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Combination of GIS, MCDA and AHP for the Selection of Most Suitable Location for Primary Health Care Facilities

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ABSTRACT

This study reveals the necessity of offering a solution to the Primary Health Care (PHC) facility site location issue in the healthcare industry. PHC is a crucial component of healthcare that serves as the first point of contact for individuals, families, and communities. It allows for the delivery of care as close as possible to people's homes and places of employment, but over time, a solution to this sector's location issues has been neglected. The purpose of this study is to locate the optimum locations in the study area for new PHC facilities. After careful evaluation of various literature, oversight organizations, and local government officials, the raw data needed were obtained. The effectiveness of a Geographical Information System (GIS), Multi-Criteria Decision Analysis (MCDA), and the Analytical Hierarchy Process (AHP) were integrated to provide a novel method for choosing acceptable locations for PHC facilities in the Ado Local Government Area. The specified criteria layers were overlaid using a weighted linear combination (WLC) approach, such as Map algebra. The results showed that within the land mass of the research region; only 10% were deemed to be the most suitable areas, while 53% of the places were suitable, and 37% of the areas were unsuitable. As a result, the study suggests that the integration of GIS, AHP, and MCDA methods is beneficial in addressing the issue of site appropriateness assessments for PHC facilities.

INTRODUCTION

Primary health care (PHC) is a crucial component of healthcare that is based on techniques and technologies that are widely available to people, families, and communities through their active participation and at a reasonable price. PHC is a fundamental component and ideally, the major emphasis of a nation's health system (WHO and UNICEF, 1978). It enables health care to be offered as close to people's homes and places of employment as possible and is seen as the initial level of contact for communities, families and individuals. Better health for all, as recognized in the statement of the world conference on primary health care in Alma Ata, Russia in 1978, is the key objective of primary health care (Rasanathan, & Evans, 2020). This goal includes accessibility, equity, and affordability of healthcare. According to Hogan, *et al.* (2018) and World Health Organization. (2018), ensuring that everyone has access to quality healthcare is crucial for both sustainable development and international security. As a result, health care-related facilities should be widely available, acceptable, and adequate for everyone. Unfortunately, most often in underdeveloped nations worldwide, healthcare services fall short of public expectations and requests. For instance, in Ekiti State of Nigeria, Ado LGA has a total of 21 government-owned PHC facilities as of the year 2020, serving a population of 444,595 (i.e., a ratio of 1: 21,000). This is obviously insufficient because the National Primary Health Care Development Agency (NPHCDA) (2020) proposed a ratio of 1:10,000, which means that a PHC facility should provide care to at least 10,000 individuals within a political ward.

Nasidi (2022), affirmed that earlier studies on the distribution of medical facilities in Nigeria tended to concentrate on first-order cities like Lagos, Ibadan, Kano, Kaduna, and Benin because these cities have specialized hospitals and a large number of private clinics. Studies on health care facilities in secondary or medium-sized Nigerian cities are quite rare. These cities and towns also make up the majority of the state capitals and local government area headquarters in Nigeria. Additionally, whereas past studies in Nigeria's main cities and state capitals employed GIS and Multi-Criteria Decision Analysis (MCDA), there is no known work that investigates the state of PHC in the Ado LGA of Ekiti State. As a result, this represents a gap that will be filled by this study. Since the research region is one of Nigeria's LGAs that has been developing quickly over the past two decades, it is intended to use GIS and MCDA to examine the best locations for the establishment of PHC.

The MCDA approach and other systems and methodologies, such as geographic information systems, are utilized in tandem. Combining these technologies has a synergistic impact that improves the accuracy and standard of spatial analysis for choosing industrial sites (Lopes *et al.*, (2021). Over the past several decades, MCDA has seen extensive use. With the help of its various approaches, including the well-known Analytic Hierarchy Process (AHP), its importance in several application fields has substantially expanded. AHP has been defined as a measuring theory that depends on pairwise comparisons and expert judgment to derive (Rao & Pawar, 2018; Kuo, 2021).

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The Study Area

Ekiti State's capital, Ado-Ekiti LGA, is located in the southwest of Nigeria. The LGA is situated between longitude 05° 06' 18" and 05°24' 00" East of the Greenwich Meridian and latitude 07° 32' 11" to 07°40' 28" North of the Equator. The LGA spans roughly 293 km2 in size. Its largest east-west stretch is around 20 km long and its longest north-south extension is about 16 km (Obele, 2020). In order to facilitate administration and bring government closer to the people, the LGA is divided into 13 political wards. Ado LGA's population has grown significantly in recent years due to the migration of individuals looking for greener pastures over the previous 20 years and its status as the capital of a new state. According to the National Population Commission (NPC), there will be 444,700 people living there by 2050 (NPC, 2007).

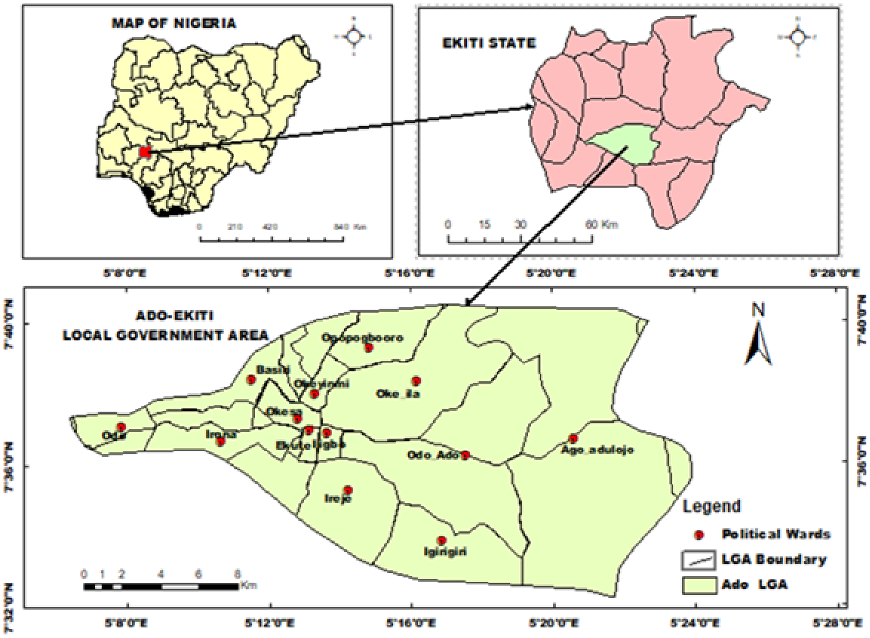

Figure 1: Map Showing the Area of Study
Source: Aroge et al (2023)

METHODOLOGY

In order to choose appropriate locations for the building of PHC facilities in Ado LGA, a novel methodology was devised by combining the effectiveness of GIS, MCDA, and AHP. This phase involves the collection of data which are both primary and secondary data: primary data was collected from the field through questionnaire, while the secondary was downloaded from relevant agencies and organizations. The selected criteria layers were layered on top of each other using the weighted linear combination (WLC) approach, which is similar to map algebra. The study uses seven influential factors to determine the preferred locations for new PHC facilities: land use or land cover, a water body, a slope, a population, a road, the service area of an existing PHC facility, and a residential area. These factors were divided into three (3) main

Table 1: Ranking of the Study's Sub-Criteria

S/N	Selection Criteria	Description of the criteria	Buffer zones	Ranking
1.	Population data	The local population should be taken into account when deciding where to place PHC. The amount of facilities that should conveniently service the population is determined using the demographic data.	<10,000 10,000- 20,000 >20,000	0 1 2
2.	Nearness to residential areas	To ensure simple access and the safety of patients and caregivers, health facilities should not be located too far from residential areas.	>5km 4km-5km <4km	0 1 2
3.	Existing PHC	The effectiveness of the service that any PHC facility currently in operation can provide in terms of trip time coverage is determined by spatial allocation. When choosing a location for new PHC facilities, it is crucial to consider the area that the existing PHC facilities currently covers	>500m >500m	0 2

4.	Nearness to roads	In order to protect patients from noise pollution, major roadways must be set back from health facilities, but these locations must still be close to roads	<45m 45-100m >100m	0 1 2
5.	Land use and Land cover	Land use indicates how humans use a piece of land, so choosing the best location to build a public facility is important.	Forest Water body Residential Cultivated	0 0 1 2
6.	Slope gradient	Buildings that cater to the weakest people (patients) in particular need to take into account the topography of the land, so flat surfaces are generally encouraged	200-450 150-200 <150	0 1 2
7.	Nearness to water bodies	PHC facilities cannot be built next to water bodies, such as ponds, dams, rivers, etc. To prevent an environmental catastrophe	<45m 45-100m >100m	1 0 2

categories: technical, socioeconomic, and environmental. After careful evaluation of various literature, oversight organizations, and local government officials, the raw data were obtained from various sources.

Identification of Site Location Criteria for PhD Facilities

A crucial phase in the site selection process is the identification of criteria. For the accurate identification of suitable places, a large number of factors have been examined from the literature. The peculiarities of the study field, as well as the purpose and goals of the research, must be taken into account when examining and evaluating the criteria. This study has carefully incorporated some standards that are used in the health sector generally as well as the PHC guidelines provided by various regulatory bodies. Not all criteria are equally relevant; depending on the goals of the study, some criteria are very significant while others are less.

Preparation of Thematic Maps

Many layers of thematic maps were needed to be prepared before carrying out site selection study. For this study, thematic were created from different map sources such as satellite images (sentinel-2), ASTER GDEM and Open Street Maps. From these maps and imageries, other criteria map layers were been extracted and prepared accordingly. These includes water bodies, elevation, slope, residential areas, population, roads, and land use. All maps are limited to the extent of the study area boundary and are projected using WGS 1984 UTM Zone 31N projection system.

Model for Decision Hierarchy

The decision hierarchy model for the location of the facilities in this study is shown in Figure 2.1. The hierarchy of PHC facility site was constructed. Seven criteria, divided into three primary groups were used in the computation process: land use or land cover, a water body, a slope, a population, a road, an existing PHC facility, and a residential. Environmental criteria are included in the first group, socioeconomic factors are included in the second group, and technical aspects are included in the third group. These groups were adapted from the study of Kmail *et al.*, (2017).

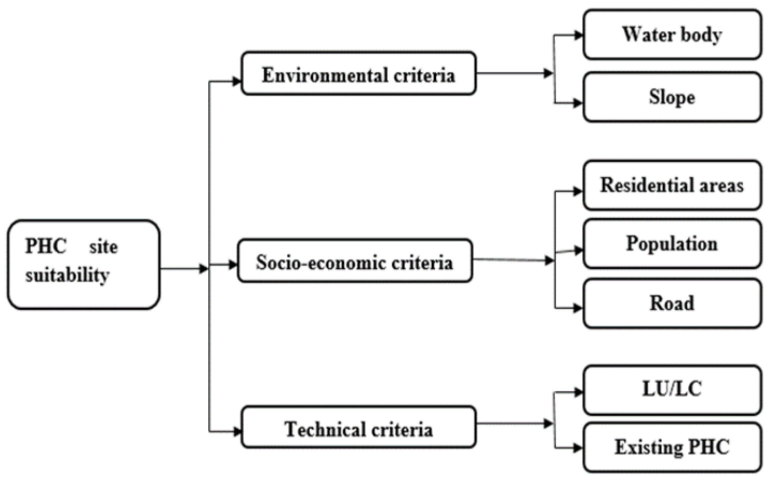

Figure 2: Showing Hierarchy Model

Calculation of the Criteria Weight

Pair-wise comparison techniques, established by Saaty in 1980, are widely employed as a step in the process of allocating weights to the criteria in the decision-making process. The computation of the weights involves three stages. The First demands that the values in each matrix column be added together. Each component of the matrix was then divided by the sum of its respective column. Second, the normalize matrix's elements' averages for each row are calculated. Lastly, multiply the total of each row's normalized scores by the quantity of criteria. An estimation of the relative weights of the being compared criteria is given by the determined average. These calculations were carried out using an AHP-based template and a Microsoft Excel spreadsheet. After that, the matrix was normalized before the weight was obtained. As a result, normalization was accomplished by dividing each value by the sum of the corresponding column.

By computing the average value of each row, that is, adding up all the values in each row, and dividing the result by

Table 2: Shows The Results of Weighing the Criteria

Criteria	Weight	Percentage
Road	0.167	16.7%
Population	0.074	7.4%
Slope	0.123	12.3%
Residential	0.039	3.9%
Water Bodies	0.207	20.7%
Existing PHC	0.068	6.8%
Land Use	0.322	32.2%
Total	**1.000**	**100.0%**

the total number of criteria utilized, the weights of all the criteria were generated from the normalization matrix.

Consistency Ratio Calculation

After calculating the weight, it is crucial to quickly examine the uniformity of the entire process. This is important because the values used to compute the weights were obtained from experts with different preferences, positions, and perspectives. As a result, there is a chance that these experts made mistakes in their judgment, which would undoubtedly have an impact on the matrix's final stage of computation (Saaty, 2005). Using the equation below, the consistency index (CI) was calculated.

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

For the weight consistency check, the CR is anticipated to be less than 0.10, which will show that the judgment is valid and suitable for analysis. To identify the causes of discrepancies and reevaluate, the assessment of the AHP matrix will need to be repeated if the CR is larger than 0.10 (Saaty, 2008; Djokanovi *et al.*, 2016). According to this study's CR value of 0.09, which is less than 0.10, the AHP matrix is consistent, and the weight given to the criterion can be used for analysis.

Combination of Linear Weights (WLC)

Weight Linear Combination (WLC) is a method that requires standardizing the suitability maps, assigning weights of relative importance to the suitability maps, and combining the weights and standardized suitability maps to obtain an overall suitability score, according to Marzuki, *et al.*, (2022). Each criterion was given a weight depending on its significance and standardized to a common measuring scale. By dividing the ranking

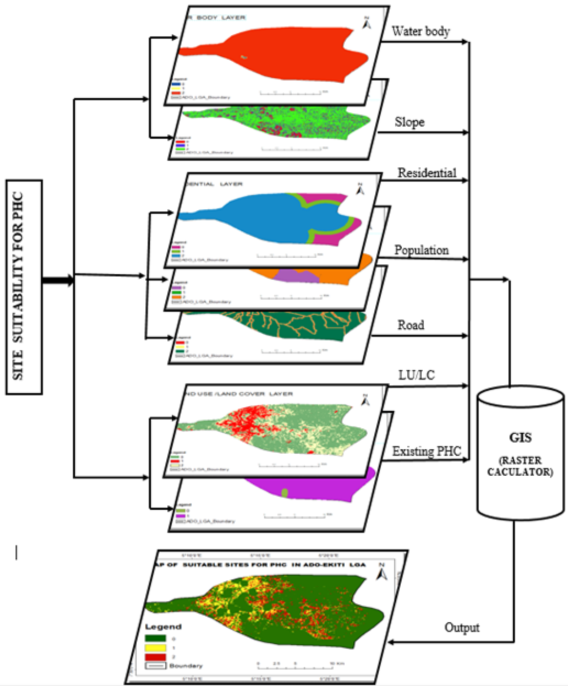

Figure 3: Site Selection Using Weighted Linear Combination

values of the sub-criteria using the Raster calculator tool in ArcGIS, the best locations were determined from the sum of the products.

Using ArcGIS 10.5, the weighted linear combination technique in map algebra was utilized to overlay the seven criteria, and a viable land location was created.

RESULTS AND DISCUSSION

The AHP method was used to generate important ranking of the criteria to create the site suitability map, several raster layers were combined to produce maps which is suitable for PHC locations. The criteria were reclassified to make the result more accurate. Similarly, the weight of criteria were used in weighted linear combination using Map algebra (raster calculator tool) in ArcGIS 10.5 based on the feedback from the questionnaire. Thus, the suitable areas were selected.

Analysis of the Site Suitability Area

Once the various map layers were overlaid using the Map Algebra tool's raster calculator operation, The PHC facility site selection for the research area was completed with the acquisition of the site suitability map. The final probable sites map was produced using the analysis by superimposing the weights for each of the seven criteria (land use/land cover, road, residential, water body, population, existing PHC and slope,) assigned to each map layer. The map of probable places that might be appropriate is shown in figures 4 and the pie chart shown in 5 below.

The most appropriate locations belong to the class with the greatest value; in this study, all areas with a value of 2 were regarded as the most appropriate sites. Then, the conditional expression for sites with a value of 2 (shown in red color) was extracted, and the remaining sites were

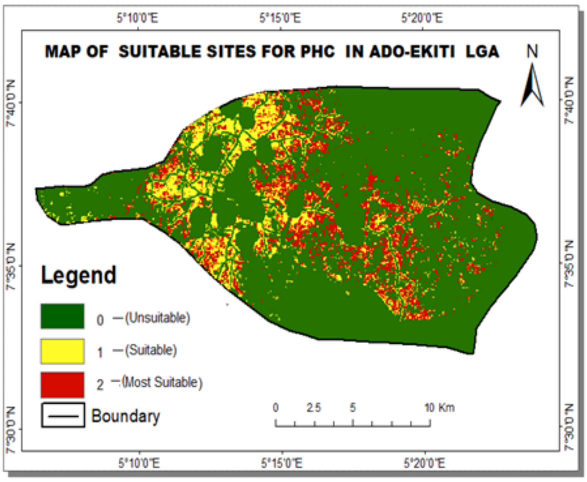

Figure 4: Map of Suitable locations

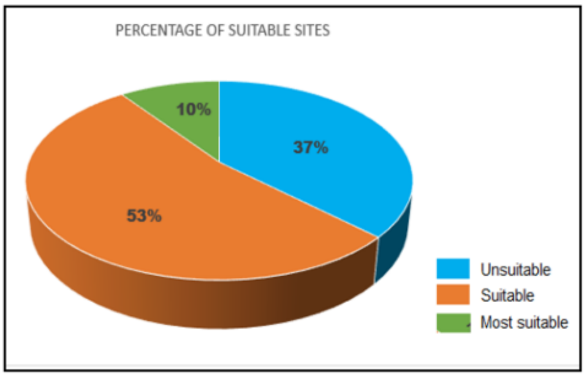

Figure 5: Pie Chart of Suitability analysis

removed from the new layer. This extraction of the optimal position was done using the con tool in spatial analysis. From the result in figure 5, it was determined that 53% of the research area was suitable, 37% was unsuitable, and only 10% was determined to be the most favorable location.

CONCLUSION

There are two main objectives for this study. The first step is to establish pertinent criteria for suitable locations for primary healthcare facilities in the study area. This is crucial because primary healthcare facilities are distinct from other types of healthcare facilities and have characteristics that set them apart from them. Using six influential factors; a water body, a population, a land use or land cover, a slope, a road, a residential area, and the service area of an existing PHC facility. These factors were divided into three main groups: socioeconomic, technical and environmental. The raw data were obtained from several sources.

The second and final goal of this work is to locate potential sites for future PHC facilities in the research area, particularly in neglected political wards. In this study, the best probable locations for PHC facilities were determined utilizing the integration of GIS and MCDA (using AHP). The application of these techniques and instruments in this study has demonstrated their efficacy in the site selection for PHC facilities. Therefore, a model to find the best sites for new PHC facilities was proposed by the research.

The study has also filled a gap in the body of knowledge by demonstrating the value of GIS, MCDA and AHP approaches in addressing the issue of PHC facility site location in Ado LGA of Ekiti State, Nigeria.

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