Contribution to the optimization of urban planning using GIS to address the affordable housing shortage in the city of Yaounde

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Abstract: The rapid urbanization of Yaounde intensifies rural exodus, resulting in an increasing housing deficit. This situation poses major challenges in urban planning, requiring innovative solutions to meet the growing needs of the population. In this context, the use of Geographic Information Systems (GIS) could be a promising approach to optimize land management by integrating spatial data. The purpose of this study was to develop a multicriteria analysis based on a suitability model to identify all areas suitable for affordable housing projects. To achieve this, the methodology adopted involves three main steps: identifying criteria, transforming these criteria into a common suitability scale, and creating the suitability model by weighting the transformed criteria. As a result, a synthesis map was created using seven criteria: residential areas, slopes, altitudes, humidity index, market prices, and accessibility to major roads and the power grid. These criteria could be more precise if the Yaounde City Council made updated urban infrastructures data publicly available. Additionally, for better social inclusion, it would be wise for the State and its relevant institutions to consider the actual income of the average Cameroonian citizen to make housing offers more accessible.

Keywords: Urban planning, affordable housing, criteria, Geographic Information Systems, suitability model.

1. Introduction

According to the urban development report published by the UN on July 10, 2014, more than half of the seven billion inhabitants of planet Earth, or 54%, live in cities (Tadjie, 2018). These numbers are expected to continue growing in the coming years. The population explosion, mainly driven by an increase in birth rates and a pronounced rural exodus, particularly affects cities and varies from one country to another. What lies ahead is nothing less than an "Urban Revolution" (Tadjie, 2018). It is in this context that the Yaounde City Council, in alignment with the Sustainable Development Goals (SDG), has developed an Urban Master Plan (UMP) with a horizon of 2035 to "better promote its urban development." Urban development, aiming to improve the living conditions of the population, places the issue of housing at the center of the challenges currently being faced.

Indeed, Cameroonian metropolises in general, and the city of Yaounde in particular, are facing challenges related to the management of urban land and estates, as well as the uncontrolled and unplanned expansion of slums caused by the acute shortage of affordable housing for underprivileged populations. In this situation, the State of Cameroon struggles to find radical solutions to the lack of accessible housing for all. It is therefore essential to develop a tool capable of advanced visualization of spatial data and providing relevant solution trials in the field of land

management, while modeling the variables involved in mapping and detecting areas with a high housing deficit in the city of Yaounde. Consequently, the question arises: how can GIS serve as decision-support tools to propose potential solutions to the housing deficit, despite the lack of precise data on urban land use in the city of Yaounde?

By situating the housing issue within the current context of Yaounde, it becomes clear that the shortage of affordable housing is a major concern that affects the quality of life of Yaounde's residents and directly impacts the city's urban development. As such, urban planning and housing policies must be adapted to effectively address the growing demand in a rapidly evolving urban environment. Therefore, this work aims to explore innovative solutions based on the use of GIS tools, in order to contribute meaningfully to the optimization of urban planning and the promotion of more accessible and sustainable affordable housing in the city of Yaounde.

Presentation of the study area

This section presents the physical characteristics of the city of Yaounde.

Located in the heart of the Centre region, in the Mfoundi division, Yaounde is situated 250 km from the Atlantic Ocean, between longitudes 11° 20'E and 11° 35'E and latitudes 03° 40' N and 04° 00' N. Yaounde is the political capital of Cameroon and covers an area of approximately 287.98 km², comprising a total of seven subdivisions. Figure 1 shows a situation map of Yaounde.

Since the 1980s, land use in Yaounde has nearly tripled. The dramatic population growth has led to increasing urban sprawl, which explains the uncontrolled and unplanned expansion of slums as well as the growing need for housing. The city has an estimated population of approximately 4.6 million inhabitants (World Population Review, 2024), a figure that continues to rise due to urbanization and internal migration. Yaounde's population growth rate is estimated at 44.6% between 2000 and 2020.

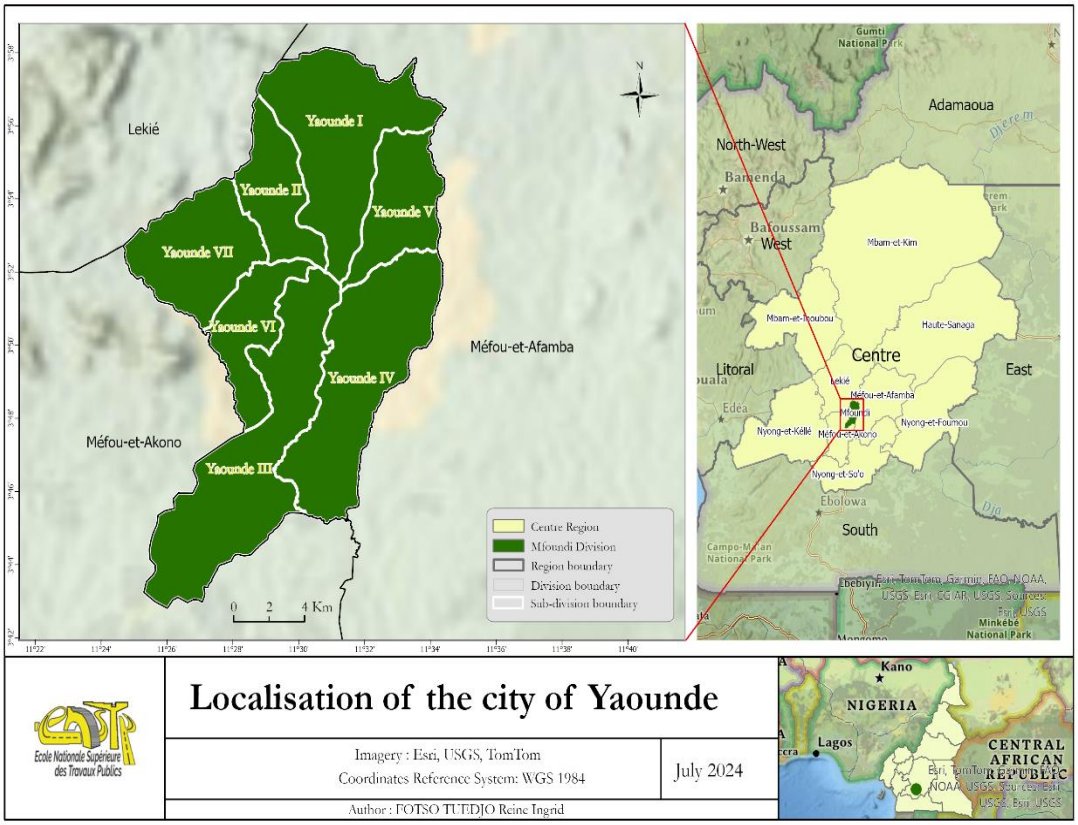

Figure 1. Localisation of Yaounde

2. Methodology

The suitability analysis conducted here is performed using the Suitability Modeler module of the ArcGIS Pro software, version 3.1.

2.1. The identification of criteria

The suitability analysis begins with the identification of criteria to be considered in addressing the core issue, which in this case is determining areas suitable for the construction of affordable housing. The defined criteria are divided into two categories: buildability and site cost.

The data used in this work is sourced from the Yaounde City Council and open online databases. These include administrative boundaries, zoning, the Digital Elevation Model (DEM), real estate price lists, and electrical and road networks. Tables 1 and 2 present the various criteria considered in each category, along with the corresponding data.

Table 1. Cost criteria

Criteria	Required Data
Land price must be lower than the city average	Neighborhood layer containing a land price field from the price index
Proximity to a main road	Major roads layer
Preference for areas with electricity supply	Electrical distribution network layer

Table 2. Constructibility criteria

Criteria	Required Data
Full inclusion in a residential zone	Zoning from the UMP
Preference for moderate slopes	Slope raster
Preference for higher altitudes	Altitude raster
Low moisture index	Topographic Wetness Index

2.2. Criteria data collection and preparation

The necessary layers are obtained from the Yaounde City Council and some open online databases.

The first step involves joining the Price index table to the attribute table of the Neighborhoods layer to add a field for prices per square meter in the attribute table. Next, since the Suitability Modeler only accepts raster layers as input, it is necessary to first convert the shapefile layers into rasters, specifically the layers: Neighborhoods, Major roads, Electrical network and Zoning and extract them based on the boundaries of Yaounde. Linear layers are converted into Euclidean distance rasters to produce a continuous raster over the study area.

Geomorphological factors are also derived from processing the DEM to extract slope, altitude, and TWI rasters.

2.3. Converting each criterion's values to a common suitability scale

The criterion values used and combined in the model must be transformed into a common suitability scale. Assuming a scale from 1 to 10, where the most preferred attributes of the criteria have the highest values and the least preferred have lower values. This transformation is applied to each value for each criterion identified in the suitability model.

2.4. Weighting the criteria

During the creation of a sub-model corresponding to each category, the criteria within the same category are weighted relative to each other based on their level of importance. These weights generally vary from a minimum of 1. In the absence of sufficient expertise, we opted for a holistic approach, considering the relevance of the factors and their relative importance in the analysis. Table 3 presents the different weights of the model.

Table 3. Criteria Weight Assignment

Category	Layer	Weight	Sub-model Weight
Site cost	Neighborhoods	1,5	1
	Major roads	1	
	Electrical network	1	
Constructibility	Zoning	1,25	1
	Slop_srtm	1	
	Extract_tin	1	
	TWI	1	

3. Results

3.1. Treatments presentation

3.1.1. Constructibility criteria

The criteria involved here are inclusion in a habitat zone, preference for moderate slopes, humidity levels, and high altitudes. These criteria stem from urban planning norms that divide the territory into constructible (aedificandi) and non-constructible (non-aedificandi) zones. Table 4 lists the weights applied to generate the constructibility factor and Figures 2 shows the criteria after conversion to the common scale.

Table 4. Weighting of Criteria in the Buildability Sub-model

Criterion	Zoning	Slope	Altitudes	TWI
Weights	1.25	1	1	1

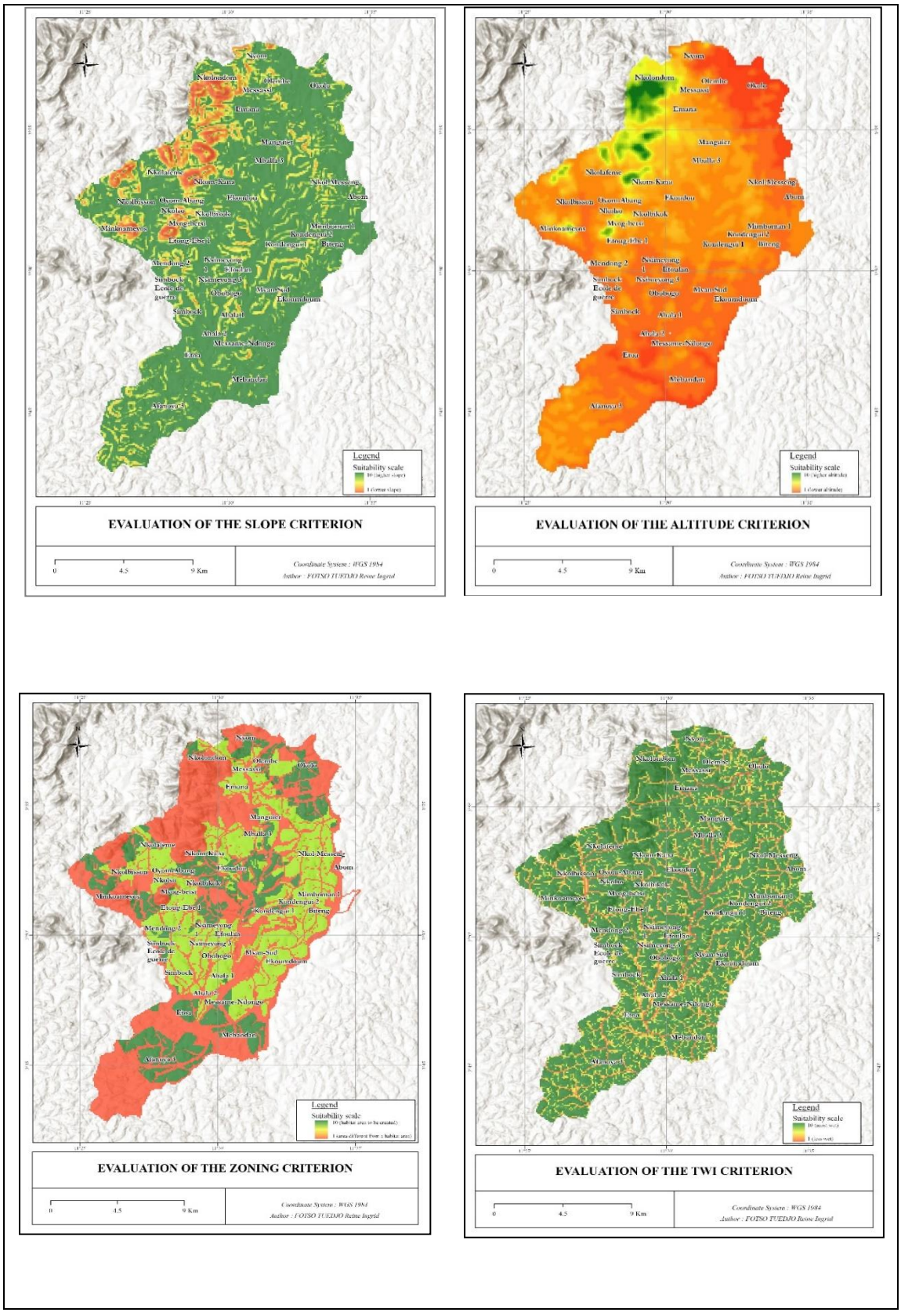

Figure 2. Constructibility criteria maps

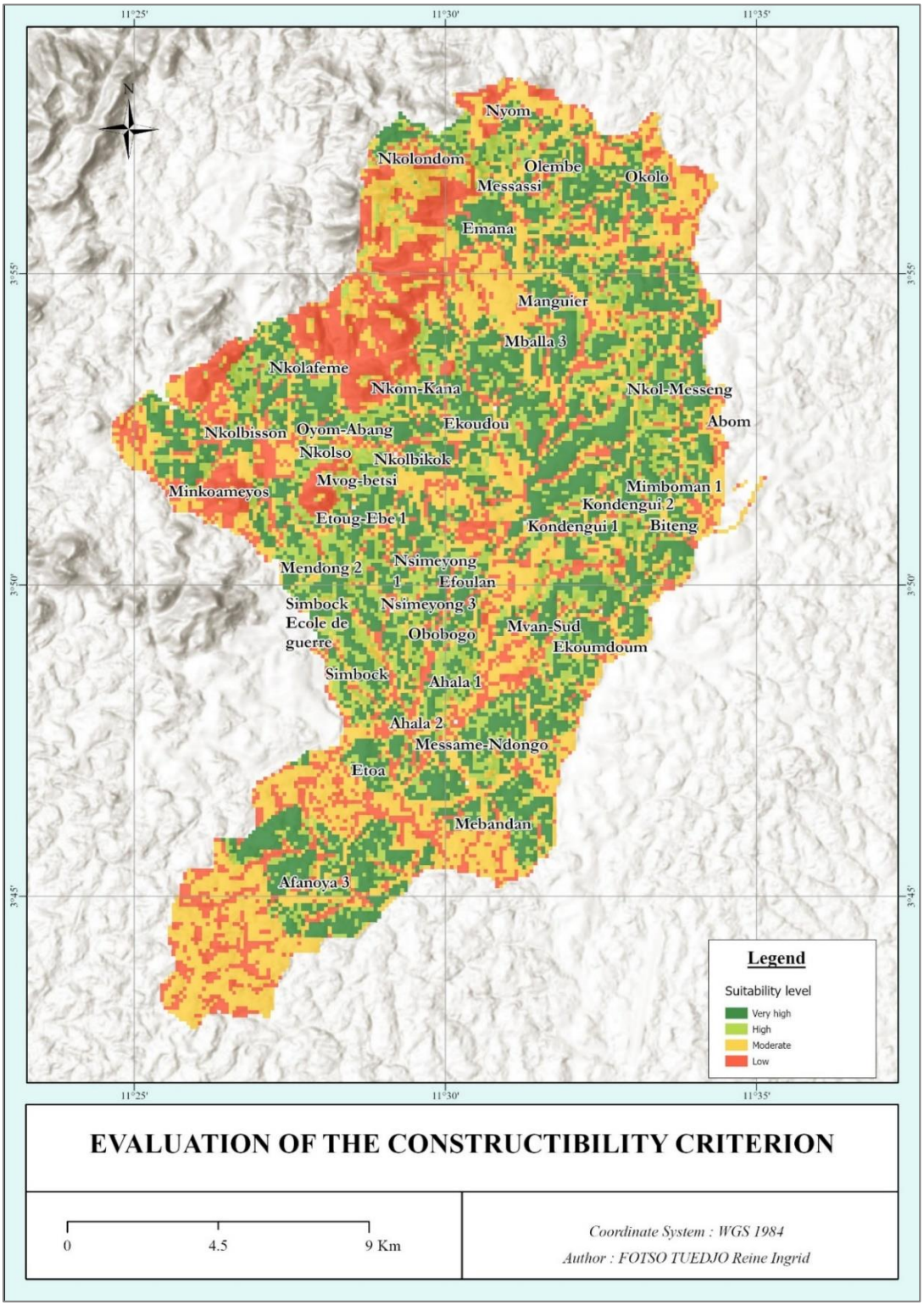

Figure 3. Constructibility Suitability Map

3.1.2. Cost criteria

The criteria involved here are the price of land per neighborhood, the distance to a main road, and the distance to the electrical network. Figures 4 to 6 show the criteria after conversion to a common scale, and Table 5 outlines the weights applied to generate the cost factor.

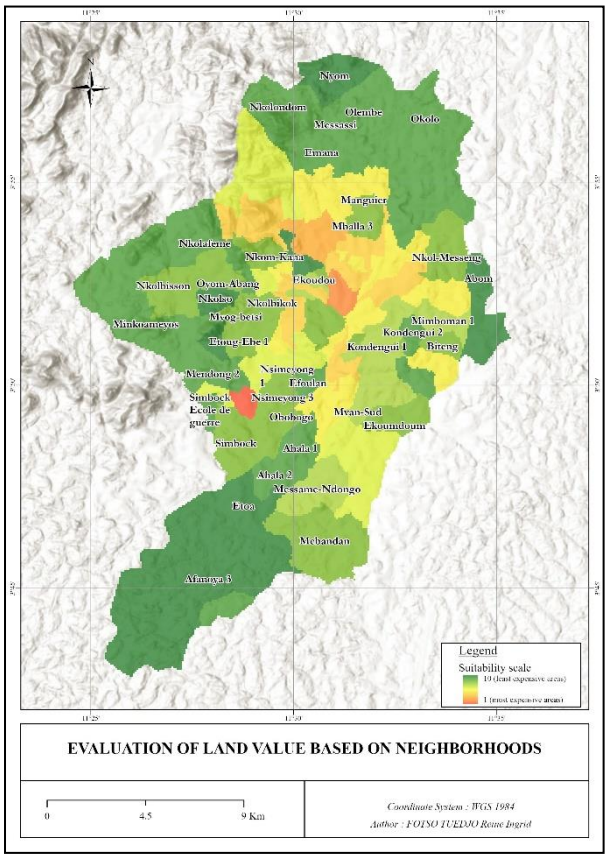

Figure 4. Transformed Neighborhood criterion

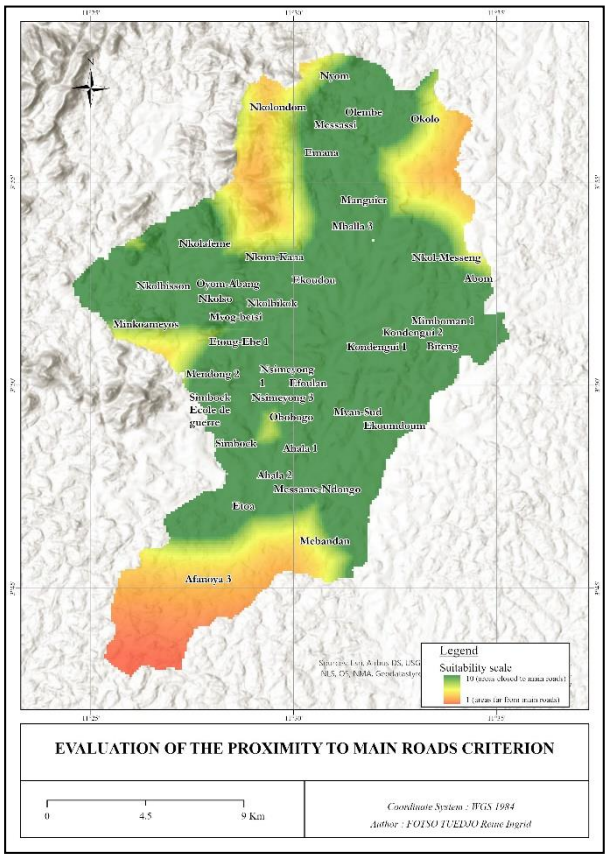

Figure 5. Transformed Distance to Roads Criterion

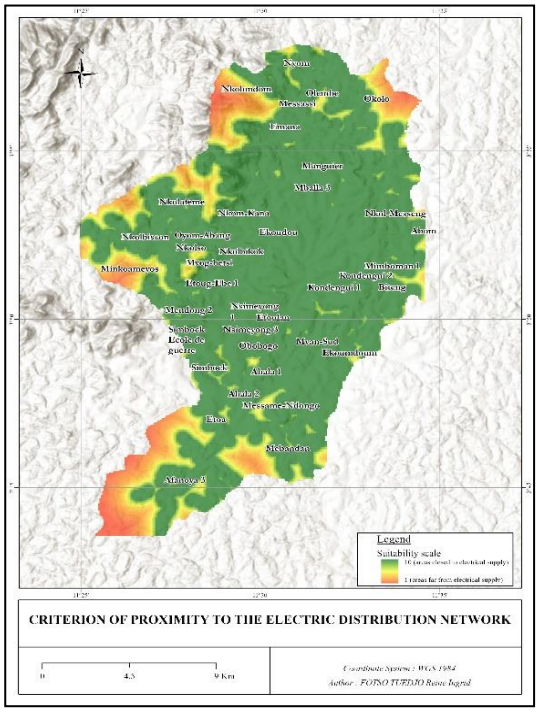

Figure 6. Transformed Distance to electrical network Criterion

Table 5. Weighting of criteria in the Cost sub-model

Criterion	Neighborhoods	Roads	Electrical Network
Weight	1.5	1	1

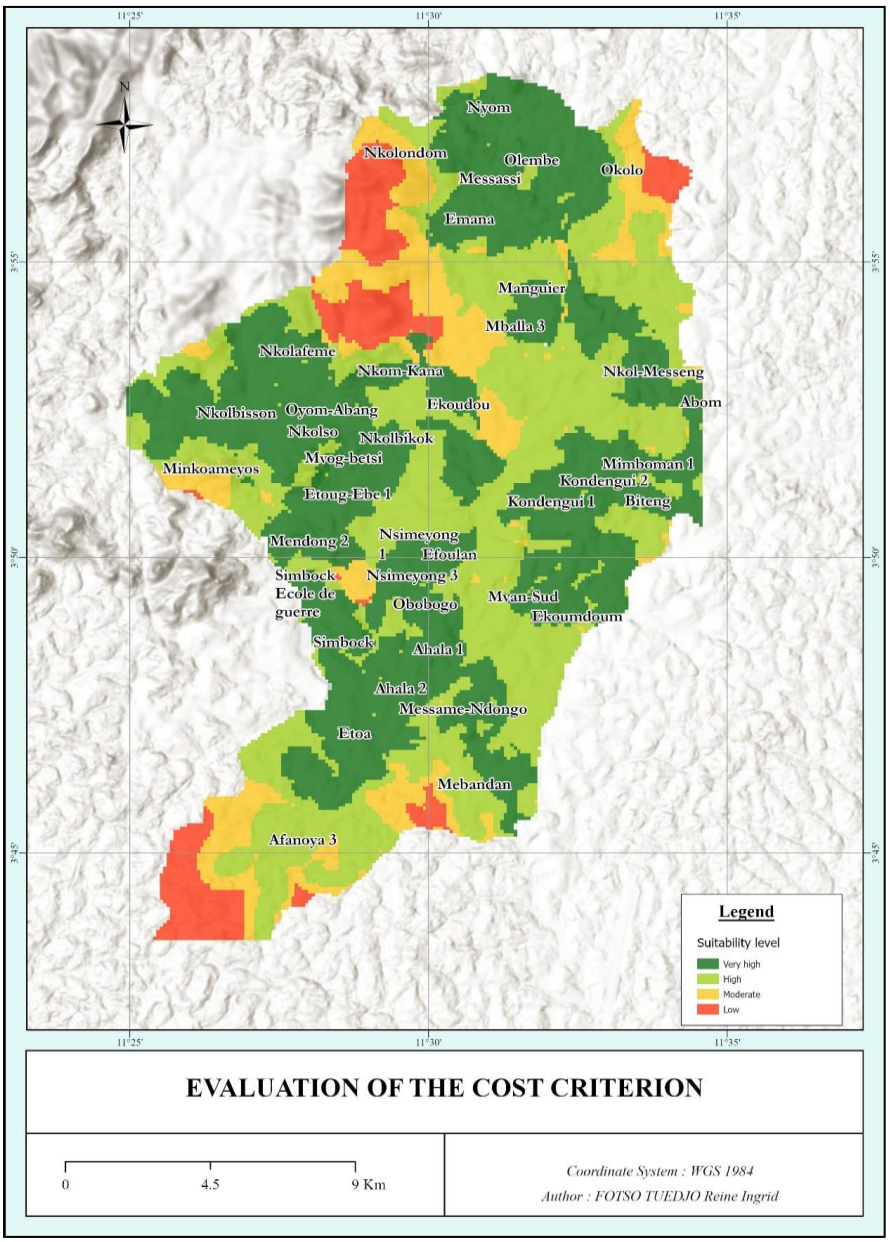

Figure 7. Cost Suitability Map

After completing the various processes, the final product obtained is a summary map of potential sites for establishing an affordable housing project. This map highlights the neighborhoods in the city of Yaounde that align with the suitable areas. A total of 39 neighborhoods have been identified as suitable, and they are listed in Table 6 below.

Table 6. List of suitable neighborhoods for the construction of affordable housing in Yaounde.

N°	NEIGHBORHOODS	N°	NEIGHBORHOODS
1	Afanoya 3	**21**	Mvan-Sud
2	Ahala 1	**22**	Mvog-betsi
3	Ahala 2	**23**	Ngousso-Ntem
4	Biteng	**24**	Nkolafeme
5	Efoulan	**25**	Nkolbikok
6	Ekoudou	**26**	Nkolbisson
7	Ekoumdoum	**27**	Nkol-Messeng
8	Emana	**28**	Nkolondom
9	Etoa	**29**	Nkolso
10	Etoug-Ebe 1	**30**	Nkom-Kana
11	Kondengui 1	**31**	Nsimeyong 1
12	Kondengui 2	**32**	Nsimeyong 3
13	Manguier	**33**	Nyom
14	Mballa 3	**34**	Obobogo
15	Mebandan	**35**	Okolo
16	Mendong 2	**36**	Olembe
17	Messame-Ndongo	**37**	Oyom-Abang
18	Messassi	**38**	Simbock
19	Mimboman 1	**39**	Simbock Ecole de guerre
20	Minkoameyos		

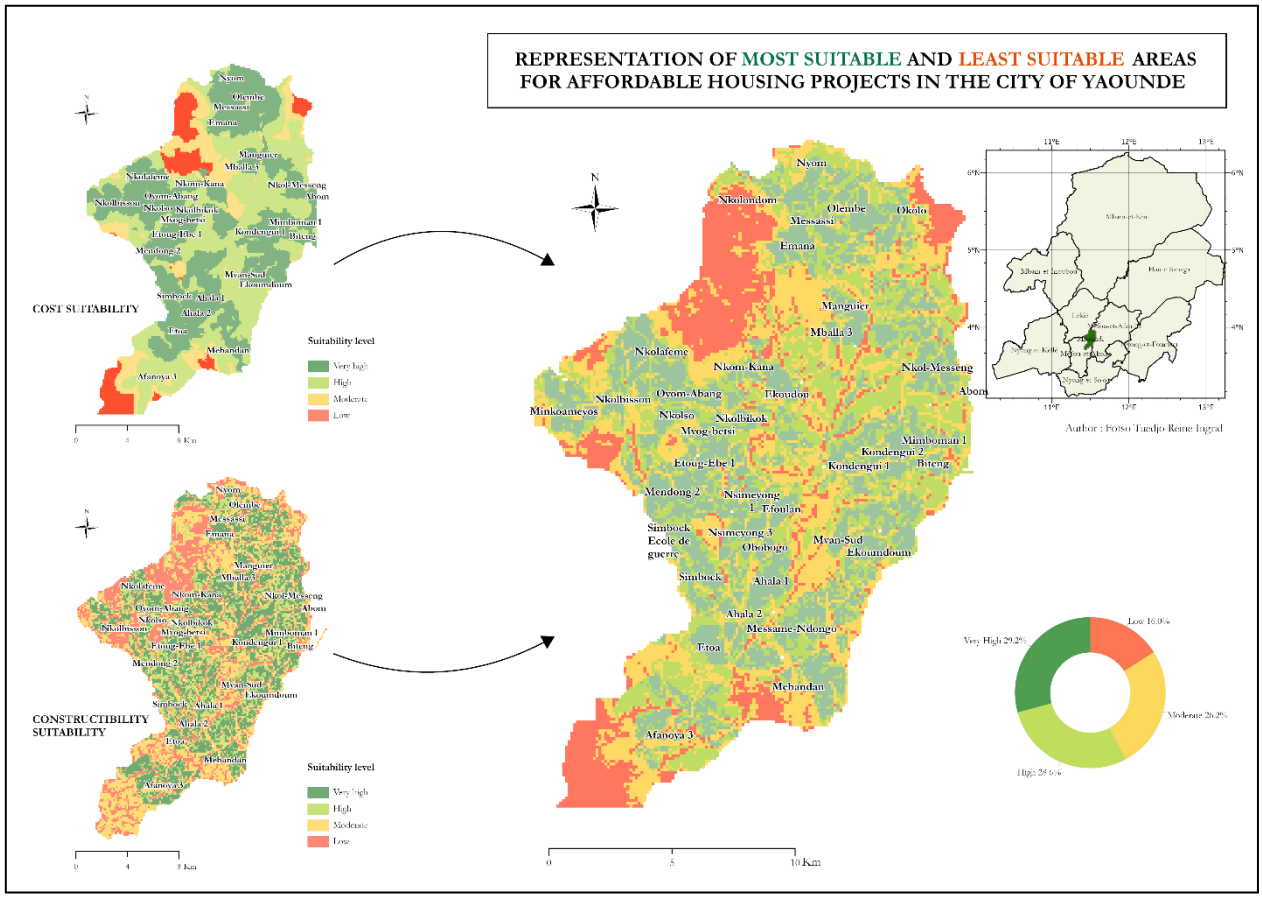

Figure 8. Final Suitability Map

Conclusion

This work aimed to demonstrate the contribution that GIS can make to inclusive urban planning and decision-making for infrastructure projects, particularly affordable housing. The adopted methodology involved data collection and the selection of criteria to be considered for creating a suitability model using ArcGIS Pro, with the goal of identifying areas suitable for affordable housing projects in the city of Yaounde. To design the most realistic model possible, two factors were considered: Constructibility (buildability) and Cost. These two factors guided the data collection process, focusing on the physical and morphological criteria of Yaounde while remaining aligned with the zoning defined by the UMP-h2035 and the land price index.

The results obtained include suitability maps for the cost and buildability factors, which, through an equal-weight overlay, produced a summary map representing the final suitability map for the targeted areas. It then appeared that 29.2% of the total area is very suitable for the purpose of establishing affordable housing projects in Yaounde.

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