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GIS-MCE based suitability analysis for sustainable estate development in Ede North LGA Osun State, Nigeria

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Abstract

Ideal areas for housing developments that are, for the most part, sustainable present critical issues in the planning and development of eco-friendly urban settlements. With this in mind and explicitly, Ede North LGA of Osun State was chosen as the case study, where a methodological framework for a land suitability analysis was adopted to identify suitable lands for real estate development with sustainability as a focus in the realization of global UN goals. This present study falls within the framework of the Multi-Criteria Evaluation (MCE) analysis, which can be integrated into Geographic Information Systems (GIS) together with the Analytic Hierarchical Process (AHP), useful for decision-making in site selection studies. For this purpose, computed relative weights from the pairwise comparisons (AHP) of 5 sub-models, i.e., terrain, environmental, socio-economic, available land, and soil factors, were inserted into the suitability analysis function of GIS and combined in a 'Weighted Sum' overlay operation to produce a final suitability map on a scale of 1–5, with 5 being the highest preference. Lastly, the 'Locate Region' Spatial Analyst tool was applied to the final suitability map to locate three (3) optimum locations to site the estate developments. Conclusively, in view of the analysis and discoveries made in this research, finding optimum locations via the GIS-MCE-based land suitability model for future housing development needs may prove highly resourceful. Hence, this study can likewise give a significant direction to future land use changes and practical and cost-effective arrangements in urban areas where conditions are similar to those in Ede North LGA.

Keywords: *Sustainable Housing, GIS, Multi Criteria Evaluation, AHP, LGA Osun State.*
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I. INTRODUCTION

This Housing is a necessity; it is one of the vital and essential needs of man. It incorporates all the modifications carried out on the environment by man. In modern times, however, housing has taken a different approach as it now carefully and deliberately incorporates a sustainability approach to its design and growth. A residential building and its environment will directly influence humans. Subsequently, sustainable development is impossible without sustainable building and housing [1]. Government development programs generally place housing development as a necessary viewpoint in that cycle. It covers wellbeing, training, business, culture, crime, and numerous different parts of life.

Presently, housing developments are now more centered around those that can meet the social, natural, and monetary requirements of individuals [2]. Hence, engineers set forth energy to construct houses that are more affordable, innovative, harmless to the ecosystem, and energy efficient. This large number of components are significant elements that could influence the general presentation of housing developments. In light of the embodiment of sustainable development, sustainable housing development intends to guarantee superior personal satisfaction for present and future generations. It ought to join and decidedly coordinate the physical, social, natural, and economic elements of sustainability. Furthermore, sustainability aims at deriving maximum benefit through the construction of environmentally friendly and socio-economic development structures while still minimizing hazards to the present and future generations and the environment as well. The purpose and design of housing projects within the built environment is the consequence of several factors, such as:

- Use i.e. Residential, Commercial or industrial.
- Environmental factors such as planning requirement, building regulation, land restriction, subsoil condition, topography of terrain and viewing aspect etc.
- Physical conditions such as the contours and shape of the land, the regular vegetation and the encompassing climatic conditions.

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More often than not, the present needs of man, as it concerns housing, also incorporate the resolve to solve the various challenges that come with it. An example of this is in the area of urbanization and its effect on driving an influx of people into a region based on the availability of infrastructure and services. These factors tend to increase the number of people in a particular region while leaving other places barren. A population explosion in a region of space can bring about pollution, waste implosion, and environmental degradation if left unchecked. The amount of urbanization is one of these things that changes how land use plans are made. On a global scale, urbanization has been identified as an all-inclusive phenomenon occurring everywhere. Due to the expansion in human population, the economy, and infrastructure drive, urbanization expansion has some advantages as it tends to improve the socio-economic condition of a society. However, whenever left uncontrolled, it tends to adversely affect ecological degradation, prompting an imbalance in land use and a shortage of its assets. Spontaneous urbanization prompts infrastructural facilities and a poverty condition [3]. Whereas the Nigerian government housing authorities (NHP) and the Central Bank of Nigeria (CBN) have identified finance as the major impediment to meeting the housing needs of its ever-growing urban population [4]. They, however, failed to take into consideration the sustainability factor, which is comprised of three aspects, specifically environmental, social, and economic. These can be referred to as the "triple bottom line" [5, 6]. Fig. 1 represents each aspect and the relationship between them. Unfortunately, the environmental, social, and economic considerations of such planned projects are often overlooked even though these important factors help create sustainable housing, which is now generally adopted in modern societies because it reduces CO_2 emissions and prevents global warming. In addition, it also helps to reduce the overhead cost of construction materials by seeking more environmentally friendly and easily recycled products, and more importantly, it helps to reduce greenhouse emissions to acceptable United Nations (UN) standards.

Consequently, the backdrop of the uncontrolled urbanization trend in emerging cities in Nigeria and its effect on catalyzing societal problems such as pollution, global warming, waste generation and social inequality among citizens has necessitated a suitability approach to be incorporated into housing policies and programs in decision making. Lastly, in order to locate optimum locations to cite these developments, geospatial technologies, with the MCE approach, offer support for planning due to their ability to combine various geographical datasets and apply algorithms for improved results over larger areas while saving costs [7-10].

The purpose of this research is to determine the best sites for the long-term development of a housing estate using GIS-based suitability analysis and MCE tools. The specific objectives are:

a) *To propagate a methodological system for understanding land use suitability procedures.*

b) *To plan and propagate a GIS-based land suitability for sustainable private use.*

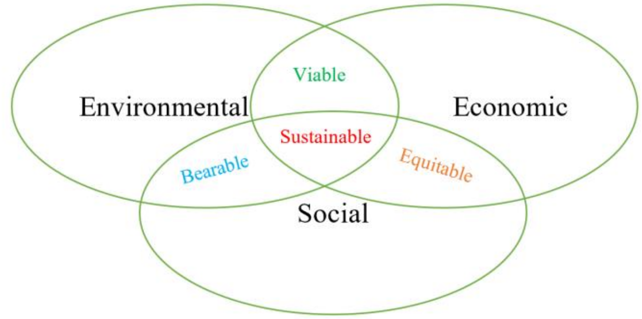

Fig. 1. Modified “Triple bottom line” concept of sustainability [5].

II. LITERATURE REVIEW

The idea of sustainability is broadly utilized in development and land projects. This can be understood by the way that land projects fundamentally affect the natural environment, society, and the economy. The real estate industry is a driver of financial development as it constructs links between the real estate area and different areas, which, thus, plays a critical part in the advancement of the economy. All the more explicitly, as revealed by the European Commission [11], real estate projects are liable for around 40% of energy utilization and 36% of CO_2 discharges in the European Union.

Mallick, et al. [3] developed a methodology for estimating a building’s safe site selection by evaluating a variety of factors in order to assess the safest location for residential building construction for sustainable urban growth. The study identified three broad aspects, namely environmental, physical, and socioeconomic criteria. The GIS-based multi-criteria decision-making approach that combines Fuzzy-AHP and the weighted linear combination (WLC) aggregation method was used to calculate the SSPZ. The final safe site suitability map generated by aggregating all criteria indicates that areas of high and moderate suitability are located near existing living areas, major roads, and educational and health services, and are not located in restricted or protected areas. The findings indicate that using Fuzzy-AHP and GIS techniques will significantly aid in the conservation of the environment. This would significantly mitigate adverse effects on the ecosystem and climate.

Al-Shalabi, et al. [12], in their paper titled "GIS Based Multi-standards Approaches to Housing Site Suitability Assessment", fostered a model to assess the conceivable area of building locations as well as attempted to arrive at a decision on the area of extra housing regions in Sana'a city. In so doing, they utilized a few decision-support apparatuses. For example, high spatial resolution remotely sensed data, GIS), and AHP-based multi-criteria analysis.

Yip, et al. [13] put forward a conceptual framework that consolidates all significant marks of sustainable housing improvement (SHD) that have been created through past reviews of literature and investigations. The focal point of the review was to accumulate indicators of sustainability involved by past analysts in concentrating on sustainability, especially in housing development. It was observed from numerous previous studies that the focus was just on a couple of explicit aspects of sustainability. This can influence the general appraisal of housing sustainability and actual sustainable results. The inspected indicators and conceptual framework can be utilized in surveying housing development completely.

Ibem and Azuh [14] introduced a framework for the assessment of the sustainability of housing programs for public consumption in developing nations. A gap between the theory and application of the concept of sustainability was proposed as useful in proposing a solution to practical earth issues in the creation and utilization of housing in developing countries. It contends that the lack of a complex assessment system for evaluating the long-term environmental, innovative, economic, and social outcomes of public housing programs is partially liable for this turn of events. The framework fundamentally speculates an immediate connection between the results and sustainability of public housing programs and recommends the reception of housing and neighborhood climate quality, housing affordability, personal satisfaction, proof of conservation of social legacy, as well as specialized practicality as boundaries for evaluating key elements of supportability of public housing plans.

Sustainable housing advancement is no more peculiar to the social, economic, and environmental issues that can influence the performance of sustainable structures. Financial sustainability challenges include maintaining a high and stable level of development and job opportunities; further developing project delivery; and expanding benefit and efficiency. From the environmental angle, issues of sustainable structures emphasize the protection of the climate by keeping away from contamination and safeguarding and improving biodiversity. Other than that, energy preservation, further developed energy effectiveness, and efficient utilization of assets are likewise the difficulties inborn in the structure's sustainable turn of events. Social sustainability for sustainable structures connects with issues in friendly advancement, which perceives the needs of everybody. Concern for employees, collaboration with neighborhood networks and street clients, and the formation of associations are critical issues for social sustainability [15].

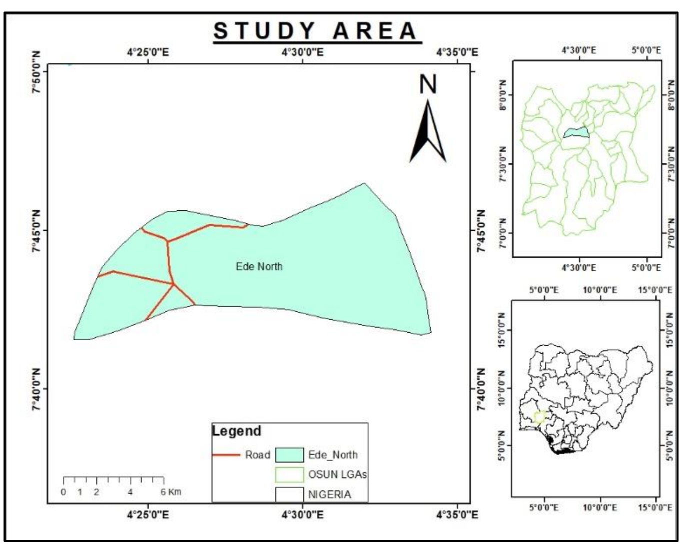

Fig. 2. Map of Study Area (including inset)

III. Material and Methods

The study area for this exercise is Ede North. It is a Local Government Area in Osun State, south western Nigeria with headquarters at Abeere. It has an area of 111 km^2 and a population of 83,831 (2006 census). This area is located close to the north of Osun state, bounded by Egbedore LGAs to the North and West, Ede South LGA to the South and lastly by Osogbo and Atakunmosa West LGAs to the East (Fig. 2).

The boundary of the study area extends between $7^0 40' - 7^0 50'$ N latitude and from $4^0 20' - 4^0 35'$ E longitude and the elevation ranges from 236 m to 398 m above sea level. The area is also drained by the Osun River (not shown in map).

GIS is an important tool used for handling spatial data in land use analysis. For the purpose of this study, the methods employed are the integrated GIS-Multi Criteria Evaluation (MCE) Analysis and the popular Analytical Hierarchical Process (AHP) techniques for determining preferences or weights to selected criterion in order to identify the most probable locations for development of real estate projects in Ede, Osun state. In principle, the GIS-based MCE could be described as a process that combines various geographical datasets as' input 'and' transforms them into a resultant decision representing an' output'. The output, in the form of a map, defines a relationship between the input and the output through the MCE procedures (or decision rules). The procedures entail the use of geographical datasets, the decision maker's alternatives or choices, and the manipulation of the datasets and alternatives according to some certain decision rules [16]. The study adopts the ESRI's GIS-MCE suitability modelling workflow [17], while Fig. 3 shows the methodological framework of the study used to achieve the aim. The workflow is given below:

1. Determine criteria, models and sub models
2. Derive criteria (generate maps and layers of each model)
3. Transform the layers to a common suitability scale
4. Determine their weights by pairwise comparison (AHP)
5. Combine layers by weighted sum overlay analysis (multiply weights)
6. Generate final suitability map
7. Locate optimum sites

Essentially, the suitability analysis functions as an effective geospatial tool for incorporating multi-dimensional variable datasets, generated from different sources, into one ultimate map. Among the various methods often used, the weighted suitability analysis was preferred and hence chosen for defining the suitability for the purpose of residential land use. In addition, working with raster data for the weighted overlay suitability analysis allows us to arrive at a solution for a multi-criteria problem quickly and easily. For this purpose, Spatial Analyst extensions and tools, such as the model builder in ArcGIS, have been used in performing the analysis. However, GIS applications have been found to be not adequate enough to solve the issue of inconsistency when judging and assigning relative preference and importance to each of the many criteria considered in a suitability analysis [18, 19]. In order to address this inconsistency issue and to test the various factors considered in suitability for residential land use purposes, the pairwise comparison techniques (AHP) have been carefully chosen.

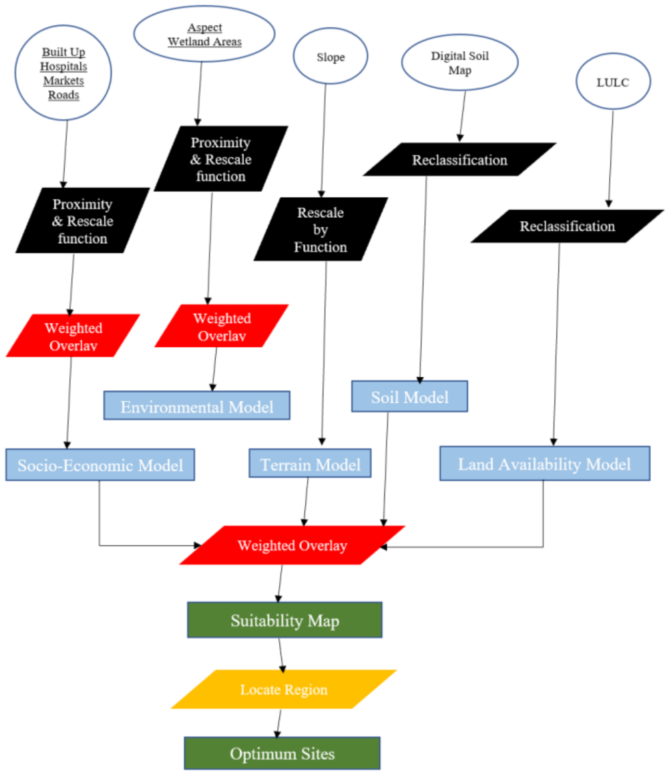

Fig. 3. Methodological framework of study

The data sources for this work comprise both primary and secondary sources. The primary sources include field work to identify the various kinds of infrastructure, as well as collecting coordinates of points of interest that are present in the study area. While the secondary sources of data include SRTM imagery data downloaded from within ArcGIS Pro interphase, This is a 30m by 30m DEM data set made available through the ESRI software. Also, satellite imagery of the study area was downloaded from the USGS website and serves as the basis from which the Land Use map was derived.

The Ecological and Environmental, Socio-Economic, and Infrastructure datasets were sourced from the GRID3 website, a non-governmental organization (NGO) resource website for free geospatial data sets. In GEOJSON file format, they include conservation, built-up, roads, hospitals, schools, markets, and wetlands areas present within the area of study. Field studies to actual areas on the ground were used to validate these datasets.

This was done to ensure accuracy in the results of the analysis. The datasets on the proximity to roads, streams, and built-up urban areas were derived from the infrastructure datasets using the Euclidean distance analysis in ArcGIS Pro. Lastly, the geological and soil datasets were sourced from a digital soil map database of Nigeria hosted on the Mendelev Data website. It contains shape files of soil texture maps of Nigeria, through which the study area was extracted for the analysis. Below is Table I showing the Criteria, Sub-models and their sources:

TABLE I. CRITERIA SELECTION FOR SUITABILITY ANALYSIS

S/N	Criteria/ Model	Sub-model	Source
1	Terrain (Elevation)	Slope	DEM imagery from ESRI's ArcGIS Portal
2	Environment/Ecology Factors	Aspect, wetlands/surface water/Rivers, conservation areas	DEM imagery from ESRI's ArcGIS Portal, Field studies, Admin Maps, GRID3
3	Socio-economic Factors	Proximity to Built Up/Hospitals/power/Market/Police Stations/Roads	Admin maps, Field studies, GRID3
4	Available Land Resources	Land Use/Land cover	Satellite Imagery from USGS, Field studies
5	Earth (Soil) condition	Geology, Soil	Field studies, Mendelev Open Data (Open Digital Soil map Database of Nigeria)

A. Determination of Criterion

The land use suitability analysis essentially took into account various criteria based on sustainability factors such as physical, environmental, social, and economic constraints, among others [3, 6, 7, 20, 21]. These factors are widely supported in literature and tend to impact on how sustainable a construction project is based on its ability to employ materials that are cheap and can be easily recycled, for example, or improve the quality of life of people and understand the physical conditions of the ground or terrain in order to gather relevant information that will be useful in trying to minimize environmental hazards, etc. Bearing these factors in mind, the factors considered include; natural capacity of land use such as available land; their physical conditions as it relates to construction, i.e., geology and/or soil; socio-economic, terrain, and environmental variables as the case may be.

Analysis of the data collected for this study included the extraction of slope, aspect wetlands, surface water, and river datasets and maps from the DEM of the study area. This task was carried out within ArcGIS Pro 2.8 using the Surface and Hydrology Toolbox set. This was, however, complemented by field studies and the data gotten from the GRID3 website. The GRID3 (Geo-Referenced Infrastructure and Demographic Data for Development) programme is an embodiment of a larger global initiative which aims to enhance access to data for decision making in all participating member countries, of which Nigeria is among them.

For the Land Use map derivative, satellite images (USGS) acquired for the region under study were processed to enhance the image attributes and features and so improve interpretation procedures. Then, the processed image was then subjected to a supervised classification workflow using Support Vector Machine techniques and image segmentation in ArcGIS 2.8

Pro. The result of supervised classification was subjected to an accuracy assessment by visual inspection with the 2020 ESRI world land cover data of the region under study. It seems to agree with the data that the observed changes could be attributed partly to the judgment and experience of the interpreter and also to the effects of time-induced natural changes in the earth's biophysical features.

The GIS suitability analysis workflows (see methodology) involve steps focused on establishing a set of criteria and sub-criteria and deriving the map derivatives such as factor maps of distance and proximity based on the available information on suitable housing demands. After that, the pairwise comparison method/matrix known as the AHP method was used to generate relative weights. Then, the derived relative weights were afterwards computed manually, keeping a view of the consistency ratio (CR) in order to prevent bias through criteria weighting. If CR is satisfactory, i.e., within prescribed limits (10%), the computed weights will be recorded for further processing.

Finally, the factor maps are transformed to a common suitability scale (1–5), with 5 being the highest, and combined with the weighted sum overlay analysis tool in the ArcGIS Pro Software.

B. *AHP Criteria Weight Derivation*

The APH criteria and their weight are summarized in Tables II – V.

TABLE II. CRITERIA PAIRWISE COMPARISON

	Terrain Factors	**Environment Factors**	**Socio-Economic Factors**	**Available Land Resources**	**Soil condition**
Terrain Factors	1	0.5	0.33	0.11	0.2
Environment Factors	2	1	0.5	0.17	0.25
Socio-Economic Factors	3	2	1	0.2	0.33
Available Land Resources	9	6	5	1	2
Soil condition	5	4	3	0.5	1
Sum	**20**	**13.5**	**9.85**	**1.98**	**3.78**

TABLE III. NORMALIZED MATRIX

Criteria						**Weights (Avg.)**
Terrain Factors	0.05	0.037037	0.033571	0.055556	0.05291	**4.6**
Environmental Factors	0.1	0.074074	0.050865	0.085859	0.066138	**7.5**
Socio-Economic Factors	0.15	0.148148	0.101729	0.10101	0.087302	**11.8**
Available Land Resources	0.45	0.444444	0.508647	0.505051	0.529101	**48.7**
Soil condition	0.25	0.296296	0.305188	0.252525	0.26455	**27.4**
Total						**100 (%)**

TABLE IV. CALCULATION OF WEIGHTED COLUMNS

						Weighted Sum
Terrain Factors	0.045815	0.037694	0.038821	0.053619	0.054742	0.23069072
Environment Factors	0.09163	0.075387	0.058819	0.082866	0.075	0.38370216
Soci0-Economic Factors	0.137445	0.150774	0.117638	0.09749	0.099	0.6023466
Available Land Resources	0.412335	0.452322	0.58819	0.487448	0.6	2.540295
Soil condition	0.229075	0.301548	0.352914	0.243724	0.3	1.427261

TABLE V. CALCULATION OF EIGEN VECTORS

Weighted sum	**Criteria weight**	**Weighted sum/Criteria weight (Consistency Vectors)**
0.23069072	0.045815	5.035266179
0.38370216	0.075387	5.089765609
0.6023466	0.117638	5.120340366
2.540295	0.487448	5.211417423
1.427261	0.273712	5.214462647
	Average λ_{max}	**5.134250445**

Consistency Index 'C.I' $= \frac{(\lambda \max - n)}{n-1}$ (1)

$$= \frac{(5.13-5)}{5-1} = 0.034$$

Now, Consistency

'C.R' $= \frac{C.I}{R.I}$ (2)

but Ratio Index (from Saaty)

'R.I' = 1.12 for n = 5 (3)

Hence 'C.R'$= \frac{0.034}{1.12} = 0.03$

'C.R' = 0.03 i.e. 3%

The consistency index, 'CI', is therefore calculated using the formula above, which gives 0.034. The Consistency Ratio 'CR', using the equation above and the R.I. value of 5 criteria from Saaty's table, is calculated as 0.03. This is equivalent to 3%, which is less than the maximum limit of 10%. Hence, these values can be adopted.

IV. RESULTS AND DISCUSSIONS

The study set out to utilize the GIS-based suitability analysis to identify optimum sites to establish a real estate development project with sustainability as the core focus. This project can either be adopted for government or private use as a policy-making document to aid decision-making and for commercial purposes. Data was collected based on a carefully selected set of criteria with a focus on sustainability, i.e., socio-economic and environmental/ecological factors; topological and ground conditions. These criteria guide the output of the data analysis, which is in turn presented with discussions on them.

A. Slope and Aspect

The slope of the region under study is given in the Fig. 4. It shows that the region is fairly level with a low range of values, varying between 0 and 10^0. The highest regions are to the east, in small patches. All buildings are sited on the earth's surface, whereas the shape or degree of inclination has an effect on the design considerations of foundations, their materials, and also on costs. The slope of the area suggests the stability of the ground slope, which is in turn beneficial to the design of buildings.

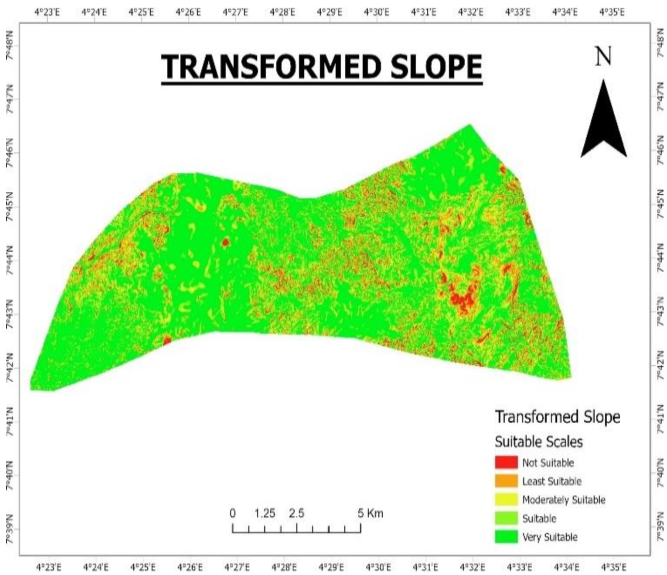

Fig. 4. Transformed Slope

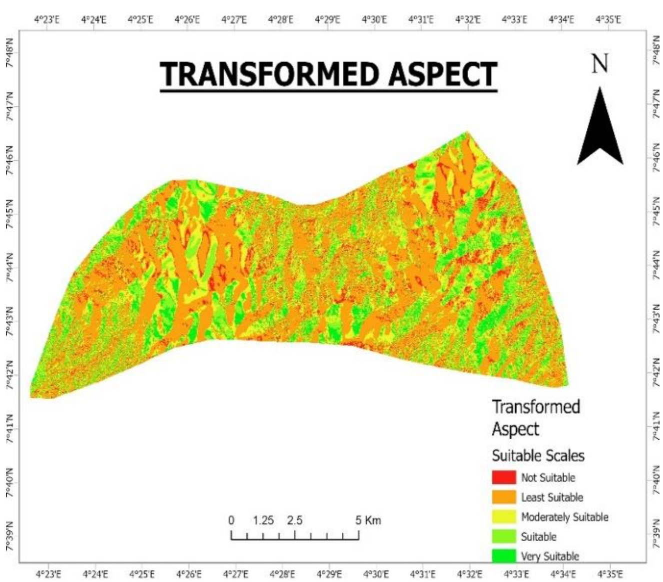

Fig. 5. Transformed Aspect

The aspect gives the slope direction with respect to the position of the sun. Due to the fact that an increase in electricity production from non-renewable energy sources, e.g., hydrocarbon sources, leads to a gradual depletion of natural resources, and has a negative effect on the environment [22]. As a result, alternative and renewable energy use (sun) is critical in the consideration of sustainable housing. From the dataset, the areas sloping East, South, East and flat beds are suitable for adoption and are therefore used in transforming the maps to a suitability scale of 1–5, with 5 being the most suitable (Fig.s 4 & 5).

B. Land Use and Availability

The land use/land cover of the study is presented below. It shows the land use classes present in the study region, which have been transformed to a common suitability scale of 1–5 (5 being the highest preference). It shows that the most preferred areas are in green while the non-suitable regions are in red, representing the wetland areas on the map. The land use map was then reclassified into two classes to identify and distinguish available land resources in the region, which included barren, cultivated land, and forests, from unavailable land, which included the remaining classes (Fig. 6 & 7).

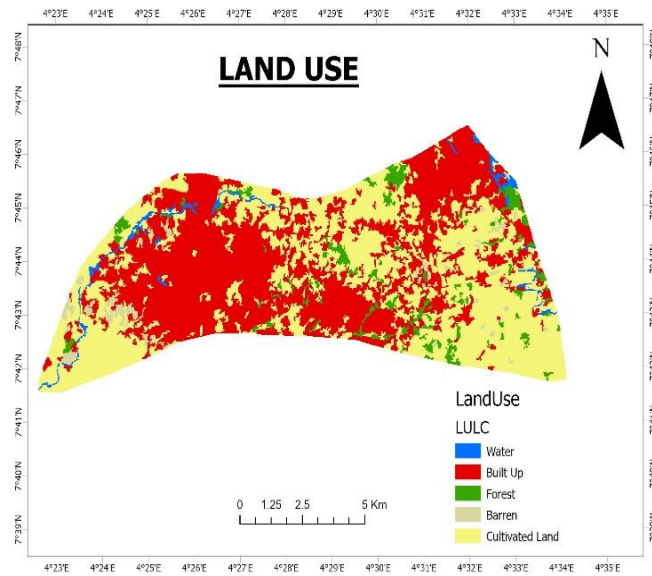

Fig. 6. Land Use

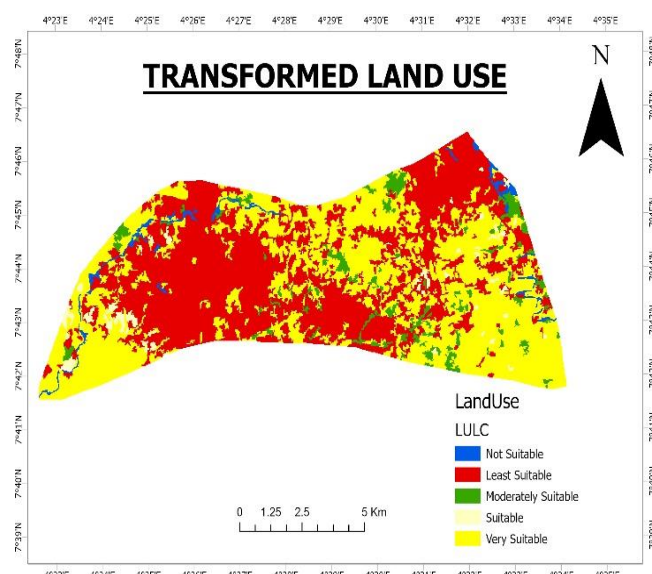

Fig. 7. Transformed Land Use

C. Soil Texture Maps

The soil texture maps (Fig.s 8 & 9) show the spatial variation in the soil particle sizes and their classes. This, in turn, is found to be connected to the bearing capacities of the soil with respect to engineering applications [23]. Building substructures are erected in the uppermost surface layers (soil) of the earth, and they operate as a support for the building by safely transferring the loads of the building onto the ground. As a rule, soil conditions can be inferred from the geology since they are related by history. The graphic below (Fig. 8) shows the study area is overlain mostly by sandy loam soils, followed by sandy clay and, lastly, clay loam soils. The second picture (Fig. 9) is a reclassified image of the soil map that has been turned into a suitability scale. It shows that sandy loam is the best type of soil (green) for building homes on.

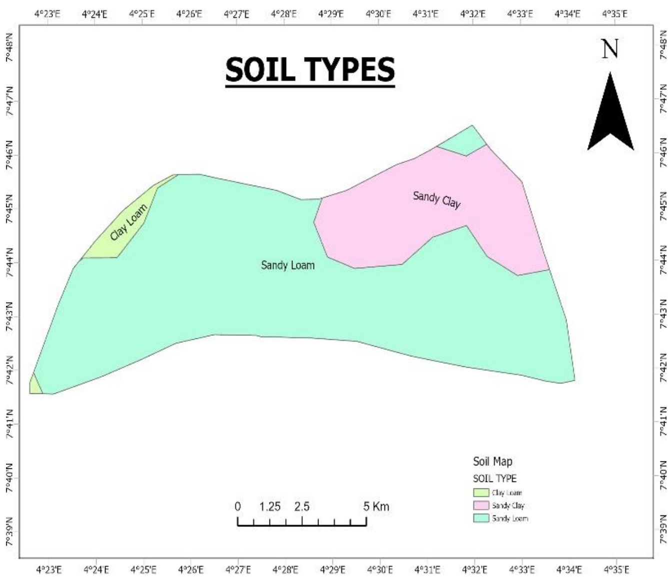

Fig. 8. Soil Texture Map

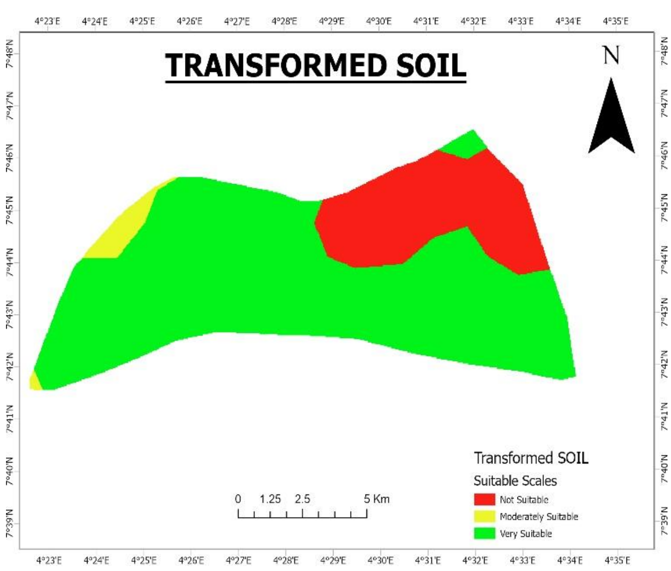

Fig. 9. Transformed Soil Map

D. Socio-Economic and Environmental Criteria Maps

Depending upon distance accumulated and reclassification, 16 criteria maps were prepared separately based on environmental and socio-economic factors (Fig. 4-19). For preparing the map of accumulated distances (in map units), appropriate distances representing proximities to target criteria are identified. Thereafter, these maps were then transformed by the 'Reclassify by function' tool to represent the suitability level of 1–5, with 5 being the most suitable preferred locations. The degree of nearness to infrastructural facilities such as roads, hospitals, markets, police stations, and built-up areas was considered for socio-economic factors among other sustainability models in this study. Distances away from wetlands, on the other hand, were carefully selected in the analysis and transformed to a suitability scale of 1-5 as needed. This was done to exclude areas that do not possess the needed criteria from the suitability analysis.

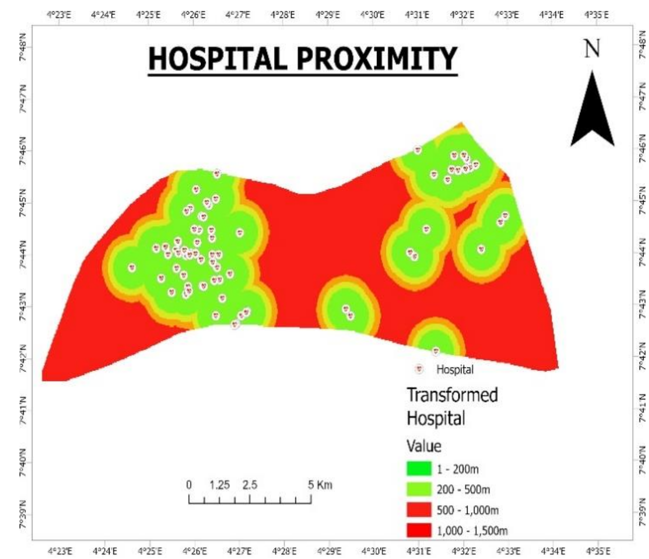

Fig. 10. Distance Accumulation (Hospitals)

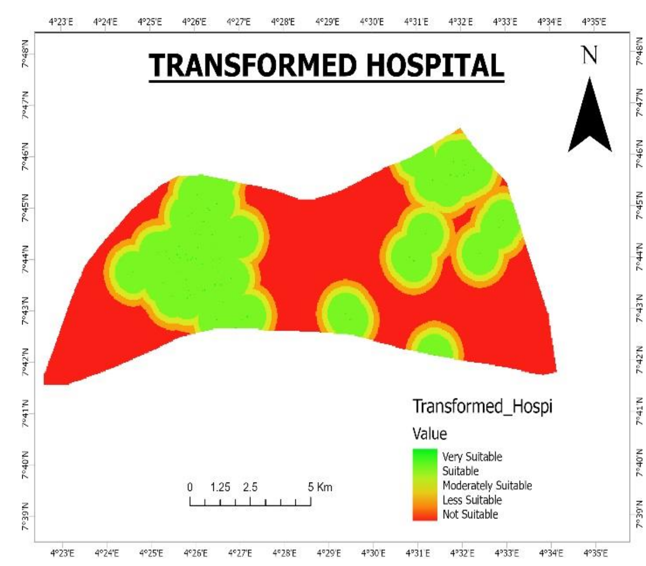

Fig. 11. Distance to Hospitals (Transformed)

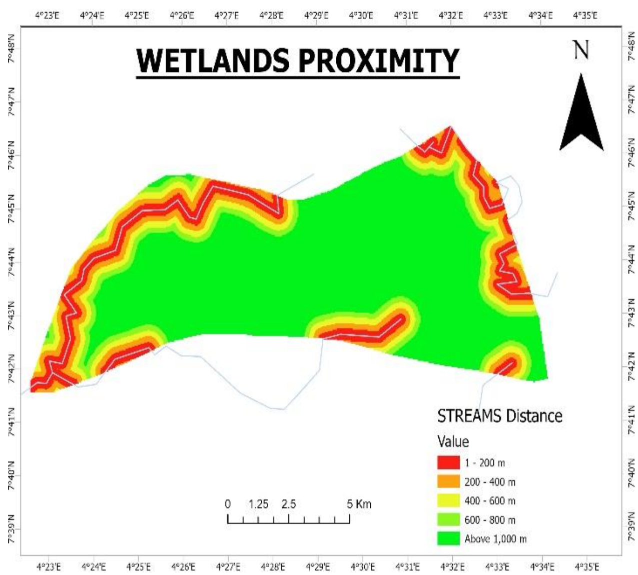

Fig. 12. Distance Accumulation (Wetlands)

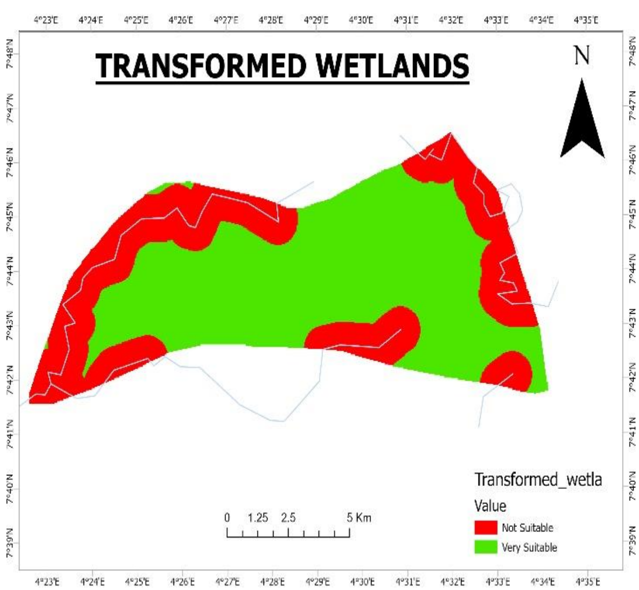

Fig. 13. Distance to Wetlands (Transformed)

E. Final Suitability Map and location of Optimum Sites

The criteria Sub-model maps, which were all in raster format after being transformed to the same suitability scale, are then combined together in a simple weighted sum OVERLAY operation in ArcGIS Pro. The result is a final suitability map (Fig. 20) of the region under study expressed on a preference scale of 1–5, (symbolized as Red to Green) representing Not Suitable to Very Suitable scales. The red corresponds to areas that are to be avoided in the location of optimum sites, while the green (deep) represents the most probable locations that are selected by the analysis.

Finally, the 'Locate Region' tool in ArcGIS Pro was used in pinpointing the optimum locations to site these real estate developments. It is a Spatial Analyst tool that uses powerful algorithms to select the pixel-by-pixel classes (from the final suitability map) that correspond to the best regions that satisfy the evaluation criterion. The result is a new layer (Fig. 21) which identifies three (3) optimum locations on the map that can sustainably erect a real estate construction building within Ede North LGA of Osun State.

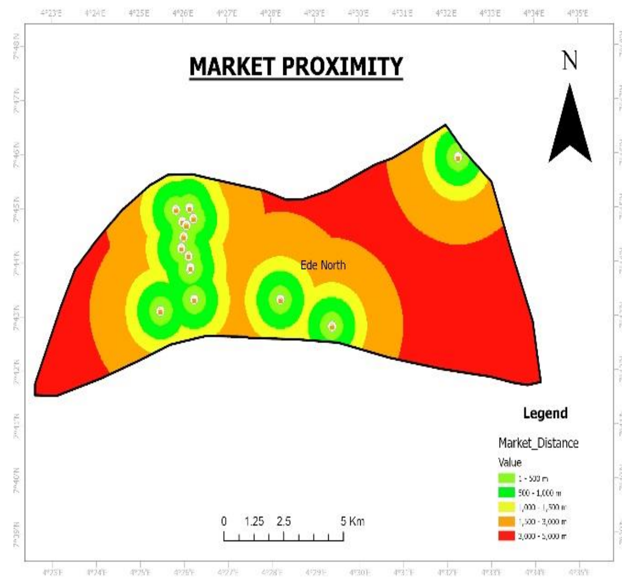

Fig. 14. Distance Accumulation (Markets)

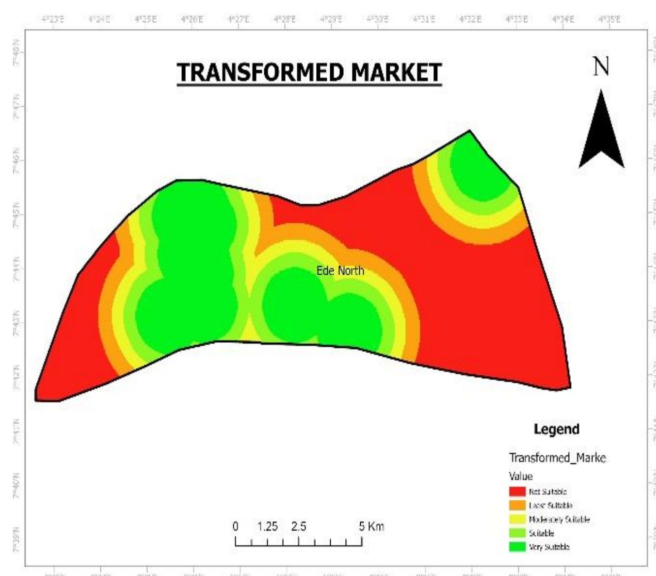

Fig. 15. Distance to Markets (Transformed)

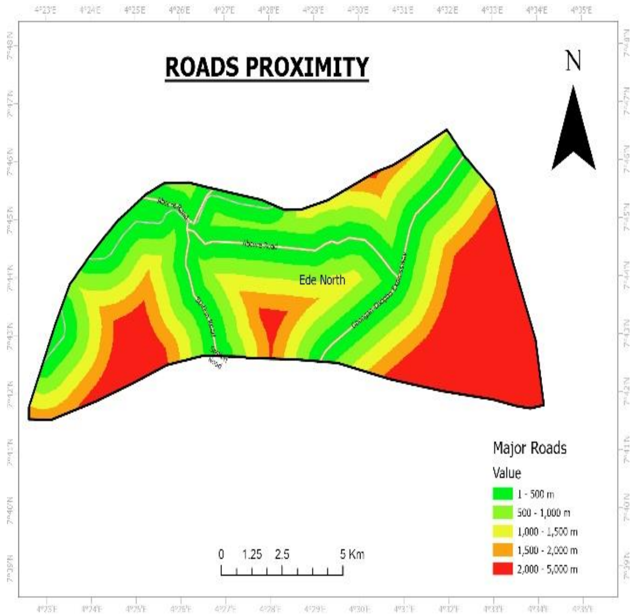

Fig. 16. Distance Accumulation (Roads)

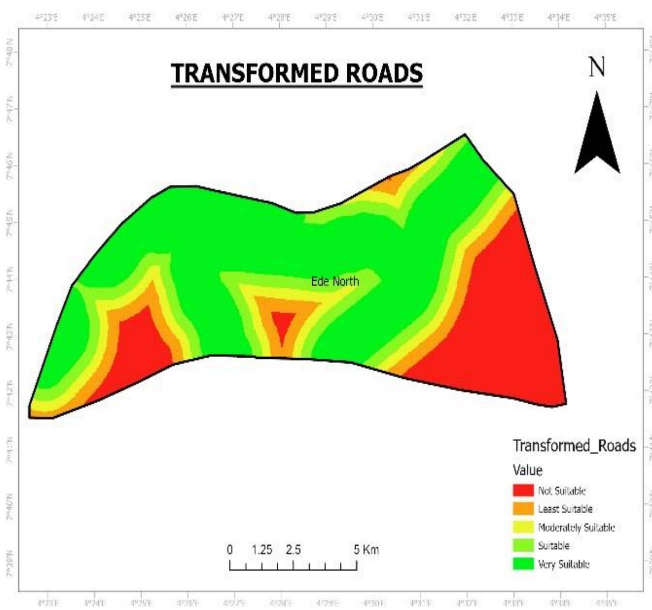

Fig. 17. Distance to Roads (Transformed)

V. Conclusion

This present study focused on the use of integrated multi-criteria AHP with GIS to determine the suitability of a sustainable real estate development in Ede North LGA of Osun State. The sustainable planning approach has largely not been considered or has been overlooked by authorities, in terms of citizens' housing needs, that is needed essentially for the growth of the city and that protects the environment at the same time.

However, the GIS based MCE suitability analysis has proven to be useful in determining suitable land for urban development using the multi-criteria AHP integration. Planning standards for optimal locations are not the only important consideration in the planning process. However, this study considered the criterion as sub-models as well as sustainable distances away or from infrastructural facilities like roads, markets, wetlands, etc..

The results show the accumulated distances of ecological factors and infrastructural facilities (e.g. roads), as well as reclassified terrain, land use, and ground conditions (soil), all transformed to a common suitability scale of 1–5, with 5 being the highest. The respective weights of the sub-models were socio-economic (12%), environmental (7%), terrain (5%), available land use (49%), and soil (27%) as derived by the Analytical Hierarchical Process (AHP).

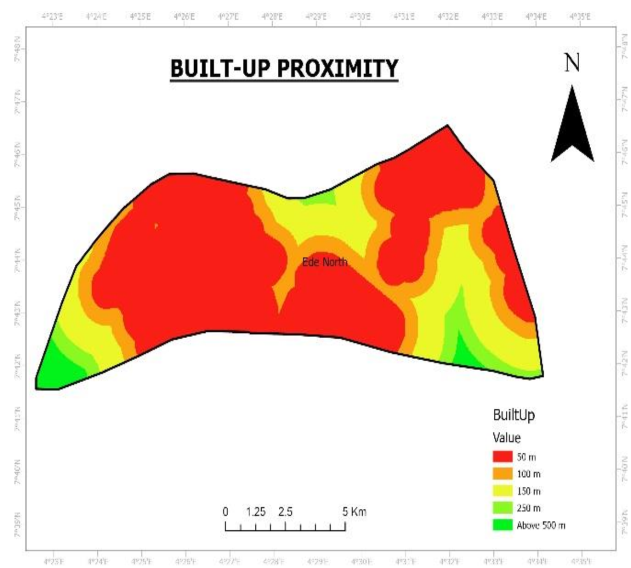

Fig. 18. Distance Accumulation (Built Up)

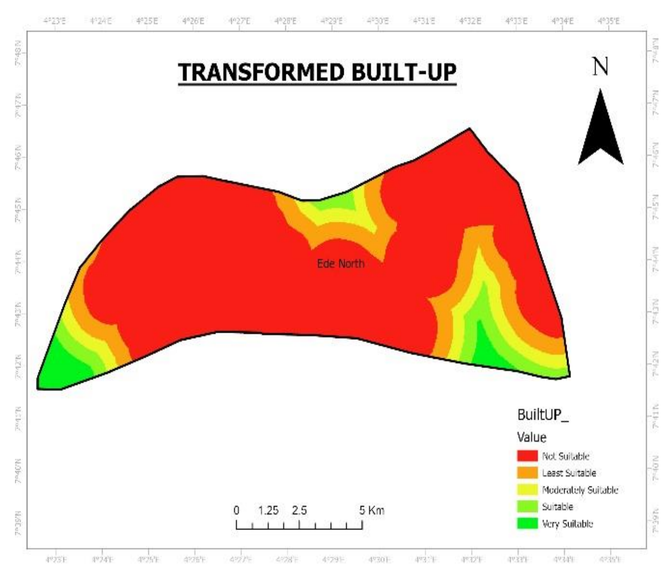

Fig. 19. Distance to Built Up (Transformed)

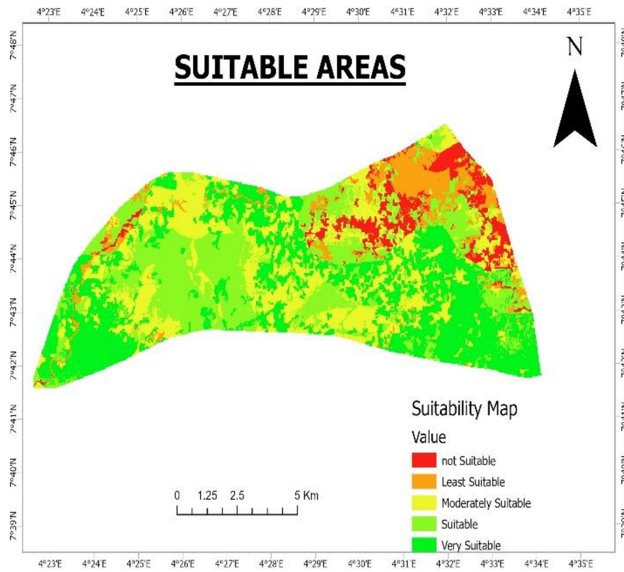

Fig. 20. Final Suitability Map

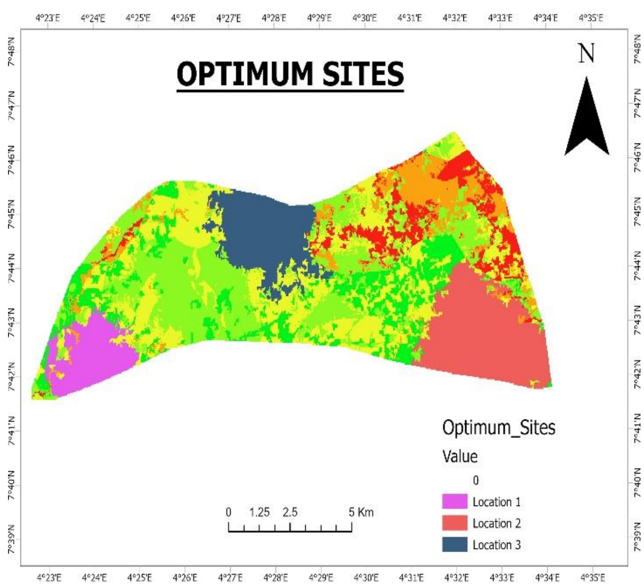

Fig. 21. Optimum Location Sites

The final suitability map was obtained by combining the sub-model datasets in a simple 'Weighted Sum' overlay operation using the Spatial Analyst toolset within ArcGIS Pro. The output represents a suitability scale of 1–5, with 5 being the highest (Fig. 20). Finally, the 'locate region' tool was used to automatically select three (3) best locations to site the sustainable real estate development. This tool uses a powerful algorithm to select appropriate pixels based on the constraints set in the suitability analysis.

Conclusively, this study can assist in providing a framework for the developmental planning process by using GIS and the Multi-Criteria Evaluation (MCE) analysis for any region in Nigeria. Likewise, it also presents the advantages of integrated GIS-based land suitability analysis as a solution for such complicated decisions. Therefore, this study can also provide important guidance for future land use changes and cost-effective solutions in the cities, where conditions are similar to those in Ede North LGA.

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