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Strategic Site Selection For Large-Scale Petrochemical Industry In Southeastern Nigeria: A Gis-Based Multi-Criteria Analysis Approach

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Abstract- The process of site selection stands as a pivotal decision-making juncture that significantly shapes the trajectory of any business venture, whether it be an initiation, expansion, or relocation. In the case of establishing a new industrial system, the importance of site identification cannot be overstated, given the profound implications it holds for the long-term investment and the overall success or failure of the industrial endeavor. In Southeast Nigeria, like in similar regions, the process of site suitability assessment is imbued with complexities arising from inherent conflicts and a multifaceted interplay of socioeconomic and ecological constraints. Such intricacies necessitate the adoption of a versatile decision-making support tool capable of accommodating a diverse set of evaluation criteria, including the varied perspectives of multiple decision-makers.This study embarks on a comprehensive exploration of the site suitability assessment for the large-scale petrochemical industry in Southeast Nigeria, employing a multi-faceted approach facilitated by Geographic Information Systems (GIS). The primary objectives of this research endeavor encompass a thorough review of planning concepts and existing planning guidelines relevant to the establishment of the petrochemical industry in the area. Furthermore, it aims to delineate the crucial factors and criteria imperative for the industry's successful implementation. By interweaving these factors and criteria, the study endeavors to pinpoint potential locations for the proposed industry while taking into account the prevalent constraints. This intricate process unfolds through the utilization of multi-criteria analysis and culminates in the production of detailed maps illustrating the suitability of various sites.The datasets mobilized for this investigation span a spectrum of critical information sources, including satellite imagery depicting land use, Shuttle Radar Topography Mission (SRTM) data, climatic data, geological information, soil characteristics, rainfall patterns, and disaster risk assessments. This wealth of data forms the foundation for the comprehensive evaluation of site suitability based on an array of criteria, including physiography, land slope, proximity to rivers, soil types, rainfall patterns, climatic conditions, land use and land cover, distance from geological structures, land systems, geomorphology, proximity to settlements, accessibility, distance from the Central Business District (CBD), and disaster risk assessment. The Analytical Hierarchical Process (AHP) methodology plays a pivotal role in the process by facilitating the comparison of criteria through matrix analysis and the derivation of relative weights for each criterion.To create the final suitability map, a weighted overlay method integrates the diverse suitability criteria maps, providing a comprehensive visualization of the most suitable sites for the petrochemical industry. An iterative post-aggregation constraint process is subsequently applied to

I.INTRODUCTION

Natural resources constitute the cornerstone of socioeconomic development, acting as the vital substratum upon which human societies thrive and flourish [1]. These invaluable assets, whether classified as renewable or non-renewable, hold an instrumental role in nurturing human well-being and underpinning both local and international trade networks. The global stage resonates with the profound significance of the oil and gas industry, a colossal juggernaut that fuels transportation systems and wields a substantial impact on the Gross Domestic Product (GDP) of nations [2]. Nestled within this expansive industry, the petrochemical sector emerges as a critical subset, responsible for extracting essential chemicals from petroleum and natural gas, thereby fortifying a multitude of sectors and facilitating grand-scale economic interconnections [2].

Nevertheless, the petrochemical industry, while undeniably a robust catalyst for job creation and economic growth, grapples with its share of environmental challenges that demand attention [3]. The selection of strategic sites for these industrial giants becomes a pivotal enigma, necessitating a delicate equilibrium between economic prosperity and environmental sustainability. In navigating this intricate choreography, decision-makers turn to the formidable arsenal of Geographic Information Systems (GIS) and the sophisticated Multi-Criteria Decision Analysis (MCDA) to chart their path, adeptly optimizing objectives and deftly maneuvering the labyrinth of intricate decision factors [3].

This research initiative stands as a testament to the potent fusion of computational sciences and the quest for more informed and sustainable choices in industrial site selection. Specifically, it harnesses the formidable capabilities of Geographic Information Systems (GIS) to provide indispensable support to planners embarking on the intricate voyage of assessing site suitability for the petrochemical industry in Southeastern Nigeria, as per the topic "Strategic Site Selection for Large-Scale Petrochemical Industry in Southeastern Nigeria: A GIS-Based Multi-Criteria Analysis Approach" [1]. At its core, this innovative system assumes the role of an oracle, furnishing expert guidance to decision-makers and proffering recommendations regarding the most fitting criteria values for selection. This feat is achieved through meticulous analysis of an extensive array of data, encompassing physical attributes, environmental variables, geographical parameters, and other pivotal aspects that harmoniously converge to facilitate a well-informed and judicious approach to site selection [1].

As this journey unfolds, it is essential to delve into the myriad facets of this research, from the realm of natural resource management to the intricate dynamics of the petrochemical industry, from the environmental challenges it presents to the pivotal role played by Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) in the decision-making process, and from the innovative contributions of computational sciences to the pursuit of more sustainable industrial site choices.

Study Area

The study area encompasses Nigeria's Southeast region, including Abia, Anambra, Enugu, Ebonyi, and Imo states. With a population of over 30 million, primarily of Igbo ethnicity, the region covers 22,525 square kilometers within Nigeria's total land area of 923,768 square kilometers. It is bordered by Benue, Kogi, Rivers, Cross River, and Delta states, with major cities such as Aba, Enugu, and Onitsha among the most populous, contributing significantly to the area's economic vitality.

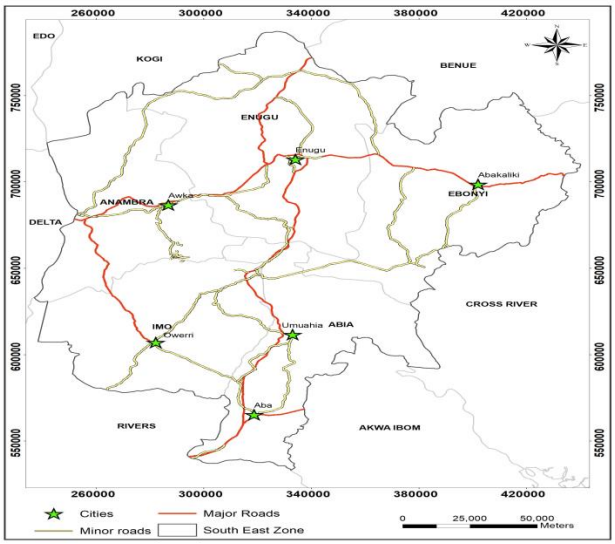


Figure 1: Map Showing South Eastern States

Material and methods

Methodology

The methodology adopted in achieving the desired goal included:

a. Research Design
b. MCE Procedure
c. Data Analysis
d. Analytical Hierarchy Process

Research Design

The investigation employed a combination of survey and experimental design methodologies. A survey was used to assess the economic suitability of specific land use for the petrochemical sector, while an experimental design was employed to evaluate the physical compatibility of the property. The methodology included data collection from primary and secondary sources, encompassing field observations, satellite imagery, documentation, GPS data, and the use of questionnaires to gather essential information. These methods were utilized to process and analyze the data, ultimately leading to the study's results and conclusions.

MCE Procedure

In the Multi-Criteria Evaluation (MCE) approach, there are three primary hierarchies: decision, objectives, and criteria. The decision involves making a choice among different objectives. Objectives, as defined by J. Ronald Eastman (1995), represent perspectives that guide the formulation of decision rules. Criteria, also defined by J. Ronald Eastman (1995), serve as the basis for measurement and evaluation. Criteria can be categorized into two types: factors and constraints. Figure 2 illustrates the structure of the Multi-Criteria Decision Analysis (MCE) framework used for identifying suitable industrial sites.

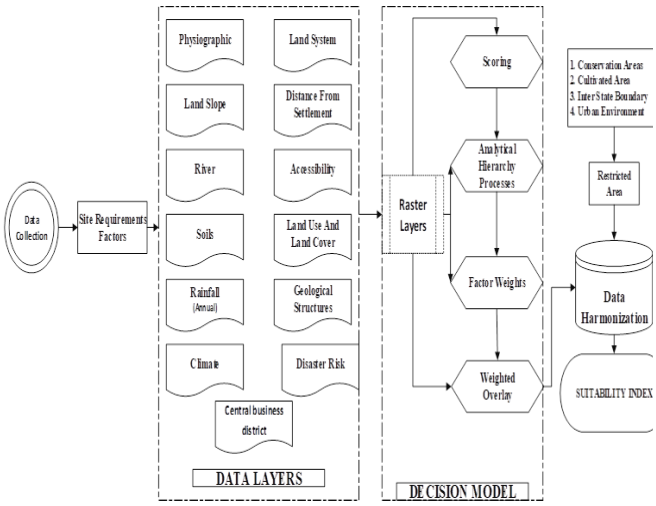


Figure2: : Flowchart summarizing the methodology for the evaluation of site suitability for the development of the petrochemical industry

Data Analysis

The analysis of the processed data employed both quantitative and qualitative methods. The quantitative approach aimed to validate the criteria weights, while the qualitative method sought evidence supporting a specific hypothesis related to a particular event. Empirical theory underpinned this analysis. Criterion suitability maps were used to discern trends, which, in turn, informed the identification of potential petrochemical industry locations through qualitative analysis. The study employed an explorative sequential mixed methods design, as depicted in Figure 3.

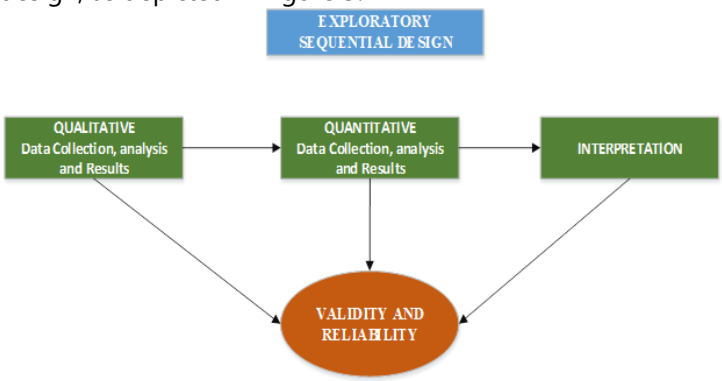


Figure3: Explorative sequential mixed methods design

Analytical Hierarchy Process

The Analytical Hierarchical Process (AHP) is recognized as a robust mathematical method for addressing intricate decision-making problems. It calculates criteria weights by systematically comparing their relative importance through a pairwise comparison matrix. In this study, 13 parameters were employed to identify suitable sites for the Petrochemical Industry. These parameters encompassed 9 bio-geophysical, 3 socio-economic, and 1 disaster-related aspects, all of which needed to be represented in geospatial data for seamless integration.

Results and discussion

Highly suitable areas for the petrochemical industry in the Southeast region are primarily located in the northwest and northeast regions, particularly in Anambra, Enugu, and Ebonyi. These locations are chosen for their consideration of both economic and environmental factors. Conversely, central areas in the region, characterized by built-up, commercial, and industrial zones, are mostly unsuitable or moderately suitable due to their proximity to sensitive structures. Such areas may have a viability of around 50%. Extremely suitable sites are concentrated in the Enugu-Anambra axis and north of Abakaliki, offering high viability due to their minimal environmental impact and potential for economic growth. Only about 3% of the region exhibits very high suitability for petrochemical industries, while 31% is unsuitable due to various constraints.

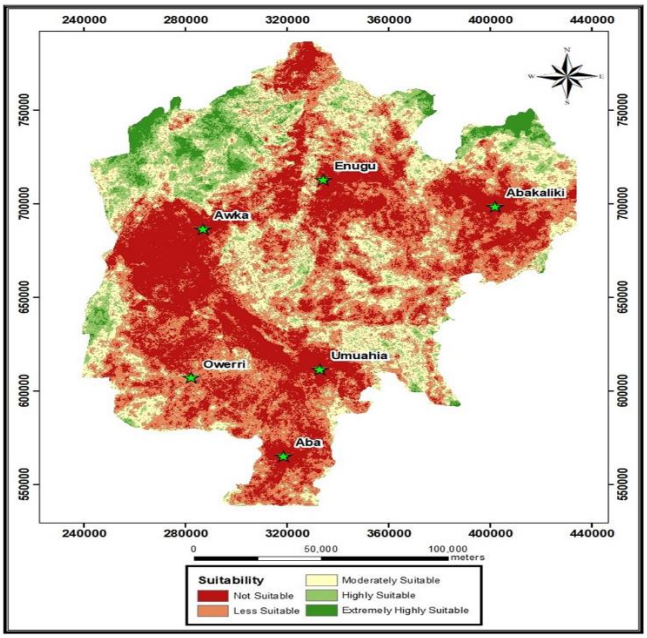


Figure4.1: Site Suitability for Petrochemical Industry in Southeast Nigeria

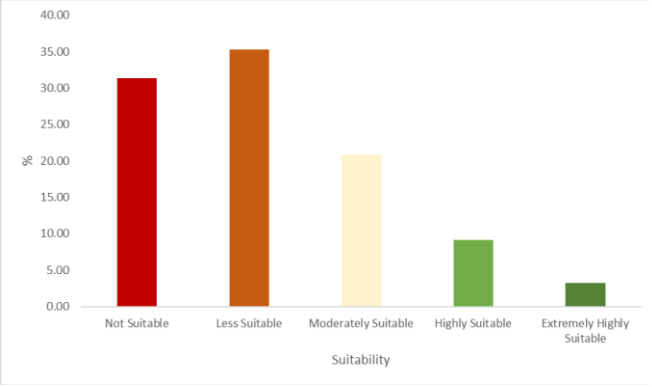
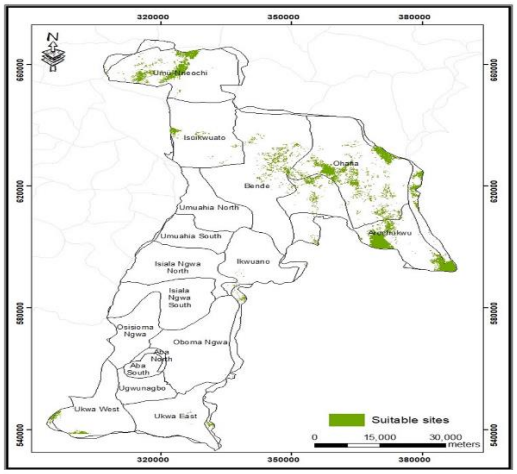


Figure4.2: Site Suitability Extent for each class

In the Southeast region, potential sites for the petrochemical industry are distributed across different local governments within each state. Some states exhibit higher potential than others in terms of area coverage.

Notably, in Abia, four local governments (Bende, Ohafia, Arochukwu, and Umu-Nneochi) have the most suitable sites for the petrochemical industry. Arochukwu, with its large suitable areas, stands out as a highly preferred location. Anambra State has a higher potential for a large-scale petrochemical industry than Abia State. Local governments with the highest potential include Anambra West, Awka, Anyamelum, and Ogbaru. This is due to the large areas of suitable sites within these local government areas.Areas in Ebonyi State, such as Izzi, Ebonyi, and Ohaukwu local government areas, feature large-scale suitable sites, suggesting the industry's capacity to exist in the state's fringes.Enugu State boasts seven local governments with suitable sites, primarily in the northwestern areas. These areas are characterized by their distance from steep slopes and urban centres. Although Enugu has more local governments with suitable sites compared to Anambra, the latter offers more extensive suitable locations.Imo State has the lowest number of areas with high suitability. Local government areas like Ohaji/Egbema, Okigwe, Ngor-Okpala, and Oguta show the highest potential for petrochemical industry sites. These areas are home to easily exploitable natural resources, and the presence of industry could contribute to more sustainable resource utilization, reducing environmental issues.



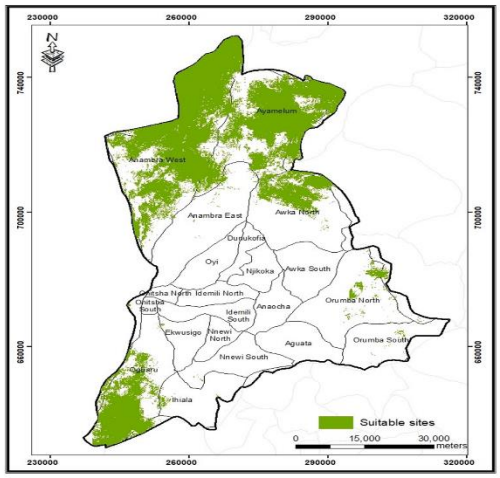
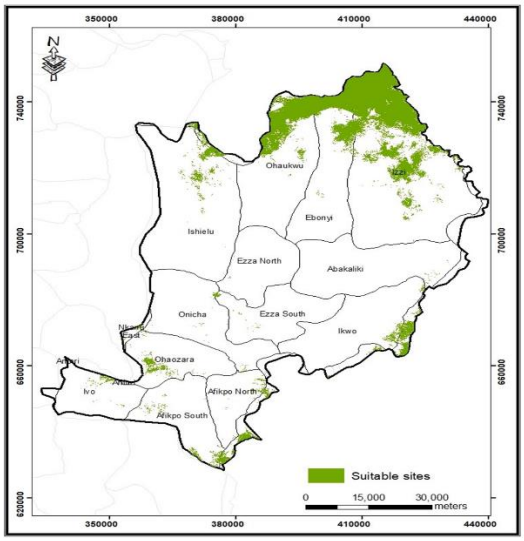


Figure 4.3: Suitable sites in Abia State**Figure 4.4**: Suitable sites in Anambra State



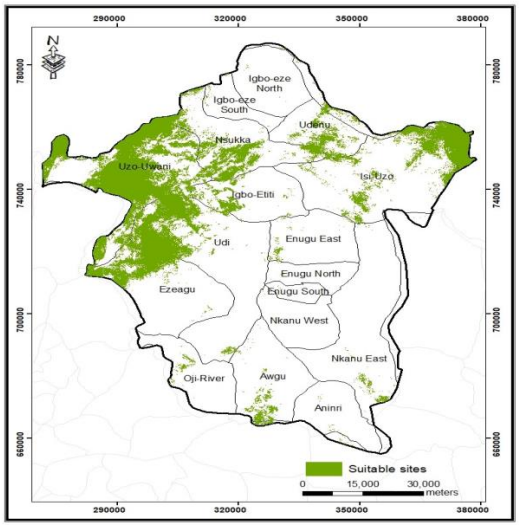


Figure 4.5: Suitable sites in Ebonyi State**Figure 4.6**: Suitable sites in Enugu State

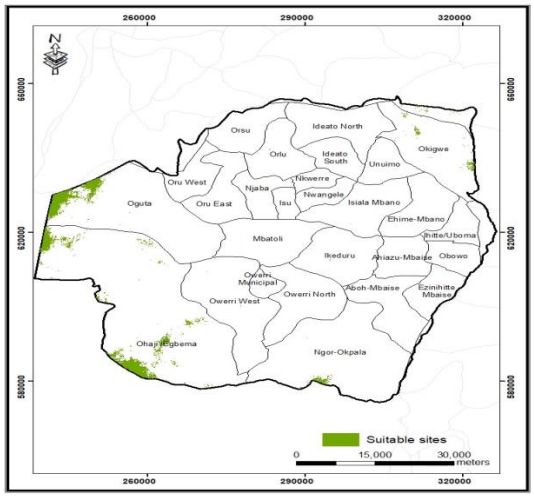


Figure 4.7: Suitable sites in Imo State

Conclusion

In summation, this research, firmly anchored in the field of Geographic Information Systems (GIS) and multi-criteria analysis, has effectively pinpointed optimal sites for the establishment of a large-scale petrochemical industry in Southeastern Nigeria. By meticulously examining a spectrum of factors and judiciously excluding areas characterized by extensive development and central business districts, the study has revealed that fringe areas emerge as the prime candidates for such endeavors. The findings underscore the region's remarkable suitability for hosting a large-scale petrochemical industry, a development that promises to usher in a host of economic opportunities, foster resource management, and, crucially, mitigate potential environmental impacts, thus harmonizing the imperatives of growth and sustainability in this specific context.

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