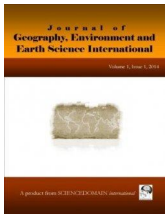

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Geographic Foci of Industries: A Suitability Analysis

Abia, Moses[1], Eja, Iwara[1], Njoku, Chukwudi Gbadebo[1*], Okeniyi, Oluwafemi Olubukola[2] and Itu, Prince-Charles Omin[1]

[1]Department of Geography and Environmental Science, University of Calabar, Calabar, Nigeria.
[2]Department of Geography, University of Ibadan, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Industrial development in the world, especially in developing countries is a prevailing issue with serious emphases on the location of these industries. Finding suitable geographic foci for industries is very important for administrators of firms, investors as well as the government. This geared this study which proffered the most suitable foci for industrial location in Calabar metropolis of Cross River State, Nigeria. In all, data obtained include locations of existing tertiary industries, airport and dumpsite. Also were population figures, pipe-borne water network, topographic, land use and cadastral data (boundaries, roads and rivers). The data analysis was done majorly with Geographic Information System operations (topographic, proximity, overlay and structured queries). Standard physical suitability criteria for siting an industry were considered. The analysis recommended the most suitable geographic foci for industries in the city. The best site deducted from the analysis covers a land area of 2.23sq km, situated at the far eastern corner of the metropolis, by the boundary of the metropolis and Akpabuyo Local Government Area. It was thus recommended that a multi-criteria site selection analysis must be executed for a more precise, effective and sustainable selection of the best site for locating industries in Calabar and elsewhere.

**Corresponding author: E-mail: chukwudi.njokupg@gmail.com;*

Keywords: Industrial location; industry; geographic foci; geographic information systems; multi-criteria analysis; suitability; Calabar.

1. INTRODUCTION

In the past, location was very important for industrial development. Based on theoretical background, distance from raw materials and markets were the major factors for industrial locations. However, interest in location has declined as part of the main factors for industrial development as a result of development of sophisticated technology and competition over time. In fact, in the world of global competition, it is argued that location is no more relevant [1-3]. Attention has shifted from country level to firm level, that is, how firms relate to each other spatially and non-spatially. This indicates that cluster or geographical concentration of interconnected companies are a prominent feature of nearly every national, regional, state and even metropolitan economy, especially in more advanced nations. Scholars have outlined three major advantages of location externalities of industries [4,5]. These advantages are; the intensity of a labor pool, the availability of related materials and other inputs at lower cost and the intensity of knowledge exchange. Therefore, geographic concentration or foci of industries play an important role in industrial development. However, recent phenomena of urbanization and environmental problems such as noise pollution, air pollutions and so on echoes the need for suitable location of industries especially in the developing nations. Moreover, decisions about geographic foci of industries typically involve the evaluation of multiple criteria according to often conflicting objectives. Geographic Information System (GIS) has remained a valuable tool to deal with such multiple criteria issues.

The impact of technology on industrial development can never be over emphasized. Generally, technology has two main impacts on industrial development. They are within and outside industrial activities. With the aid of technological development, the operation in the industry have become effective and efficient. As a result of technology development, operations in industries has shifted from manual to automatic which has automatically helped the output. In addition, the development of technology has not only helped industrial activities but others outside which eventually contribute to smooth running of industries. The technologies of telecommunication and transportation have great impact on industrial development. In fact, the availability of these technologies have reshaped the explanation of industrial locations. More so, these technologies have made the world a global village in which everywhere seems closer to each other. The role of location is all but absent. If anything, the predisposition has been to see location as weakening in importance as globalization allows industries to source capital, goods and technology from anywhere and to locate operations wherever it is most cost effective. For example, majority of industrial products used in the USA are from China, with a total of $478.8 billion worth of goods imported from China in 2016 [6]. This has become possible with ease as a result of present development in technology [7,8]. Therefore, the inkling of cost of transport has almost become antique. However, labour and external economic of scale are still relevant factors being considered in the location of industries.

Furthermore, overtime, location have been absent in explaining industrial development, however, [9] argued that situation, that is, relative location of industries is very important. Porter's idea gives clusters a prominent role. Clusters are geographic concentrations of interconnected companies, specialized suppliers and service providers, firms in related industries and associated institutions in particular fields that compete but also cooperate. Such clusters are a striking feature of virtually every economy, especially those of more economically advanced areas. While agglomeration has long been part of the economic landscape, the configuration and the role of clusters seem to be taking on a new role [7,9]. This means modern economic activity is also carried out through a complex external division of labour between establishments, firms, and industries, which in turn have to relate to each other through transactions. This intra and inter-industry input–output structure has a geography; location. Furthermore, studies have shown that there are positive externalities in geographic foci of industries [4,5,10]. Therefore, based on the background, geography; location is a significant factor in present industrial development.

More so, economic activity is clustered in this way to create a controlled environment for industrialization to flourish especially in the presence of chronic infrastructural deficits. This has traditionally taken the form of industrial

estates or parks. The main benefit of the localization of firms in this way is that it allows for infrastructural provisions to be prioritized and to give firms a competitive edge while offering access to raw materials, skilled labour, technology and materials. Nigeria has a number of large industrial estates and complexes but has also witnessed the spontaneous development of small clusters across the country. The latter includes the computer village in Otigba, Lagos, the auto and industrial spare parts fabricators in Nnewi, the leather tannery in Kano and the footwear, leatherworks, and garment cluster in Aba [11]. More so, prominent feature of the industrial sector in Nigeria is the existence of a number of special economic zones which is also an idea of geographic concentration of companies. There are approximately 25 free trade zones licensed by the federal government of which two are located in Cross River State and Calabar to be precise (the Calabar Free Trade Zone and the Tinapa Free Trade Zone and business resort). However, less than 13 of them are currently operational. Some are under construction and in the early phases of development [11]. Two types of free trade arrangement operate in Nigeria; the specialized and the general purpose trade/export zones, which are managed by two bodies; the Nigerian Export Processing Zone Authority for the general-purpose zones and the Oil & Gas Free Zone Authority for the oil and gas zone. They have the mandate to approve new zones, modify existing ones, grant permits and approvals for operators in the EPZs, and manage the zones.

Geographic Information Systems (GIS) has proven to be a very efficient tool, through multi-criteria decision support systems. In a site selection process, the analyst strives to determine the optimum location that would satisfy the selection criteria. The selection process attempts to optimize a number of objectives desired for a specific facility. Such optimization often involves numerous decision factors, which are frequently contradicting, and the process often involves a number of possible sites with each having advantages and limitations. Decision making is based on numerous data concerning the problem of selecting an appropriate site. Decisions about industrial location typically involve the evaluation of multiple criteria according to several, often conflicting, objectives. While many decisions we make are prompted by a single objective, it also happens that we need to make decisions that satisfy several objectives. Decision making is based on numerous data concerning the problem and it has been estimated that 80 percent of data used by managers and decision makers are geographical (spatial) in nature. Decision problems that involve geographical data are referred to as geographical or spatial decision problems. In the past, site selection was based almost purely on economic and technical criteria. Today, a higher degree of sophistication is expected with critical consideration of physical and spatial characteristics as was done in this study.

Historically, the focus for industrial location research has been on those variables influencing the choice of location for new firms. In their prescriptions for industrial location planning, some authors in the past [12,13,14] repeatedly emphasized the importance of critical demand factors (location of competitors, proximity to consumer markets, etc.), and cost factors (land, labor, materials, transportation, etc.). These authors looking at cost and demand factors did not however consider the spatial and physical factors. Also, to date in Nigeria, there is a dearth in the study of systematic multi-criteria analysis to select the most suitable location for industries based on spatial factors. The multi-criteria analysis is a decision support systems developed to provide effective location decision aid for location planners. It should be pointed out that qualitative discussion of location factors is common, but careful spatial assessment has been greatly limited. Following from these, this study thus aimed at suggesting the best site (s) for locating future industries in Calabar considering standard physical and spatial criteria.

2. MATERIALS AND METHODS

The study area is Calabar metropolis of Cross River State, Nigeria. Calabar metropolis is made up of Calabar Municipality and Calabar South Local Government Areas (LGA), located by the coastal south eastern part of Nigeria [15] as shown on Fig. 1. At the end of the slave trade, the city was a major port for palm oil trade and commodities export and imports from the South East of Nigeria. It became the biggest colonial administration in Nigeria by 18th and 19th and early part of the 20th centuries. The old Calabar served as a centre of learning as well as headquarters of several British parastatals during the colonial period. It was also the first capital of Southern Nigeria. The study was influenced by the fact that Calabar being one of the ancient cities in Nigeria has witnessed outstanding

growth and development over time, from the coming of the missionaries, colonisation just to a few.

Calabar is situated geographically between Longitudes 8°18′00″E to 8°24′00″E and Latitudes 4°54′00″N to 5°04′00″N. It shares boundary with Calabar River to the West, Great Kwa River to the East, Odukpani LGA to the North and the creeks of the Cross River as it empties into the Atlantic Ocean in the South. Calabar Municipality possesses an area of 222km^2 and Calabar South possessing an area of 111km^2 [15]. Calabar Metropolis has a population of about 371,022 people according to the 2006 census reported by the National Population Commission. 179,392 people are resident in Calabar Municipality while 191,630 people are residents of Calabar South. Calabar Municipality is made up of 10 political wards while Calabar South is made up of 12. Industrialization is still budding in the city with the presence of some tertiary industries and industrial foci such as the Export Processing Zone (EPZ), Niger Flour Mills, Tinapa as well as the new garment factory and its conglomerates presently under construction. There are also secondary and primary industries dispersed informally within the metropolis. Fig. 2 shows study area and the tertiary industries in the metropolis.

Object and field types of data were employed in the research. Object data types used in the study include the location of the airport, existing tertiary industries and the municipal solid waste dumpsite. Field data is made up of both continuous and discrete types. Continuous data types used include slope data, pipe-borne water utility, roads, landuse data, satellite imagery and Digital Elevation Model (DEM). Primary data included coordinates of the dumpsite, airport and existing tertiary industries which were collected using a handheld Global Positioning System equipment. The secondary data sources consisted the Cross River State Water Board Limited who provided the pipe-borne water utility network data and the Office of the Surveyor General, where cadastral data were obtained. Landuse data was obtained from a 70cm resolution Landsat satellite imagery of the United States Geological Survey Google Earth platform. The DEM was downloaded from the Earth Explorer platform.

The data analyses involved spatial techniques using ArcMap GIS tools. In line with, and guided by [16] the standard physical suitability criteria adopted in selecting the most suitable location for an industrial foci consists of 4 criteria groups with varying items, constraints and values as depicted in Table 1.

Additionally, as required for the multi-criteria analysis, the built-up environment data for the year 2017 was derived from the acquired Landsat imagery. The imagery was classified in into 4 classes (built-up, urban greenery, forest and water body). Also, the slope data was gotten from the acquired Digital Elevation Model DEM) through a raster surface analysis. The slope was classified to 3 classes (0-5 percent, 5- 150 percent and 150 – 300 percent) as depicted in Fig. 3. The items considered as shown on Table 1 and Fig. 4 were imported into the Environmental Systems Research Institute's ArcMap software platform where the proximity tool (*multiple ring buffer*) was used to create

Table 1. Criteria adopted for site selection of most suitable industry location

S/n	Criteria group	Items	Constraints	Values
1	Terrain	Slope	Not prone to erosion, well-drained and constructability	< 5 percent
2	Existing infrastructure	Utilities	Distance to pipe-borne water pipe network	> 1.6km
		Roads	Distance to state and interstate roadways	> 1km
		Airport	Distance to commercial airport	>5km
		Landuse	Distance to built-up areas	> 1.6km
		Solid waste dumpsite	Buffer to avoid contamination	> 1.6km
3	Natural resources	Water bodies	Buffer to avoid pollution and flooding	> 1.6km

Source: Adopted from [16]

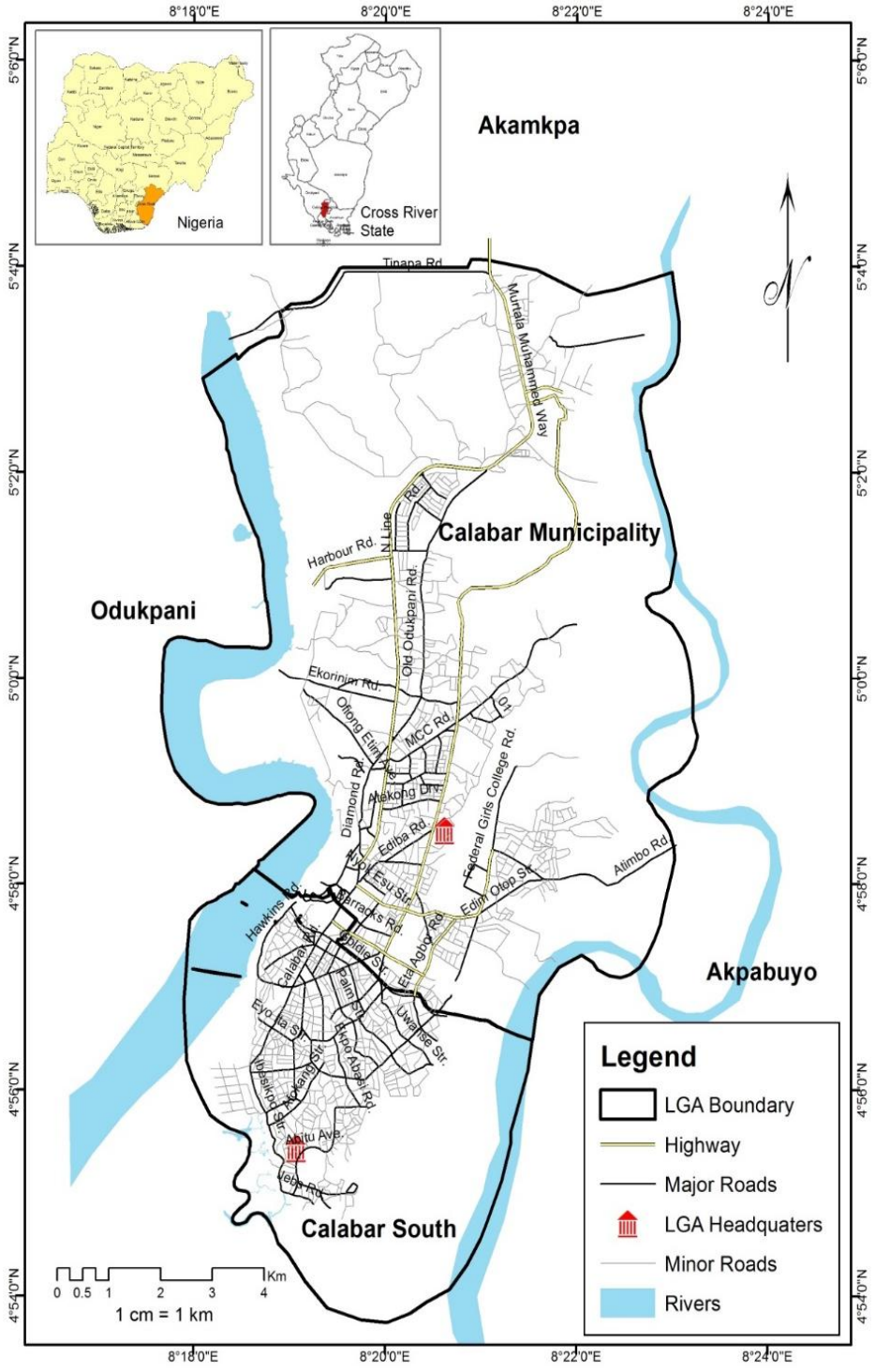

Fig. 1. Map of Calabar metropolis

distance rings around the items at specified values. The outputs of the buffers were overlaid to derive a single layer using the u*nion* tool and based on the buffer attribute tables, Structured Query Languages (SQL) were used to select suitable sites from the database of each buffered

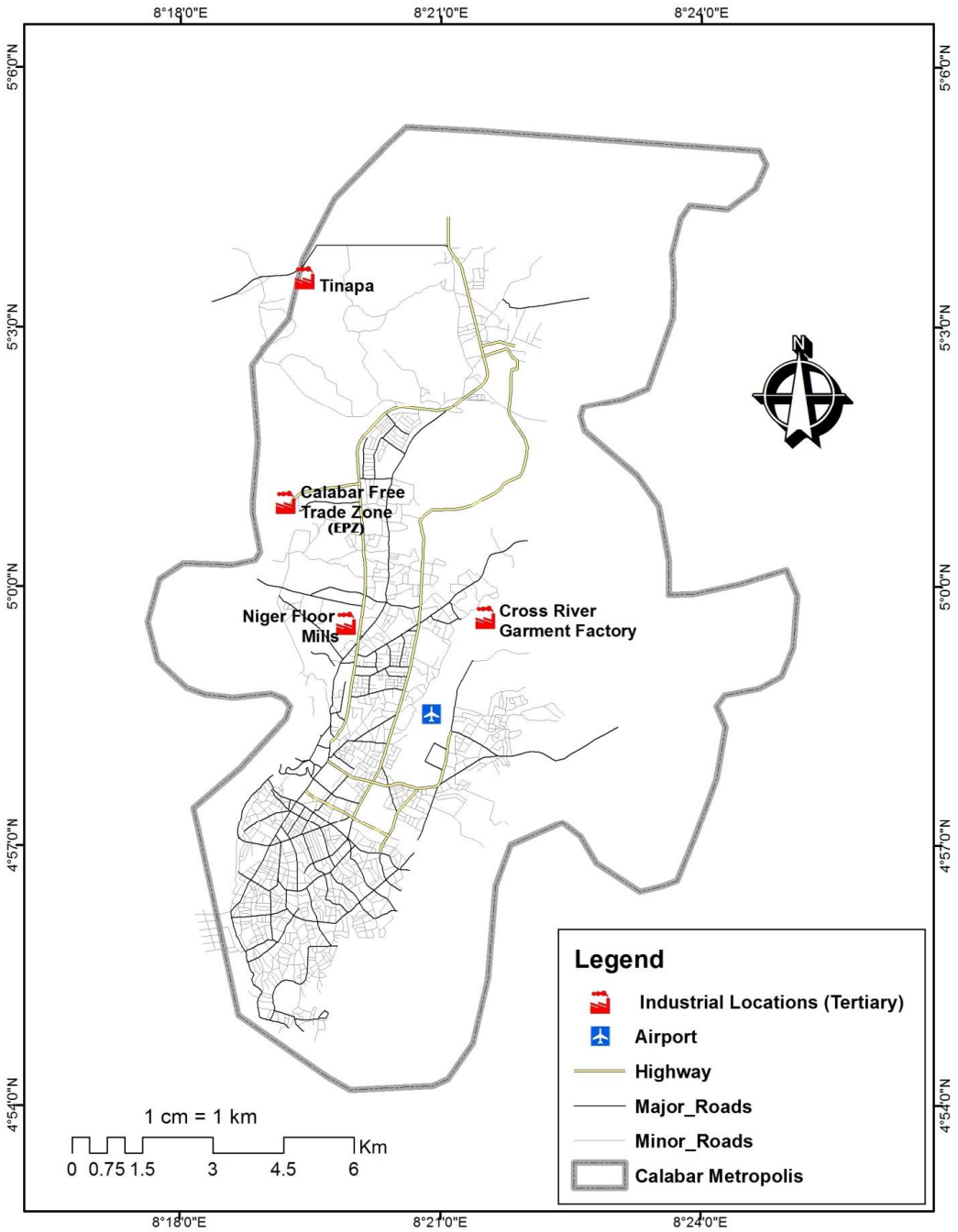

Fig. 2. Map showing selected tertiary industries in Calabar metropolis

item. Single-criteria analysis was done as well as multi-criteria queries to quiz the data and make necessary deductions. The multi-criteria technique is best for any land suitability assessment. Its assessment involves many factors that directly or indirectly control the ability of a part of land to adequately host a land use, in this case; industries. Performing land suitability evaluation and generating maps of land suitability for a particular land use in an area would facilitate sustainable development [17]. The multi-criteria suitability assessment has been adopted by various authors before now. [18] Used multi-criteria queries to determine the

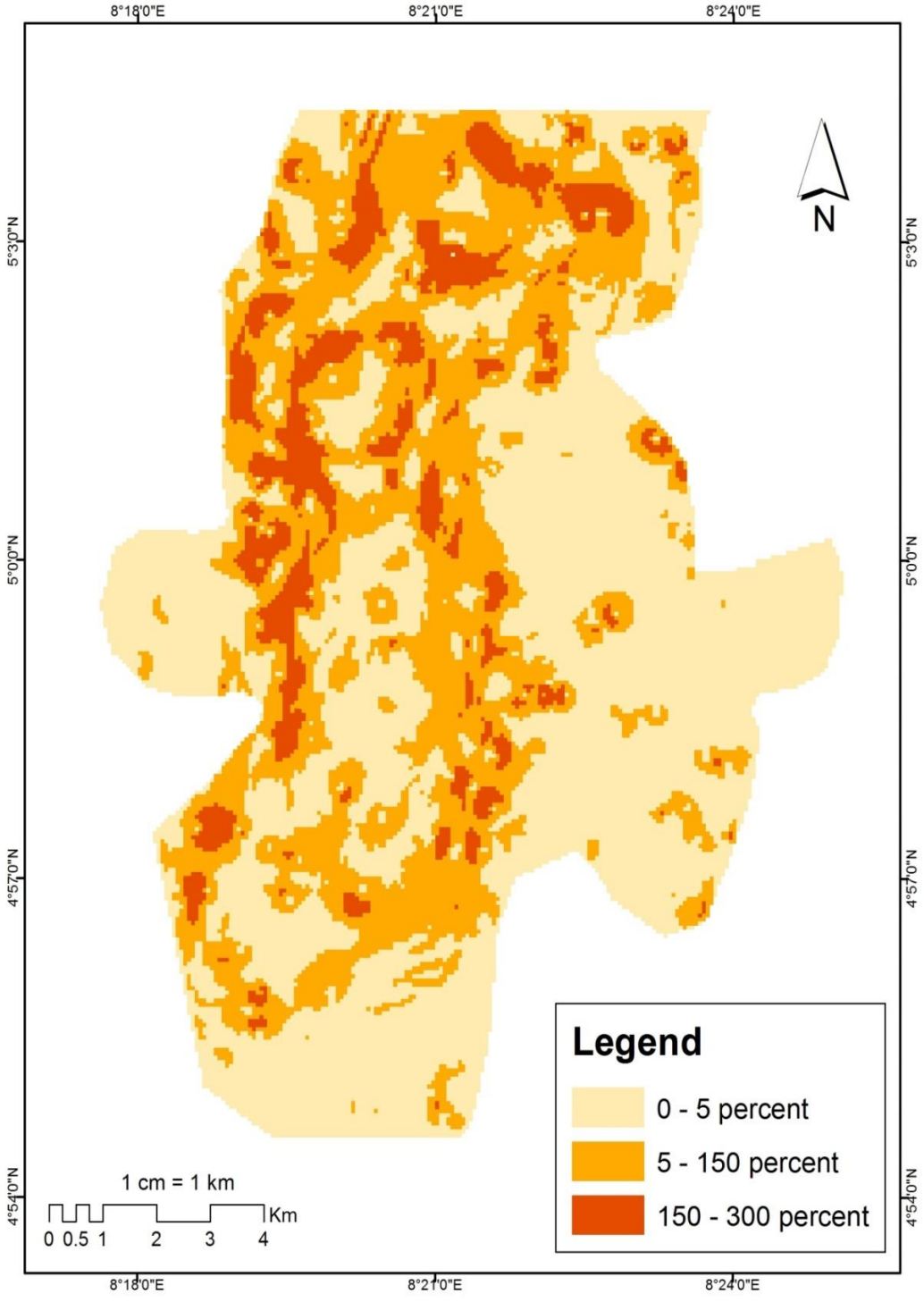

Fig. 3. Slope map of Calabar metropolis

most suitable sites for solid waste collection in Owerri, Nigeria. [17] Also demonstrated beyond reasonable doubt the use of GIS in attending to the spatial problem of petrol filling station siting in Oyo Town, Nigeria applying the spatial multi-dimensional technique.

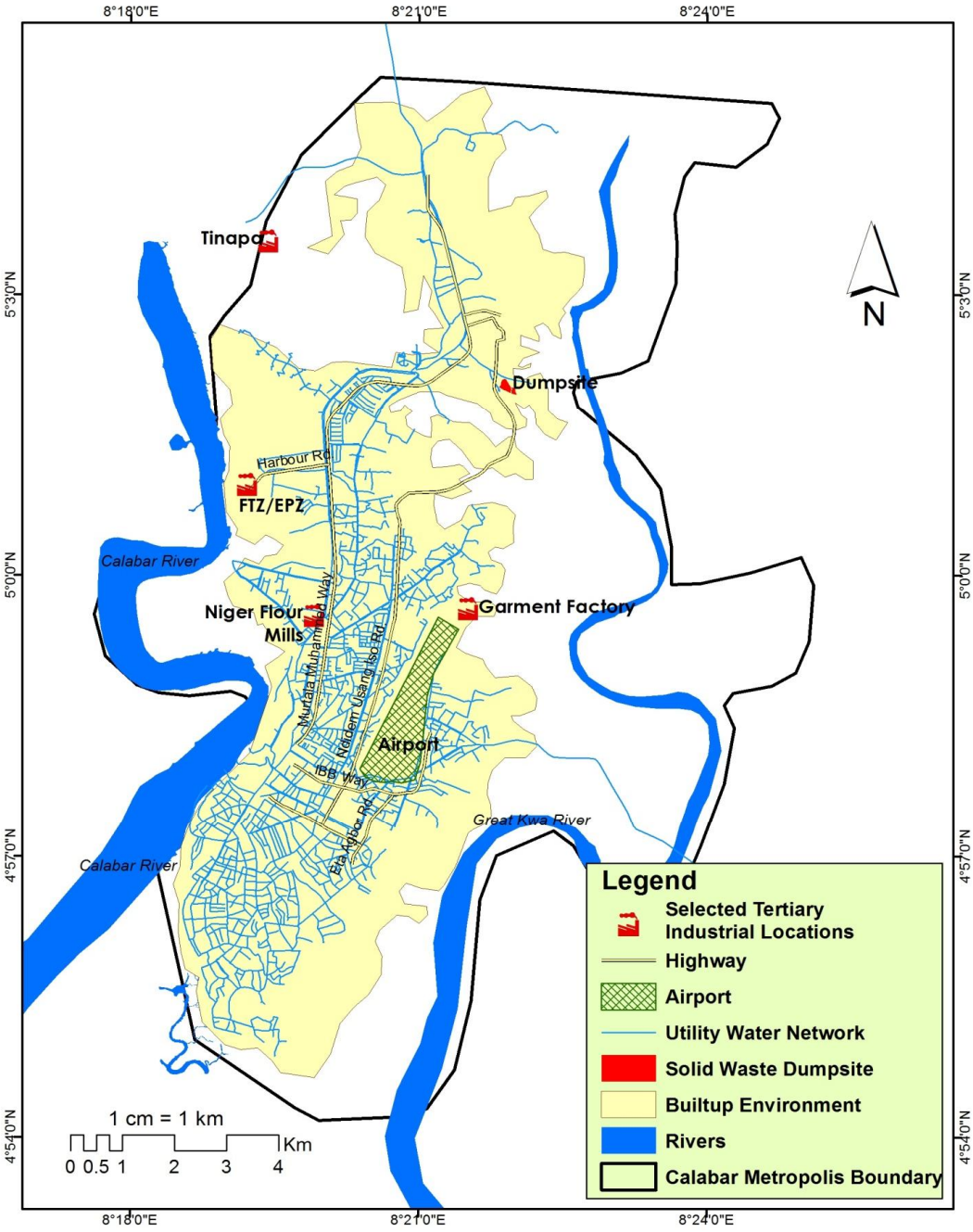

Fig. 4. Inputs for site selection analysis

3. RESULTS AND DISCUSSION

3.1 Most Suitable Location for an Industrial Area in Calabar

Single-criteria results from the site selection analysis are shown on Figs. 5 to 11. The outputs show locations that are suitable for siting an industry based on each criteria. Fig. 5 shows locations that can be considered away from the airport, Fig. 6 depicts suitable locations away from built up areas as industries are better not sited amidst residential or recreational land uses. Also shown on Fig. 7 are suitable locations away from the solid waste dumpsite that can potentially pollute the water

used by the industry amongst other nuisances it can portend. The best locations away from the highway, pipe-borne water network and rivers were also singularly considered. For the highway, a minimum distance of 1km was specified because, whereas the industry must

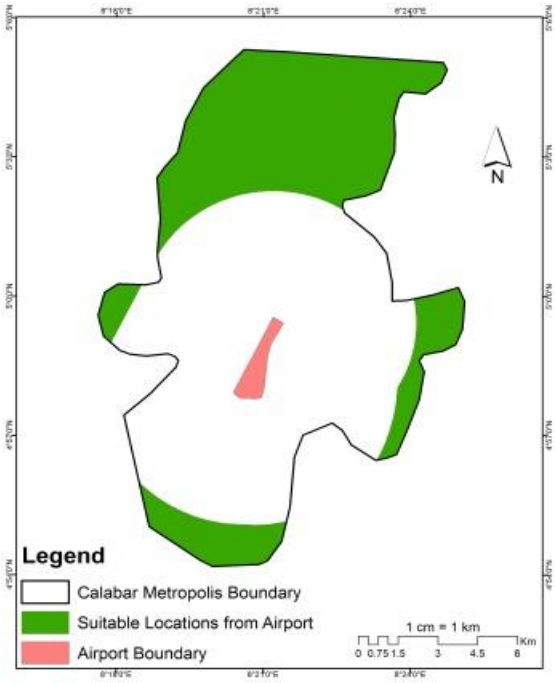

Fig. 5. Suitable locations from airport

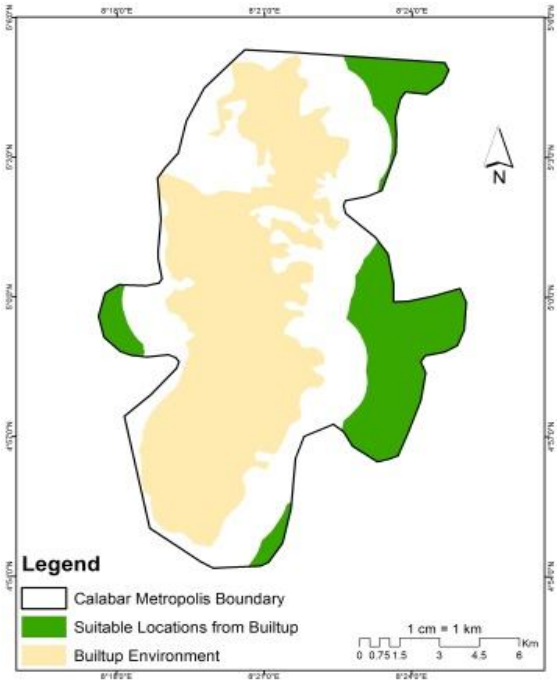

Fig. 6. Suitable locations from built-up areas

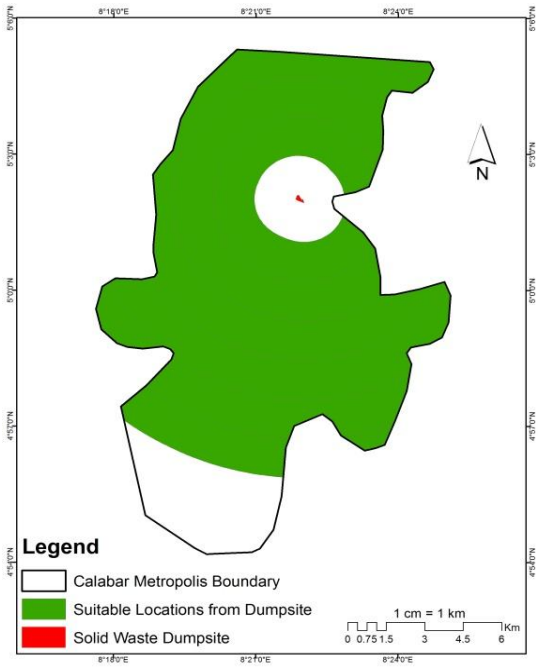

Fig. 7. Suitable locations from solid waste dumpsite

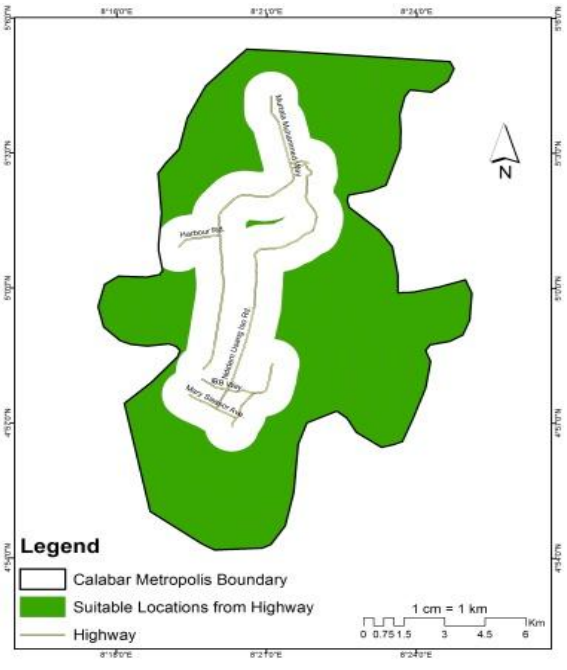

Fig. 8. Suitable locations from highway

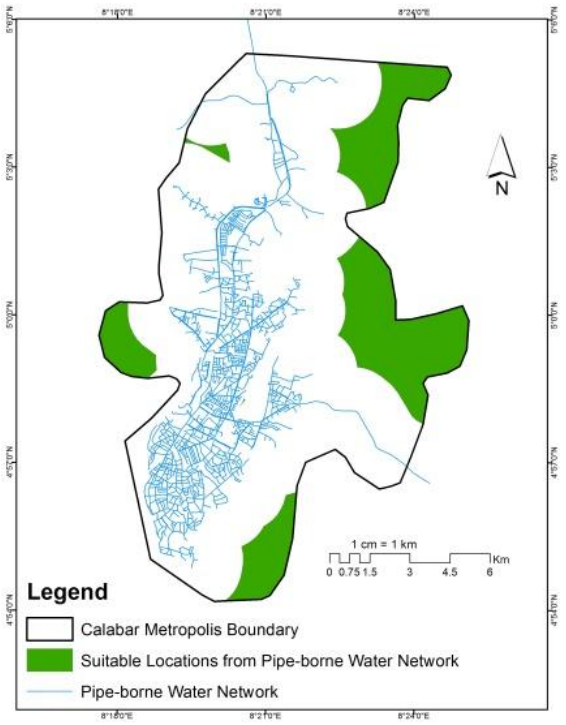

Fig. 9. Suitable locations from pipe-borne water network

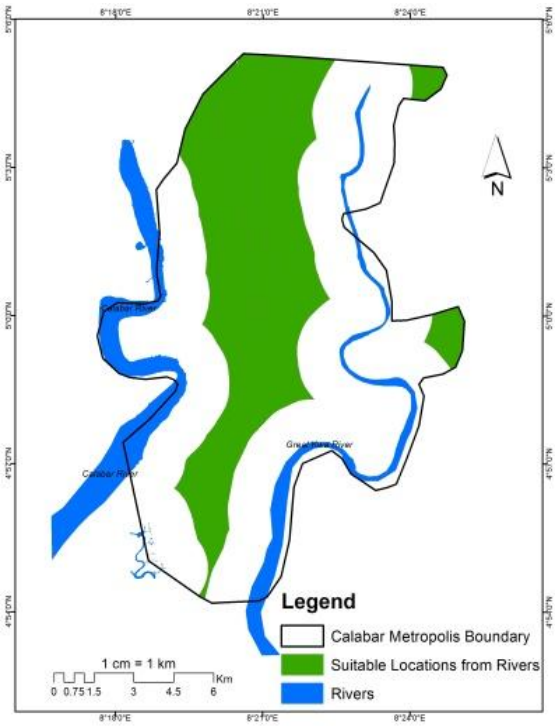

Fig. 10. Suitable locations from rivers

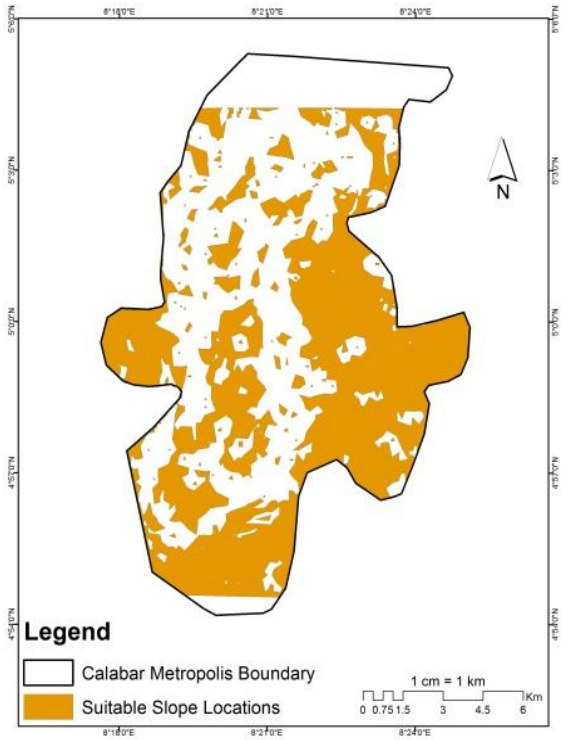

Fig. 11. Suitable slope locations

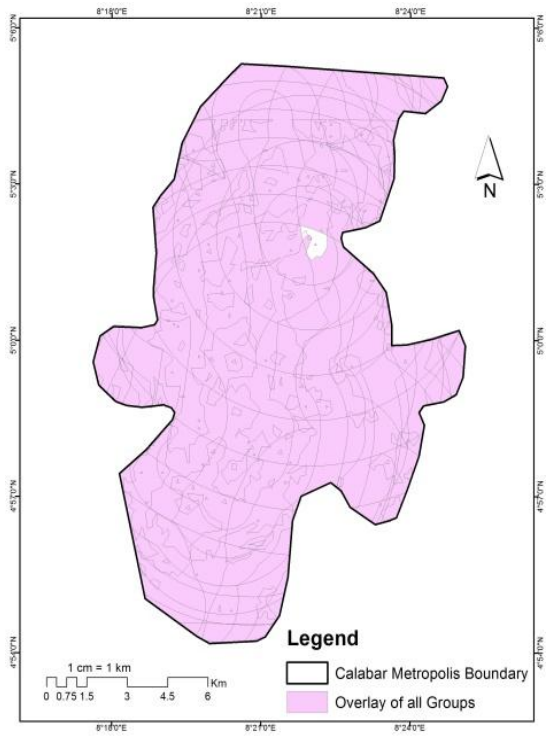

Fig. 12. Overlay of all Suitable locations

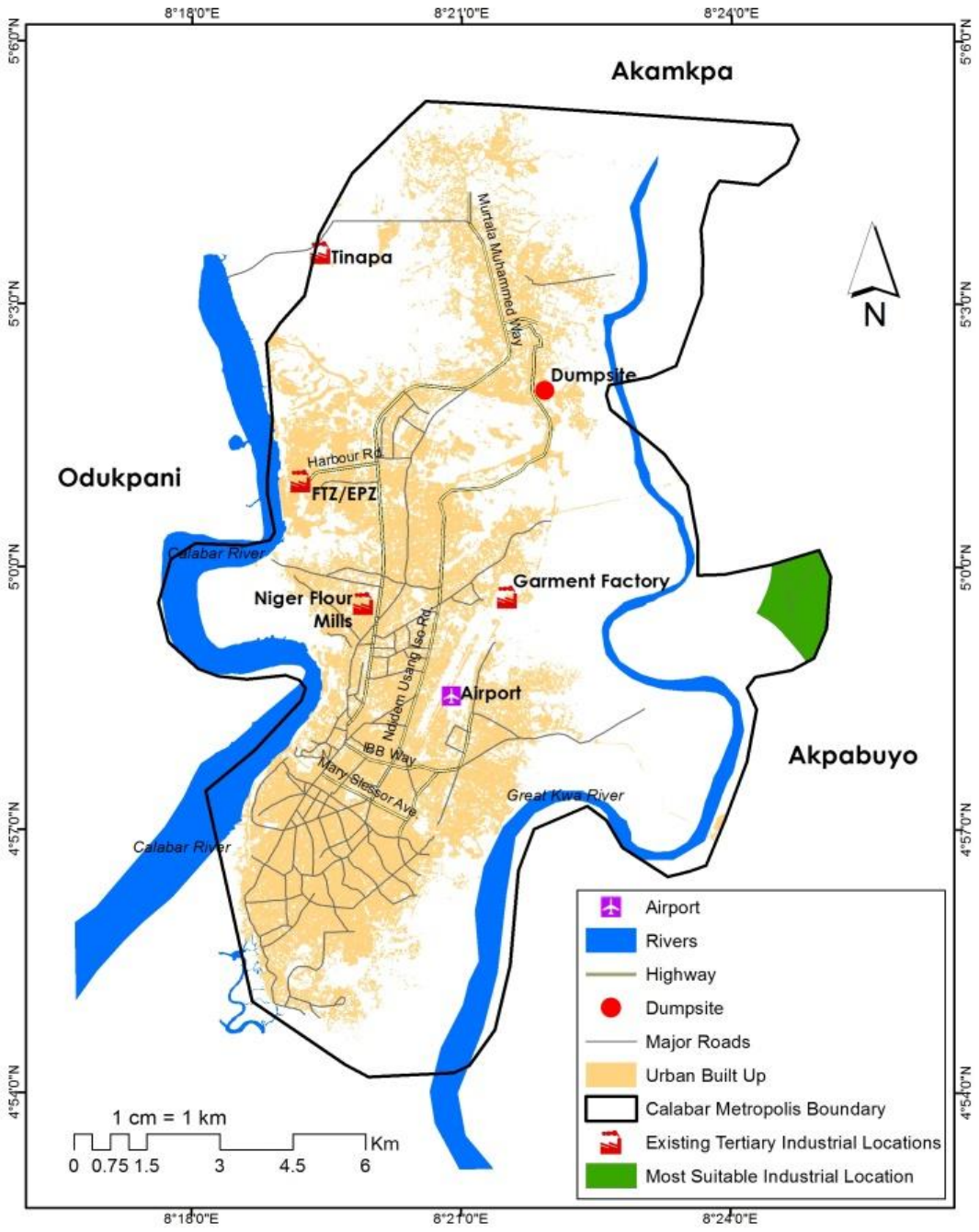

Fig. 13. Most suitable industrial location

be accessible, it must also not cause traffic congestion due to its potential of becoming a beehive of human activities (Fig. 8). For the Rivers, as shown on Fig. 10, a distance of 1.6km was used. The buffer from Rivers is necessary to allow the industries treat their effluent properly before discharging it in to the River if they choose such waste disposal method. The proximity assessment from the existing pipe-borne water network was also necessary to ensure that while the industry is far enough not to contaminate or damage piping infrastructure, they can also have access to the service (Fig. 9). The most suitable slope locations (<5 percent) shown in Fig. 11

ensures that the location for the industry is not prone to erosion, well-drained and constructible. Fig 12 is an overlay of all the single-criteria outputs. This output was used for the multi-criteria analysis.

Most importantly, the output of the multi-criteria analysis as illustrated in Fig. 13 shows the most suitable site for industrial location. The site is situated on the far eastern corner of the metropolis, by the boundary of the metropolis and

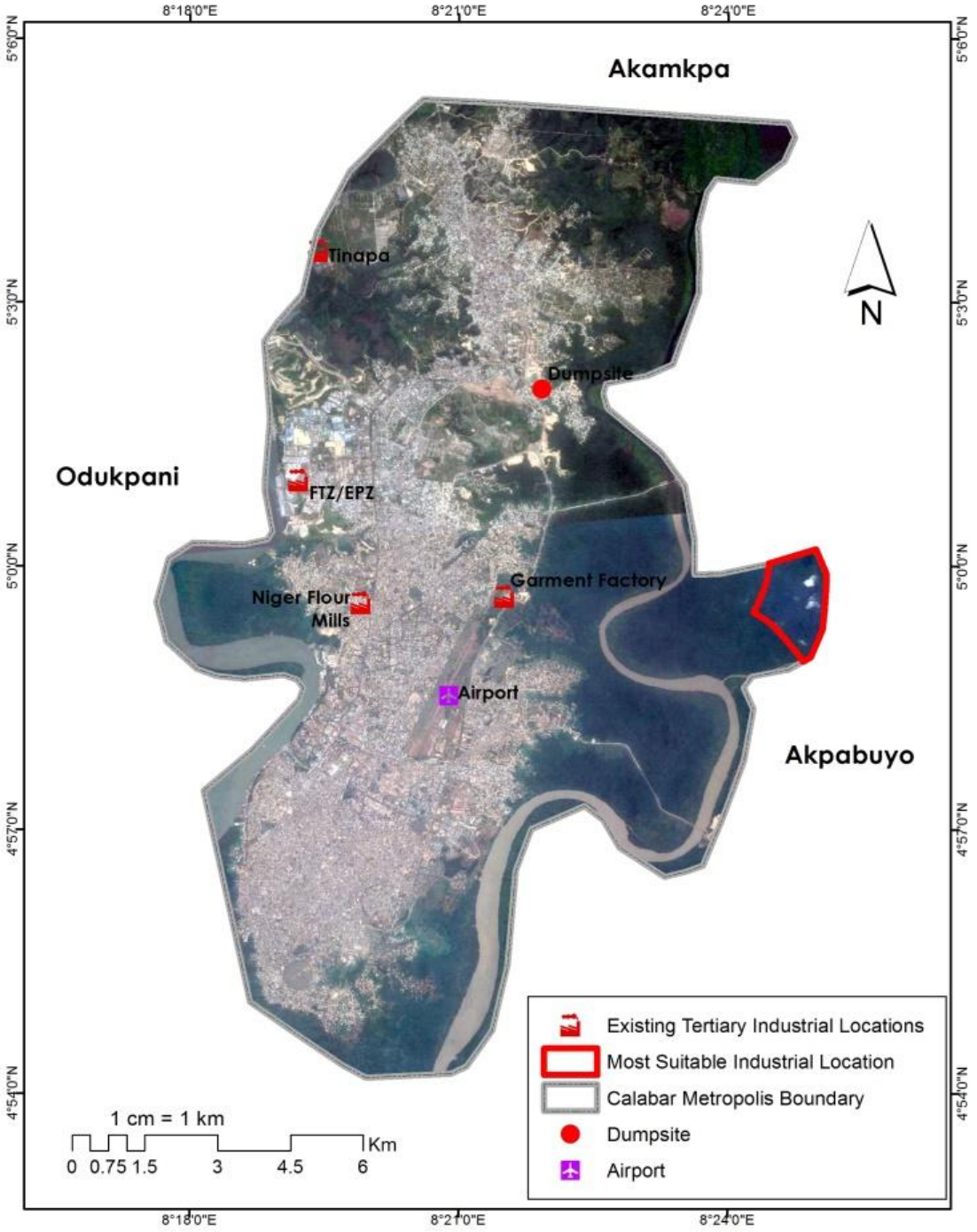

Fig. 14. Most suitable industrial location and satellite imagery

Akpabuyo LGA. The location satisfies all the criteria specified and covers a land area of 2.23sqkm. Thus, in the need of setting up a new industrial area by the government or any firm, the derived site is considered most suitable in view of physical and spatial requirements. Fig. 14 shows the site overlaid on the satellite imagery of the metropolis to provide a clearer picture of the landuse situation at the proposed location. The area is a forested piece of land without built-up, topographic, hydrological and other encumbrances.

4. CONCLUSION

It is obvious that technology has great impact on industrial development. Historically, market and raw materials were factors considered. However, due to technological advancements, location has become silent in its role in industrial development. Notwithstanding, the role of location cannot be overlooked. Decisions of location must thus involve scientific processes because of the influence of urbanization and environmental problems and GIS multi-criteria decision systems is at the forefront of solving such spatial problems. This study, informed by the problems accruable to the location of industries thus provided workable answers by proffering the most suitable geographic foci for industries in Calabar considering standard physical and spatial criteria.

The study showed that more needs to be done by relevant individuals and authorities to improve the industrial drive in the Calabar. It is very salient that in setting up any industry, a multi-criteria site selection analysis must be carried out to make sure the best site is selected. In this study, only physical and spatial factors were considered. The multi-criteria analysis is however not limited to only such factors. Thus, other factors such as the social angle can be included as a criterion for a more complex multi-criteria analysis to arrive at a more precise and effective selection of the best geographic foci for industries. When this is done, industries will thrive better and sustainably, without jeopardizing the well-being of people around both in the present and the future alike.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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