IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
August 2019 Vol.:13, Issue:2

Determination of Optimal Locations for Building New Health Facility Services Based on Multi-Influencing Factors - A Case Study of Kibaha District-Tanzania

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INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

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Submission: 21 July 2019
Accepted: 26 July 2019
Published: 30 August 2019

Keywords: Analytical Hierarchy Process (AHP), Weighted Linear Combination Model, Optimal Sites, GIS, Health Facilities.

ABSTRACT

Access to health services by patients in most parts of Tanzania is a challenge; especially those in rural areas, in some of the village's health facilities are located far from people's residents. The availability of health facilities near people's residents contributes significantly to a healthy community. Uneven geographical distribution of health facility is a problem for quality health services provision. The study uses GIS techniques with Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) methods to accesses factors affecting accessibility and HFs utilization. In an attempt to achieve the study objectives of identifying the suitable area for building new health facilities, a Handheld Geographical Positioning System (GPS) device was used to collect coordinates points of HFs and Village Centers in Kibaha District. Shape-file of Kibaha District and population were obtained from the National Bureau of Statistics (NBS), road network shapefile was downloaded from Open Street Map (OSM). Arc-Map version 10.3 was used to process the spatial data and to create a thematic map of each assessed factor. AHP was used to determine the influence weight of factors in health facility utilization. The thematic maps and influence weight were combined using the WLC model to obtain optimal sites for building a new Health Facility. The influence weight of the accessed factors indicates that the population has the highest influence weight of 65%, road infrastructures have the influence of 17% residents have an influence of 11% and water supply has an influence of 7%. That means the area with a high population should be considered for building new health facilities. It was finally observed that the integration of GIS and Analytical Hierarchy Process enables the identification of optimal locations for building new health care facilities.

1.0 INTRODUCTION

In Tanzania, the accessibility and uneven distribution of health facilities have remained a challenge despite the government's efforts to increase the number of health facilities. According to the National Bureau of Statistics (2016)**,** Tanzania mainland has a total of 7,493 registered working health facilities. This number includes public and private health facilities in 3,802 wards and 12,423 villages, which accounts for an average of 2 health facilities in each ward and 1 Health facility at a village level. This implies that a large number of population from some villages have to travel to where health facilities are located (Prime Minister's Office, 2012).

There are factors that contribute to the uneven distribution of health facilities some of them being geographically based factors and population distribution (Smith, Tang, & Nutbeam, 2006). A previous research study by (McLafferty, 2003) reported that population distribution and geographical factors play a crucial role in influencing health services accessibility and utilization. To facilitate priority setting with regard to accessibility and distribution of health facilities in the country, the study realized the urgent need to assess factors influencing health facility services accessibility and utilization. Among the assessed factors that influence accessibility and utilization of health, facility includes the distance from health facility to roads, water supply and residence location in relation to the health facility and population size of the given geographical area served by a particular health facility.

In Tanzania, health facilities are constructed and run by the central government, local government, religions, and private sectors. These Health facilities include Dispensaries, Health Centers, and Hospitals. Tanzania Health System offers health services from the village level (Dispensaries) up to the highest level of referral hospitals. Primary health care (PHC) services from low to high level, there are in a pyramidal structure where the number of health facilities decreases from dispensaries, health centers to hospitals.

Primary Health Care has been defined as "essential health care based on practical, scientific and socially acceptable methods and technology that are universal accessible to individuals and families in the community through their full participation and at affordable cost to maintain the spirit of self-reliance and self-determination" (MOH, 2008) with a vision of having a healthy community, which contribute effectively to an individual development and the country as a whole. Its mission being to facilitate the provision of basic health services,

which are proportional, equitable, qualified, affordable, and gender-sensitive so as to improve the health and well-being of all Tanzanians, with a focus to those most at risk, and encourage the health system to be more responsive to the needs of the people. Its objectives were to ensure, health services are available, accessible and utilized with all people wherever they are in the country, urban or rural.

According to United Republic of Tanzania Ministry of Health and Social Welfare, (2015) objectives under Primary Health Services Development Program (PHSDP) 2007 – 2017 stipulated the requirement for one dispensary per Village, one health center per Ward and a hospital in every district in order to reduce the problem of unequal distribution of health care facilities. However, to achieve the set up objectives it requires an establishment of 5162 dispensaries, 3127 health centers, and human resource to achieve PHSDP objectives (MoHSW, 2015).

Previous research in Tanzania has highlighted a number of reasons to limited accessibility and utilization of health facilities in the country, location of health facilities in relation to residents, quality of services provided in health facilities, accommodations, costs, and cultural beliefs. Moreover, geographical factors like roads in Tanzania have been reported to have a contribution to births that takes place at home (The United Republic of Tanzania Ministry of Health and Social Welfare, 2007).

In an attempt to address the situation while encouraging planning for future improvement of accessibility and utilization of health facilities in Tanzania, there was a need to assess the factors influencing utilization of health facilities using Geographical Information Systems (GIS) so as to optimally locate health facility services in relation to identified barriers and needs of the community so as to reduce geographical inequalities of health facility services location too long sentence break it up in to two sentences. GIS is a comprehensive technology that has been specifically designed to compile, process, analyze, display and archive extensive volumes of data. (McLafferty, 2003) reported the increase in the application of GIS by public health professionals for planning, monitoring, and surveillance. The capability of GIS to perform optimal analysis, visualization and present data enables quick assessments of trends and interrelationships of different phenomenon (Xie, Zhou, Vivoni, Hendrickx, & Small, 2005).

2.0 METHODOLOGY

The study used quantitative research methodology with GIS-Multi-Criteria Decision Making Analysis (GIS-MCDMA) and Analytical Hierarchy Process (AHP) to assess the potential influence of factors to health facilities utilization, accessibility so as to optimally locate new health facilities to reduce the uneven distribution of health facilities.

2.1 Study Area

Kibaha district is one of 7 districts of Coast region. It is geographically located in 6.7813^0 S 38.9929^0E in the eastern part of Tanzania. Kibaha district has two councils, Kibaha Town Council (KTC) and Kibaha District Council (KDC). There are 22 Wards in Kibaha District and is boarded by other districts and regions. In the southern part is bordered by Kisarawe District and western by Morogoro region, Eastern part Dare es Salaam Region, Northern part is boarded by Bagamoyo District.

Small scale agriculture is the main economic activity of the people of Kibaha. Crops grown include paddy, cassava, Cashew nuts, and Groundnuts. Kibaha district was chosen as a study area due to its geographical location. Geographically the area covers urban part almost the entire Kibaha Town Council on which population, health facilities, water supply, and road network distribution is different compared to Kibaha District Councils where most part of the council is a rural area. The study focused on determining the relationship between Health facility, water points, road infrastructure, population distribution, and health facility utilization but also the impact of health services provision to health care facilities. The district currently is served by 56 operating health facilities (1 hospital, 5 health centers, and 49 dispensaries) according to Tanzania health facility portal **Ministry of Health Gender and Disabled 2017).**

2.2 Data Collection and Processing

Data collected were based on the requirement of proximity analysis model, health facility utilization, population and health services provided. Data were pre-processed by the ArcGIS catalog that enabled suitability analysis of the assessed criteria in health facility services accessibility and utilization in the Kibaha District.

Primary data collected were village centers coordinates points, water points, health facility coordinates points by field survey through Global Positioning System (GPS) direct from the field. Secondary data were collected in the health facility registry portal, ministry of water, other data are road network layers, Open Street Map (OSM) shapefile, Kibaha wards layers, wards population and data of health facility utilization rate were collected in DHIS2. The coordinates were projected in the UTM grid reference of WGS_84, 36S spatial reference system. The coordinates points were loaded to spatial analyst tools of ArcGIS 10.3.1 software where the distance between points was computed and the assessed factors were analyzed. The software was used to create a standardized map showing the distribution of each factor in relation to health facility location. Pair-wise comparison method was used to assign ranks to each factor and then reclassified to determine its influence weight in health facility accessibility. Weighted linear combination model (WLC) was used to combine standardized maps of each assessed factors with its influence weight to create an optimal area for building new health facilities.

2.3 Ranking of parameters and weighted overlay analysis (WOA)

The Ranking of parameters and weighted overlay analysis involved the use of the Saaty model to rank the influence of each parameter and perform weighted overlay analysis so as to determine the weight of each parameter in influencing health facility utilization.

Through the use of the Saaty model based on AHP, weights of various thematic map layers such as population distribution, road networks, and water supply points and residents location were computed. The relative importance to the health facility utilization rate of each individual parameter was compared from one another by pair-wise comparison method and the matrices for assigning a weight to each parameter were created.

Table 1: Pairwise Comparison Matrix

	(RN**)**	**(**PD**)**	**(**DRHF**)**	**(**WD**)**
Road Network (RN)	1	0.24	2	2
Population Distribution (PD)	4	1	6	9
Distance from Residents to Health facility (DRHF)	0.5	0.2	1	2
Water Points Distribution (WD)	0.5	0.11	0.5	1

After computing the pairwise comparison matrix the sum of each column of the pairwise comparison matrix was calculated by adding each cell of the parameters column-wise as indicated in Table 2.

Table 2: Sum of Each Pairwise Comparison Matrix

	(RN**)**	**(**PD**)**	**(**DRHF**)**	**(**WD**)**
Road Network (RN)	1	0.24	2	2
Population Distribution (PD)	4	1	6	9
Residents to Health facility (DRHF)	0.5	0.2	1	2
Water Points Distribution (WD)	0.5	0.11	0.5	1
Sum	**6**	**1.5**	**10**	**14**

After computing the sum of each element of the pairwise comparison matrix the next stage was to compute normalized pairwise comparison matrix by dividing each element of the pairwise comparison matrix by the sum of its column as it is shown in Table 3.

Table 3: Normalized Pairwise Comparison Matrix

	(RN**)**	**(**PD**)**	**(**DRHF**)**	**(**WD**)**
Road Network (RN)	0.1667	0.1636	0.2105	0.1429
Population Distribution (PD)	0.6667	0.6545	0.6316	0.6429
from Residents to Health facility (DRHF)	0.0833	0.1092	0.1053	0.1428
Water Points Distribution (WD)	0.0833	0.0727	0.0526	0.0714

The final operation was to compute the influence weight of each parameter, the elements computed by normalized pairwise comparison matrix were averaged to obtain the normalized weight (W_j) for each cell as shown in Table 4.

Table 4: Computed Normalized Weight Wj

	(RN**)**	**(**PD**)**	**(**DRHF**)**	**(**WD**)**	**W_jX100**	**W_j%**
Road Network (RN)	0.1667	0.1636	0.2105	0.1429	0.1709	17
Population Distribution (PD)	0.6667	0.6545	0.6316	0.6429	0.6489	65
Residents to HF (DRHF)	0.0833	0.1092	0.1053	0.1428	0.1102	11
Water Points Distribution (WD)	0.0833	0.0727	0.0526	0.0714	0.0700	7
CHECK-SUM	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**100**

The last column in Table 4 represents the computed influence weight of each parameter, the Sum of normalized weight ($\sum wj = 1$) must be equal to 1, the results by (AHP) Saaty model was indicated in the last column in Table 4. The influence weight to health facility utilization was as follows; the population has the influence of 65%, followed by a road network with an influence of 17%, residents location with influence weight of 11% and the lowest was water supply with influence weight of 7%. Thematic map layers for parameters that influence health facility accessibility and utilization were a map showing population distribution, road networks, resident's location in relation to the health facility and water points. A total of four map layers were produced. Thematic maps created were integrated with its influence weight to create a map showing optimal locations of new health facilities based on the assessed parameters.

3.0 RESULTS AND DISCUSSION

In this section, results obtained from the main objective was analyzed and properly discussed. The results present the assessed factors' influence on health facility accessibility and utilization. The parameters influence weight obtained by AHP were integrated with factors' thematic maps to create an overlay map that shows optimal locations for building new health facilities in Kibaha District.

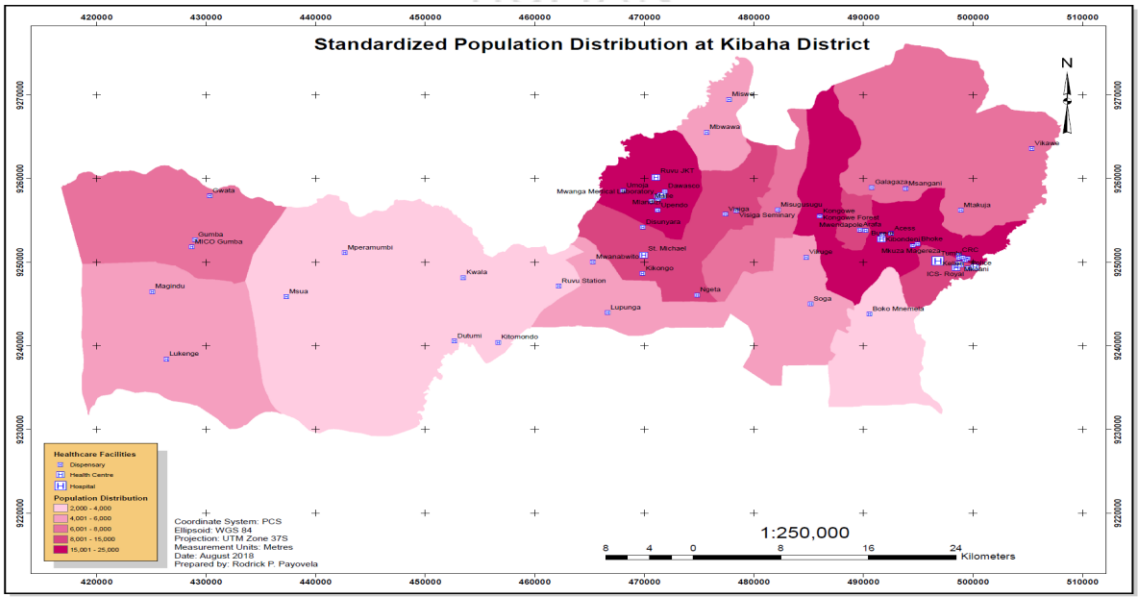

Figure 1. Kibaha District Population Distribution in Relation to Health Facility Location

Figure 1 presents the relationship between population distribution and health facility location. Population distribution was presented by coloring. Areas with faint reddish have a low population and areas with deep red color have a high population. But also health facilities are concentrated in areas with a high population because the accessibility and utilization of health services are high.

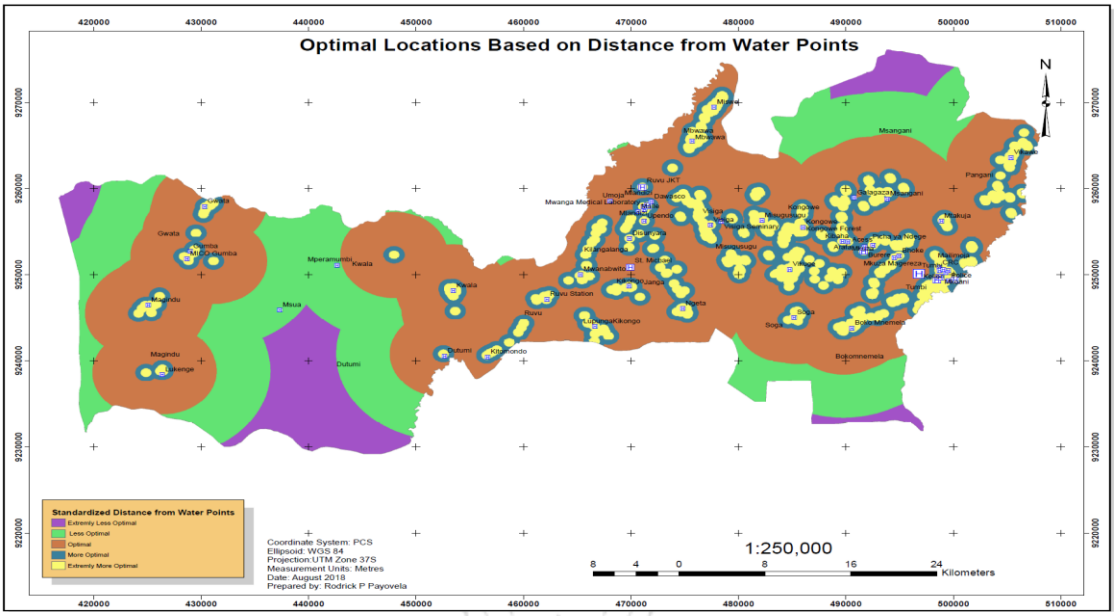

Figure 2: KibahaDistrict Water Points Distribution in Relation to Health Facility Location

Figure 2 indicates areas suitable for building health facilities with a reliable supply of water services. In the thematic map in Figure 2 shows that areas with yellow color have extremely good water supply and health facilities located in the area receive water services in short distances compared to health facilities located in areas with green color. Health facilities located in areas painted with green color were considered to have a poor water supply.

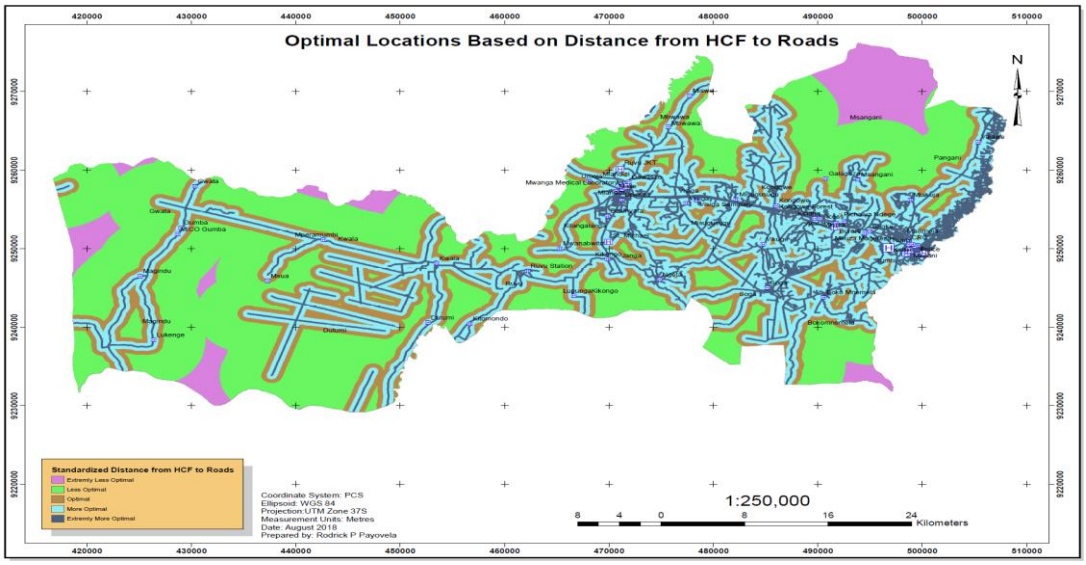

Figure 3: Kibaha District Road Network Distribution in Relation to Health Facility Location

Distribution of road networks and health facilities as indicated in Figure 3 shows that the optimal area to build new health facilities those with are black and dark blue colored. As indicated in the map health facilities located in green and violet color are poorly accessible.

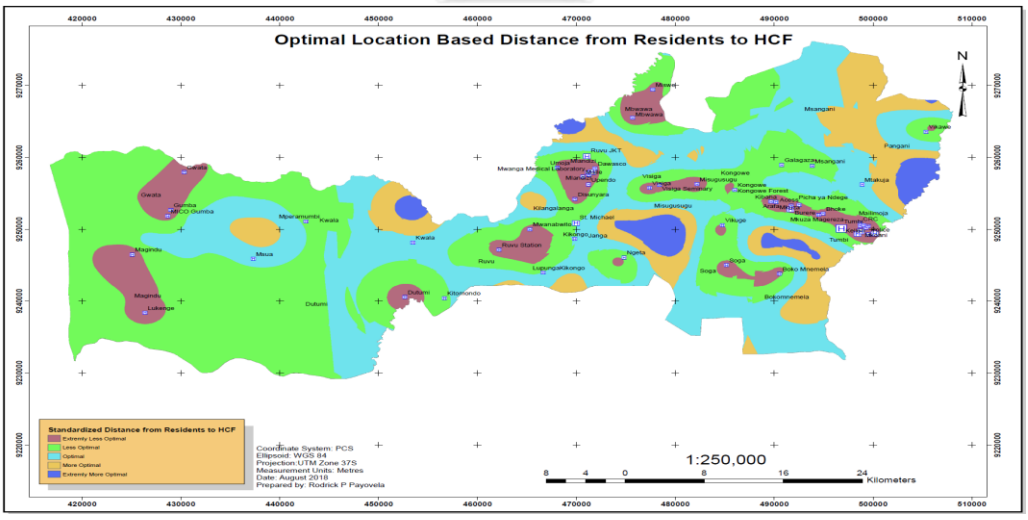

Figure 4: Kibaha District Residents Distribution in Relation to Health Facility Location

A thematic map in Figure 4: The buffer zones created show residents concentrations in relation to health facility location. Green colored zone areas are which lack nearby health facilities and was considered as an optimal area for building new health facilities. Residents that access health facilities in a short distance were presented by red color.

3.1 Weighted Linear Combination Method and Multi-Criteria Evaluation

A weight of each factor obtained through Analytical Hierarchy Process by pairwise comparison matrix with its created standard map for each assessed parameter was integrated using weighted linear combination method $S = \sum_1^j Cj \times Wj$ where W_j is a weight of j^{th} predictor computed from pairwise comparison matrix using (AHP) and C_j as a standardized maps of j^{th} predictor and S as a map showing suitable sites selected after weighted overlay tool and raster calculator (multiplication operator) being implemented.

Weighted overlay tool with standardized optimal maps as an input data set was used to create a map showing optimal locations for building new health facilities. The process involves; multiplying each created standardized criterion map with its corresponding weight, generating an overall suitable score for each alternative by summing up the weighted standardized maps and finally ranking the alternatives according to overall outcomes. That means the four criteria maps were integrated with its weights mathematically as: [Population]* 0.65+ [Distance to road] *0.17+ [Distance to residents] *0.11+ [Distance to water] *0.07. To create a map showing optimal sites for building new health facilities.

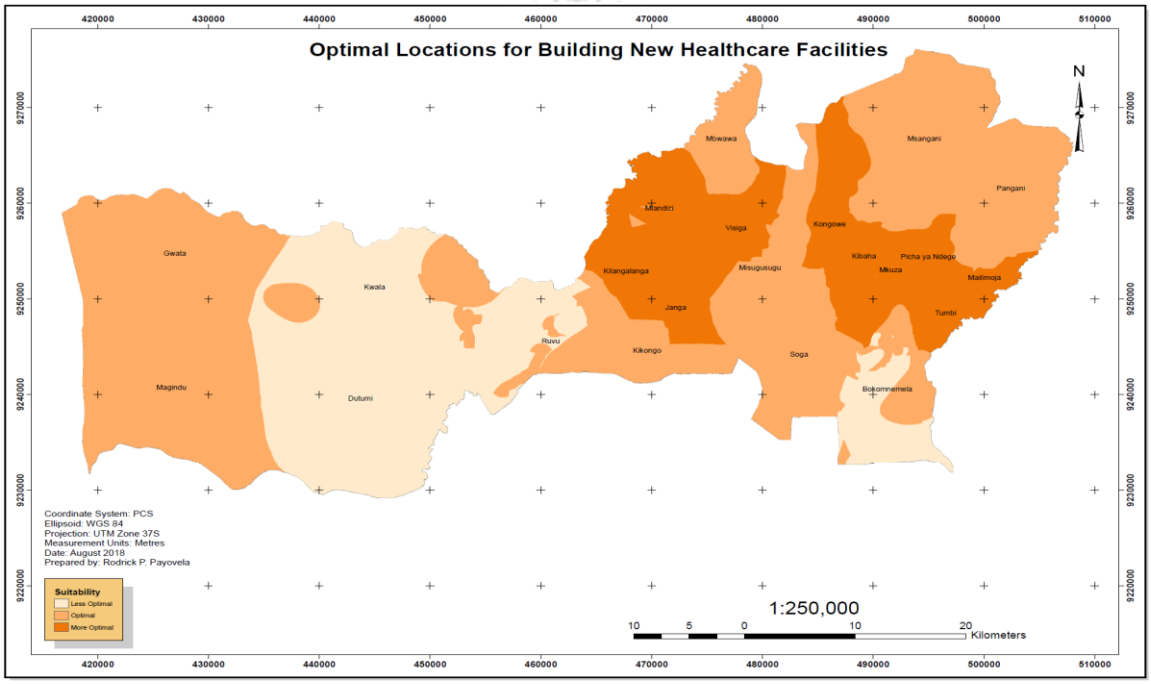

Figure 5: Kibaha District Optimal Sites for Building New Health Facilities

After the implementation of the weighted linear combination model, the result was an optimal map showing areas required to build new health facilities based on the assessed parameters.

Results revealed that in four assessed parameters on how they influence accessibility and utilization of health facilities the outcomes were as follows; population has an influence weight of 65%, followed by road network with an influence of 17%, residents location with influence weight of 11% and the lowest was water supply with influence weight of 7%. As indicated in Figure 5. Areas presented with deep yellow color was found to be the most optimal area for building new health facilities.

4.0 CONCLUSION AND RECOMMENDATION

This study highlights the effectiveness of GIS techniques in creating map layers of four parameters used in assessing its influence weight in health facility utilization. The study used AHP introduced by Professor Thomas Saaty to determine the influence of population distribution, road network, water supply and resident's location in health facility utilization. The influence weight obtained was used in overlay operation with Weighted Linear Combination Model (WLC) $S = \sum_1^j Cj \times Wj$ to identify areas suitable for building health facility services based on assessed factors influence weight. The results indicate that the population has the strongest influence with 65% followed by a road network with an influence weight of 17%, residents with an influence weight of 11% and water supply with an influence weight of 7 %. AHP has been proved to be a robust model to handle Multi Influencing Factors (MIF) as shown by the results of this study. Based on the findings of this study, the priority to build new Health Facility Services by either Government, Parastatals or private sectors should be in optimal locations in villages with high population and that lack health facilities, also areas with good road infrastructures for easy accessibility should be given considerations so as.

- To ensure the proportional distribution of health facility services and population distributions by placing new health facilities in areas with a high population.

- To rehabilitating or improving road infrastructures in health facility location to insures accessibility and utilization of health facility services.

- To assess other factors influencing the accessibility and utilization of health facilities to reduce the problem of over-serving and underserving health facilities.

In determining health facility accessibility and utilization village centers were used as residence point, in order to improve the study, it is recommended to sample and use

household coordinates as a resident reference point due to the fact that human settlements are not uniform but scattered and linear. The study recommends a further study to be carried out inward or division level including other factors that determine health facility accessibility and utilization like cultural beliefs and cost of health services.

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