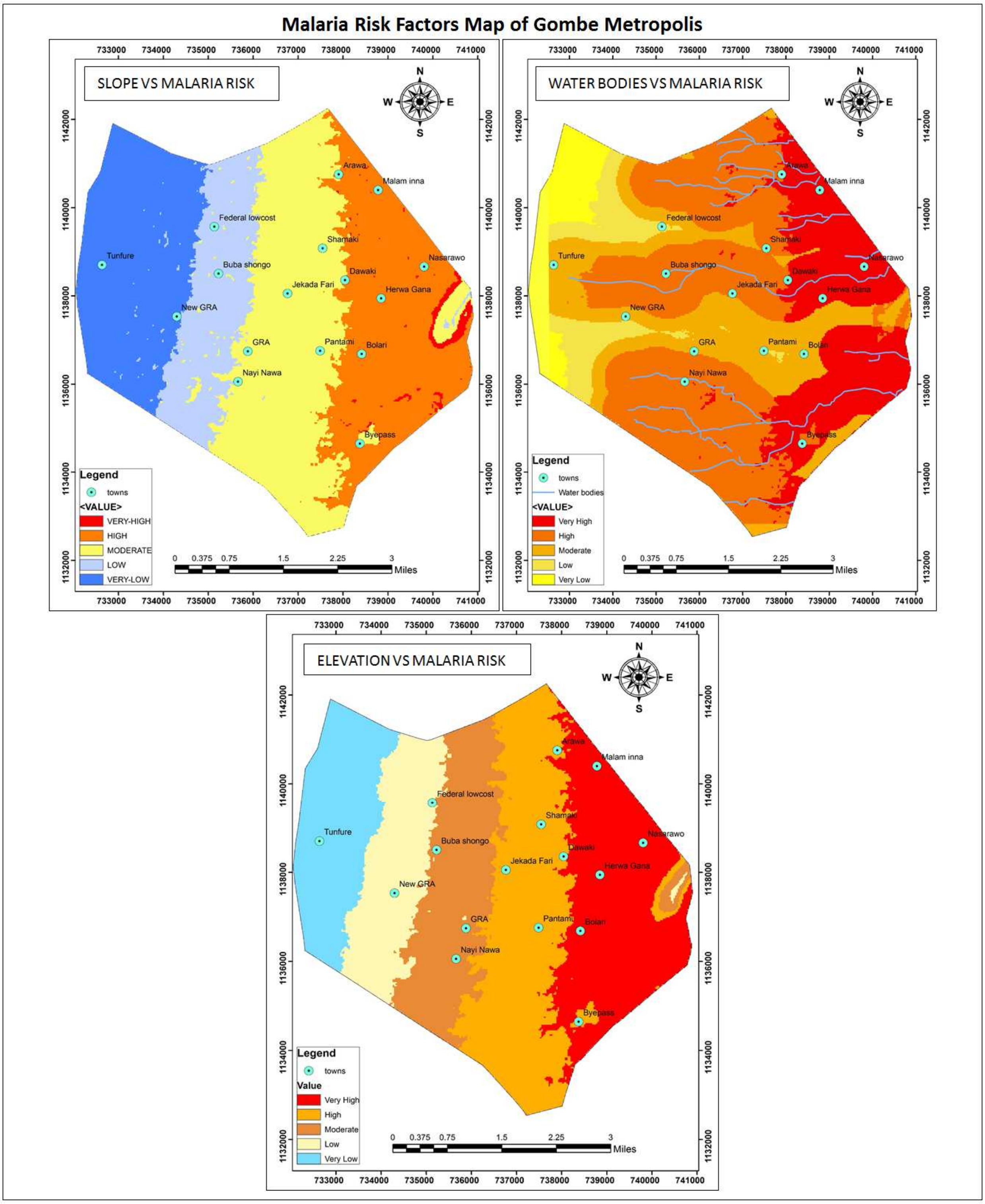
Heed was taken of the maximum flying distance of anopheles mosquito from the distance to stream as 2 km a basis for reclassification of distance to the stream layer. Distance to water bodies was calculated using Spatial Analyst Tool, Distance, Euclidean Distance. Then river distance raster layer was further reclassified using natural break standard reclassification method in ARC GIS 10.1 software into four subgroups and the reclassified subgroups of stream distance raster layer were ranked according to mosquitoes flying distance threshold value. This indicates that areas out of the flying distance threshold were considered as less malaria risk level, and so new values were re-assigned in order of Malaria Risk rating. Flying distance of anopheles mosquitoes from water bodies of Gombe ranged 0-2.km.

B. Elevation Factor:

Elevation is a prominent factor for malaria transmission, this is because of elevation highly determines the amount of heat which, in turn affect mosquito breeding as the length of immature stage in life cycle. In high temperature, the egg, larval and pupil stages will be shortened so that the turnover will be increased and also affect the length of the saprogenic cycle of the parasite within the mosquito host i.e. when temperature increases, the period of the saprogenic cycle will be shorted, [2] (Ministry of Health, 1999; Ahmed, 2014). The elevation map was produced by the processing the DEM (30m resolution), using Arc GIS software, Spatial Analysis Tool, Surface Analysis. The elevation raster layer, which was reclassified in five sub-group using standard classification schemes namely quantiles. This classification scheme divides the range of attribute values into equal-sized sub ranges, allowing one to specify the number of intervals while Arc Map determining where the breaks should be. Finally, the elevation was reclassified into continuous scale in order of malaria hazard rating. The elevation in Gombe ranges from 405 to 640 meters.

C. Slope Factor:

Slope is the other topographic parameter that may be associated with mosquito larval habitat formation. It is the measurement of the rate-change of the land per unit distance which may affect the stability of the aquatic habitat [2] (Stephen, 2000; Ahmed, 2014). The slope map was produced by the processing the DEM (90m resolution), using Arc GIS software, Spatial Analysis Tool, Surface Analysis, Slope. The slope raster layer, which was reclassified in five sub-group using standard classification schemes namely quantiles. This classification scheme divides the range of attribute values into equal-sized sub ranges, allowing you to specify the number of intervals while Arc Map determining where the breaks should be. Finally, the slope was reclassified into continuous scale in order of flood hazard rating. The slope in the sub-basin ranges from 405 to 640 meters. Slope values of Gombe ranged between 0 to 52%.



Source: Author Analysis (2019)

***Figure 2.** Malaria Risk Factors Map of Gombe Metropolis.*

Table 5. *Weighted Malaria Risk Ranking for Gombe Metropolis.*

S/N	Factors with Units	Weight	Class	Ranks/ Rating	Naming /Degree of Vulnerability
			0-50m	5	Very high
			50-100m	4	High
1	Distance From Water Bodies	0.669	150-150m	3	Moderate
			150-200m	2	Low
			>200m	1	Very low
			400-450m	5	Very high
	Elevation		450-500m	4	High
2		0.087	500-550m	3	Moderate
			550-600m	2	Low
			>600m	1	Very low
			0-6%	5	Very high
	Slope		6-12%	4	High
3		0.242	12-26%	3	Moderate
			26-52%	2	Low
			>52%	1	Very low

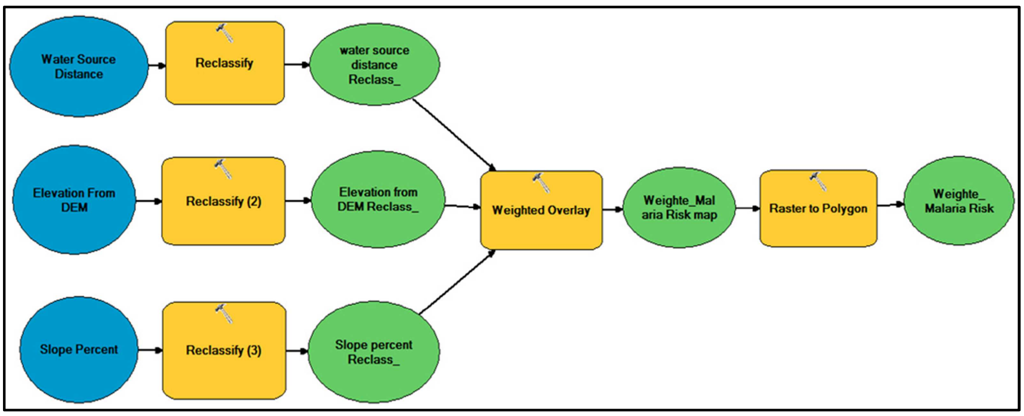
A model builder in Arc GIS was used to facilitate the overall malaria Risk assessment by combining all impact factors. It is a visual programming language for building geo-processing workflows. Geo-processing models automate and document our spatial analysis and data management processes. We create and modify geo-processing models 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. The following procedures were followed to create, add data/tools and running Malaria Risk Mapping Model in Arc Map Model Builder:

1. First, Malaria Risk Mapping Model in ARC Map was created: In order to create the model, Arc Toolbox window should be opened by clicking on the Arc Toolbox window button. Right-click somewhere on the empty area inside the Arc Toolbox window -> Add Toolbox. The Add Toolbox window appears. In the Add Toolbox window, navigate to the location where you created your new toolbox, select it and click Open. The toolbox will appear alphabetically in the Arc Toolbox window. To create a new model, right click the toolbox, we just added to open its contextual menu->New->Model. The Model Builder window opens. Inside the Model Builder window, click on the Model menu->Model.

2. Secondly, adding data, tools and running a model: First one has to make sure that the Model Builder window for our model is open in edit mode (right-click the model ->Edit) and that one can see both the Model Builder window and the Arc Toolbox window. To add data and tools to the model, In Arc Toolbox, locate the tool which would be used (e.g. Spatial Analyst Tools ->Overlay->Weighted Overlay), drag and drop it in the Model Builder window. The white rectangle is connected to a white ellipse through a connector. The ellipse indicates the output. The white colour means that the parameters have not been set yet. Double-click the tool (the white rectangle).

A tool-specific dialog window will open, where we set the parameters for the operation. Once the input have specified the input to be used in the model have been specified, it will appear as a blue ellipse, connected to the rectangle tool. The output will be indicated through a green ellipse. Once all parameters are set, the white rectangle will turn yellow. Double-click the white rectangle of the tool to active its tool-specific dialog window. Before we run the model, right-click on the green ellipse indicating the output, and select Add to Display. The output file containing the results from the model will now be added to the Table of Contents in Arc Map.

3. Thirdly, run the model, click on the Model menu, where two options will be seen: Run and Run Entire Model. Run will only run the parts of the model that have not been ran previously, while Run Entire Model will execute all operations from start to end Malaria Risk Analysis workflow using Model Builder in Arc GIS environment:



Source: Authors Analysis ARCGIS (2019)

Figure 3. *Malaria Risk Analysis workflow using Model Builder in Arc GIS environment.*

3. Results and Discussion

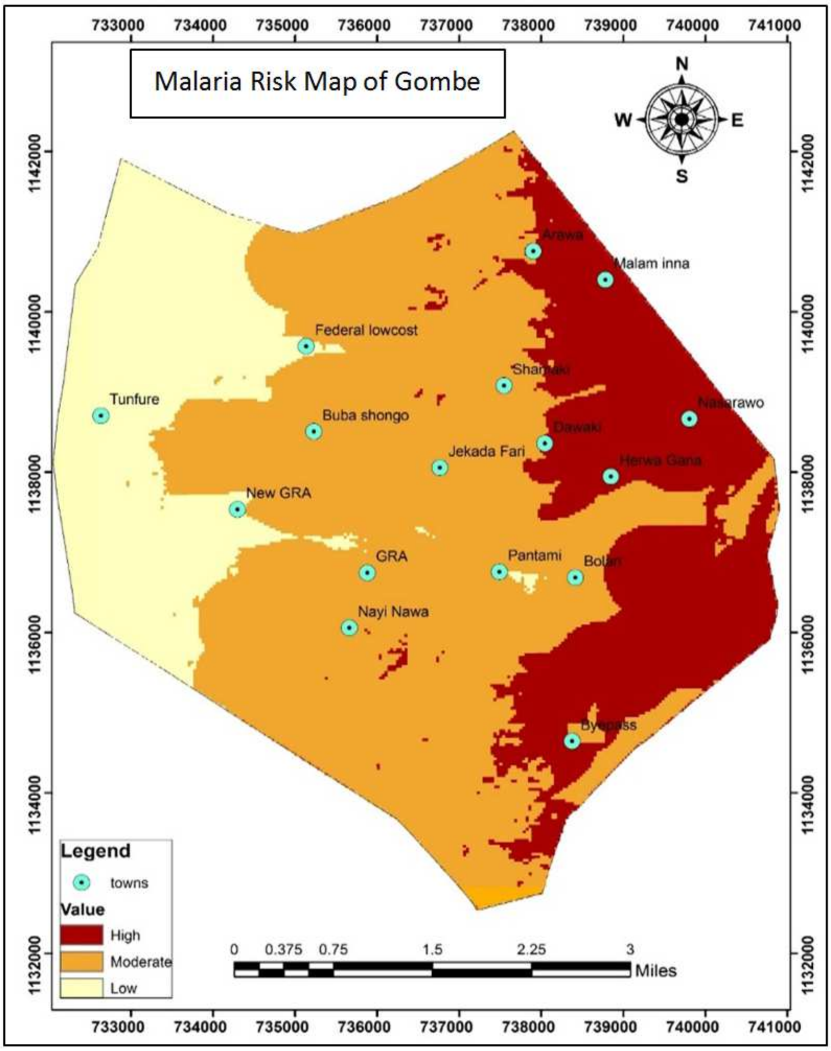
3.1. Classification of Results

This section should specify the criteria, figures and measurements used in classifying areas of malaria risk transmission as very high, moderate and low.

Very high: The zone has a gentle slope and moderate to low elevation provide most conducive environment for breeding of malaria parasite. It is 22% of the total area amounting to (1201.10 hectares). These areas were found in the northeastern part of the study area with many water bodies.

Moderate: These areas were cover the central and to southern parts of the study area with less water bodies, high to moderate slope and moderate to high elevation. These features provide less moderate favorable conditions for the parasite to breed. This category accounts for 57% of total area (3031.84 hectares).

Low: Low priority areas were found mainly in the western part of the study area. The zone has high elevation and steep slopes which provide less favorable condition for the malaria parasite to grow. It accounts for 21% of total area (1124.9 hectares).



Source: Authors Analysis (2019)

Figure 4. *Malaria risk map of Gombe.*

Table 6. *Area Coverage in ha and Percentage Share of Malaria Hazard in the study area.*

Malaria Risk Level	Area in Hectare	Percent
Low	1124.9 hectares	21%
Moderate	3031.84 hectares	57%
High	1201.10 hectares	22%

3.2. Identified Areas of Malaria Risk

According to the malaria risk map it was estimated that 1201.10 (22%) was the high risk zone (Arawa, Nasarawo, Herwa Gana), 3031.84 ha (57%), made up the moderate zone. (Shamaki, Pantami, GRA), while 1124.9 (21%) was the low risk zone (Tumfure Federal lowcost, New GRA). of Gombe is subjected to, high, moderate and low malaria risk area. As it can be seen from the malaria risk map, areas in the very high malaria risk zones are mainly parts of Gombe within or close to the major rivers and water bodies. (Figure 4).

The final malaria risk map of Gombe (Figure 4) also revealed that distance from water bodies and elevation are the most important factor for malaria risk in Gombe. While slope is relatively the least important factor. On this premise and health care planning and development, it is recommended that regular clearing of drains and the surrounding environment on monthly basis should be intensified most especially during the months of July, August and September when the wet season is at its peak. The distribution of anti-mosquito nets by the three tiers of government should be intensified. Additionally, the residents should embrace the various health programs of reducing mosquitoes as specified in the local, state and federal government health policies.

4. Conclusion and Recommendation

In this study, different factors were considered for malaria risk mapping. Distance from water bodies, elevation, and slope were considered as factors. Then a MCA model in Arc Map Model Builder was built to analyze all factor maps by giving them different weights, and to get the final malaria hazard map. The research identified, the most important factors for malaria risk in Gombe are distance from water bodies, and elevation, while slope was the least important factor. From this GIS based SMCET application for malaria risk mapping in Gombe, it is possible to conclude that GIS tools facilitate a systematic and comprehensive malaria risk mapping in a more effective and scientific way by combining and spatially assessing multiple factors.

This study also indicates that GIS based SMCET developed in Arc Map Model Builder can serve as a support tool to facilitate the overall malaria risk assessment by combining all impact factors, automate and document our spatial analysis and data management processes, output of one process as the input to another process, and run and run entire model.

The malaria risk analysis of Gombe revealed that mainly parts of the metropolis within or close to the major rivers were within very high malaria risk zones. On this premise and health care planning and development, it is recommended that regular clearing of drains and the surrounding environment on monthly basis should be intensified most especially during the months of July to September when the wet season is at its peak. Moreover as the distribution of anti-mosquito treated nets should be intensified as this helps to curb the risk of malaria transmission in the area of study. Therefore, malaria hazard and risk maps should be integrated with water resource harvesting development activities. The following mitigation measures should be considered while implementing water resource harvesting development activities and crop cultivation using irrigation at high or very high malaria hazard area implement environmental management measures such as filling and leveling of borrow pits, cleared vegetation from the pools or drained to prevent mosquito breeding and resting sites.

References

[1] Akpama, (2010), The Limits and Intensity of Plasmodium falciparum Transmission: Implications for Malaria Control and Elimination Worldwide.

[2] Ahmed, A., (2014), Geographic Information Science and Remote Sensing for Malaria Risk Mapping, Ethiopia. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, 2014 ISPRS Technical Commission VIII Symposium, 09 – 12 December 2014, Hyderabad, India.

[3] Bates I, Fenton C, Gruber J, Lalloo D, Lara AM, Squire SB, et al. Vulnerability to malaria, tuberculosis, and HIV/AIDS infection and disease. Part 1: determinants operating at individual and household level. Lancet Infect Dis. 2004; 4: 267–77. doi: 10.1016/S1473-3099(04)01002-3.

[4] Khaskia M. A. AHP Khaskia Software (2013).

[5] Gething PW, et al. (2010), a new world malaria map: Plasmodium Falciparum Endemicity in. Malar J. 2011; 10: 378.

[6] Gahutu J. B, et al. (2011) Prevalence and risk factors of Malaria among Children in Southern Highland Rwanda. Malar J.; 18 (10): 134.

[7] Gunawardena, DM. et al. (1994). Patterns of Acquired Anti-malarial Immunity in Sri Lanka. Mem. Inst. Oswaldo Cruz, 89: 61-63.

[8] Gething PW, et al (2010) Climate Change and the Global Malaria Recession. Nature. 465 (7296): 342–50.

[9] Hay SI, et al. (2004), the Global Distribution and Population at Risk of Malaria: Past, Present, and Future. Lancet Infect Dis.; 4 (6): 327–36.

[10] Ribera JM, Hausmann-Muela S. The straw that breaks the camel's back. Redirecting health-seeking behavior studies on malaria and vulnerability. Med Anthropol Q. 2011; 25 (1): 103–21. doi: 10.1111/j.1548-1387.2010.01139.x.

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

[12] Singer BH, Castro MC. Reassessing multiple-intervention malaria control programs of the past: Lessons for the design of contemporary interventions. In: Selendy J, editor. Water and Sanitation Related Diseases and the Environment: Challenges, Interventions and Preventive Measures. Hoboken, New Jersey: John Wiley & Sons, Inc; 2011. pp. 151–166.

[13] WHO, (2005). World malaria report. World Health Organization, Geneva, Switzerland.

[14] WHO, (2006). The Africa Malaria Report. World Health Organization.

[15] WHO/UNICEF, (2003). The Africa Malaria Report. WHO/ CDS/MAL/2003.1093. World Health.