

# GIS-Based Evaluation of Spatial Accessibility and Equity in Educational Service Distribution in Khartoum Locality, Sudan

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**Abstract** - Equitable access to education remains a major planning challenge in Khartoum State due to the uneven spatial distribution of schools. This study evaluates the spatial suitability of primary and secondary school locations in Khartoum locality using Geographic Information Systems (GIS), integrating school location data with population density and infrastructure indicators. The results reveal a pronounced spatial imbalance in educational service provision. A total of 177 primary schools (90 boys' and 87 girls') and 53 secondary schools (30 boys' and 23 girls') were identified, with strong spatial clustering in Burri, Al-Amarat, Al-Sahafa, Al-Shajara, Al-Jeraif West, and Jabra, contrasted by significant service deficits in Al-Lamab, Al-Shajara, and Suba. GIS-based spatial analysis effectively delineated areas of surplus and deficiency, highlighting its value as a decision-support tool for data-driven educational planning aimed at improving accessibility and spatial equity.

**Keywords:** Primary School, Secondary School, Education, GIS, Spatial Distribution.

## I. INTRODUCTION

Education is an organized process aimed at enabling learners to acquire knowledge, skills, and experiences through specific methods, helping to develop their intellectual and behavioral abilities and preparing them to meet societal and life demands. Education is a fundamental requirement for development and progress, and Geographic Information Systems (GIS) play an important role in supporting planning and decision-making related to the distribution of educational institutions.

This study aims to analyze the geographical distribution patterns of primary and secondary schools in Khartoum State and evaluate the extent to which their spatial distribution complies with planning standards. The research applies spatial analysis methods, including standard distance, geographic mean center, distribution direction, and service coverage. The study highlights the importance of efficient educational

service distribution in response to rapid population growth and urban expansion, ensuring that schools adequately meet community needs.

The education system consists of three main components: inputs, processes, and outputs. Educational inputs include teachers and their qualifications and skills, students and their motivations and attitudes, the quality and organization of the curriculum, and the educational environment with its available resources. Educational processes involve teaching methods, teacher-student interaction, learning activities, and assessment techniques. The outputs of education include improving students' knowledge and skills, enhancing their intellectual and social abilities, modifying behavior, and increasing their ability to deal with different life situations.

Education is delivered through various types, including academic education, technical and vocational education, craft-based vocational education, and comprehensive education that combines academic and vocational learning. Education plays a vital role in developing individual skills, promoting critical thinking, creating employment opportunities, and supporting social and economic development.

The Ministry of Education is responsible for developing and managing the education system through policy formulation, statistical data collection, and identifying future needs. Educational planning involves several stages, including data collection and analysis, policy formulation, and forecasting future educational requirements.

Education in Sudan has evolved historically, beginning with traditional Quranic schools (Khalawi), followed by modern schooling during the Turco-Egyptian and Anglo-Egyptian periods, and continued development after independence despite increasing demand for education. The Sudanese education ladder includes pre-school education, primary education, and secondary education.

The learning environment is a key factor in the success of education, as it includes the physical location, teachers,

students, teaching methods, and educational resources. School site selection follows planning standards to ensure safety, accessibility, and equitable distribution, while considering proximity to services and distance from hazards and noise sources.

Education is an organized process aimed at enabling learners to acquire knowledge, skills, and experiences through structured methods, contributing to the development of their intellectual, social, and behavioral capacities and preparing them to meet societal and life demands. Education is widely recognized as a fundamental driver of development and social progress, and its effectiveness depends largely on sound planning and equitable resource allocation. In this context, Geographic Information Systems (GIS) play a crucial role in supporting educational planning and decision-making, particularly in analyzing the spatial distribution of educational facilities and assessing accessibility and service efficiency.

This study aims to analyze the geographical distribution patterns of primary and secondary schools in Khartoum State and evaluate the extent to which their spatial distribution complies with planning standards. The research employs several spatial analysis techniques, including geographic mean center, standard distance, directional distribution, and service coverage analysis, which are widely used in evaluating spatial equity and service adequacy. The study highlights the importance of efficient educational service distribution in response to rapid population growth and urban expansion, ensuring that schools adequately meet community needs.

The education system consists of three interrelated components: inputs, processes, and outputs. Educational inputs include teachers and their qualifications and competencies, students and their motivations and attitudes, the curriculum, and the educational environment with its available resources. Educational processes involve teaching methods, teacher–student interaction, learning activities, and assessment techniques that influence learning outcomes. The outputs of education include improving students' knowledge and skills, enhancing intellectual and social abilities, modifying behavior, and increasing their ability to cope with life situations ..

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The learning environment is a key factor in the success of education, as it includes the physical location, teachers, students, teaching methods, and educational resources. School site selection follows planning standards to ensure safety, accessibility, and equitable distribution of educational services.

### 1.1 Research Problem

The education sector in Khartoum State is witnessing increasing challenges related to the imbalance in the distribution of educational institutions. A large concentration of schools is observed in some neighborhoods in central and eastern Khartoum, which is met with a clear shortage of educational services in the peripheral areas. However, the current spatial distribution does not reflect the actual needs of the population, nor does it conform to modern planning standards. Based on the above, the problem of the study can be defined as:

The lack of fair and effective spatial distribution of primary and secondary schools in Khartoum locality

### 1.2 Research Objectives

- To study the geographical distribution of primary and secondary schools in Khartoum locality.
- To determine the extent to which the locations of existing schools comply with approved planning standards.
- To identify areas of educational gaps that suffer from weak or insufficient educational services.
- To analyze the pattern of concentration and spacing between schools using Geographic Information Systems (GIS) tools.
- To propose suitable locations for establishing new schools that contribute to achieving an equitable distribution of educational services.

## II. THE STUDY AREA

Khartoum locality was chosen because it is the administrative center of Khartoum State and an important educational hub in Sudan, with numerous schools, educational institutions, and population centers. It is bordered to the north by latitude 36815°N, to the east by longitude 3532°E, to the south by latitude 30615°N, and to the west by longitude 29932°E. Its total area is 28,165 square kilometers, and its population is estimated at 2,682,431, resulting in a population density of 162 inhabitants per square kilometer.



Figure 1: The study Area

### 2.1 Data Collection

Local data for Khartoum was obtained from multiple sources, with a focus on relevant authorities to ensure data quality.

*Ministry of Education:* Data was collected on schools (primary and secondary), including school coordinates and names in the area.

*Ministry of Urban Planning:* Data obtained includes local administrative boundaries, Khartoum, roads, airport, industrial area, and hospitals.

Software ArcGIS 10.3.

## III. RESULTS AND DISCUSSIONS

The geographic analysis was performed using ArcGIS software through three main processes:

*Distribution, Coverage, and Suitability:* Initially, the spatial distribution of government primary and secondary schools was analyzed to determine their spread pattern, which helped to reveal areas with a shortage of educational institutions. Next, the geographic coverage of these schools was assessed by measuring the distances between them and residential neighborhoods, which allowed for the identification of underserved areas. Finally, a suitability analysis was conducted by integrating several geographic factors such as distance from main roads, proximity to hospitals and the airport, as well as location relative to the district Industrial and military zones, to determine the optimal locations for establishing new schools and improving the distribution of educational services to achieve the best results.

### 3.1 Spatial Distribution

Spatial distribution is defined as the spread of phenomena or elements within a specific geographical area. The pattern and density of the distribution reflect much, especially in the context of our research, where a layer of primary and secondary schools was created to perform analysis and process the results using ArcGIS software in order to reach a scientific decision.

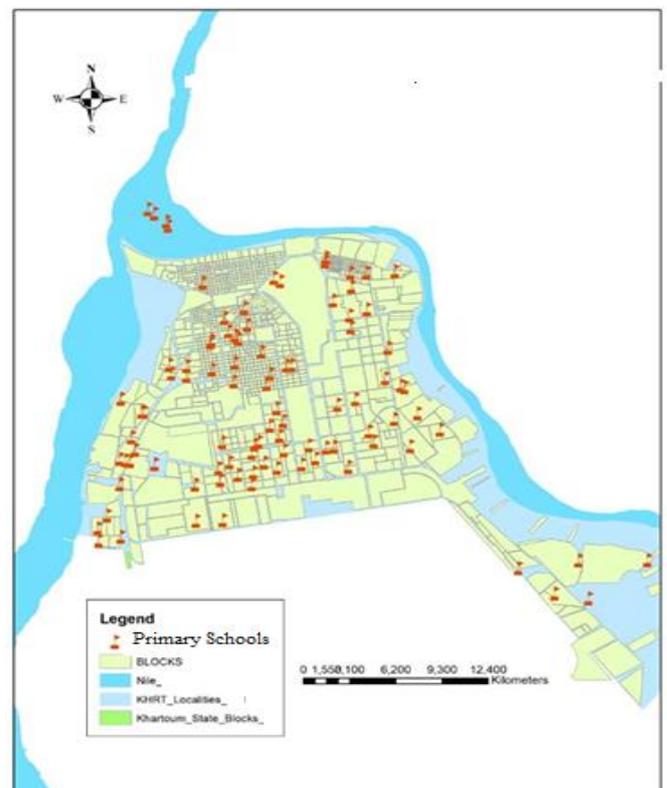


Figure 2: Spatial Distribution of Primary Schools for Boys

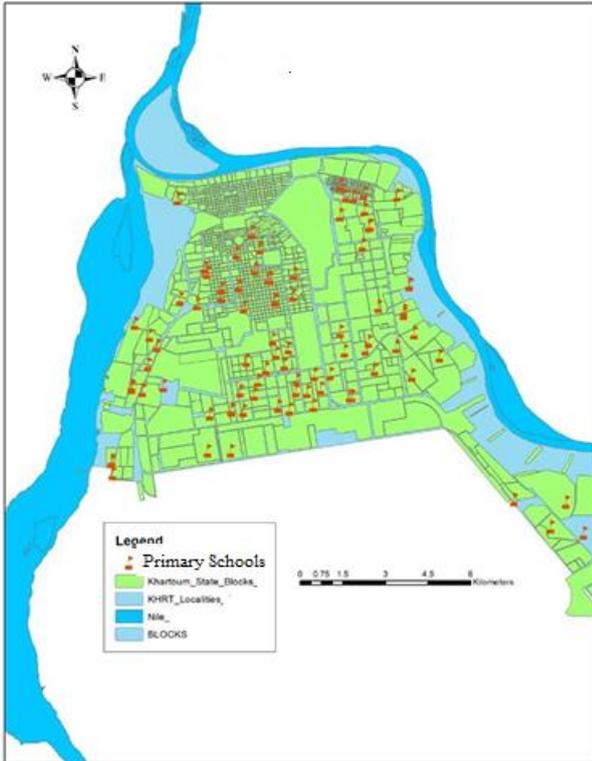


Figure 3: Spatial Distribution of Primary Schools for Girls

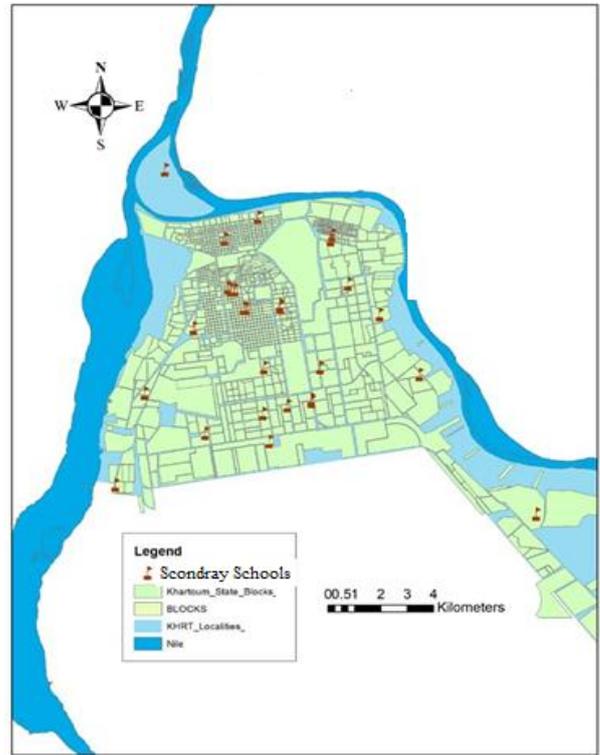


Figure 5: Spatial Distribution of Secondary Schools for Girls

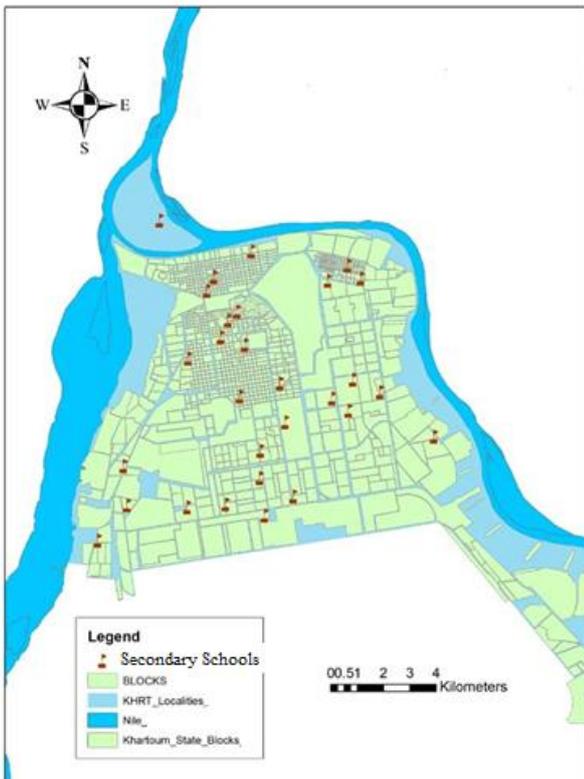


Figure 4: Spatial Distribution of Secondary Schools for Boys

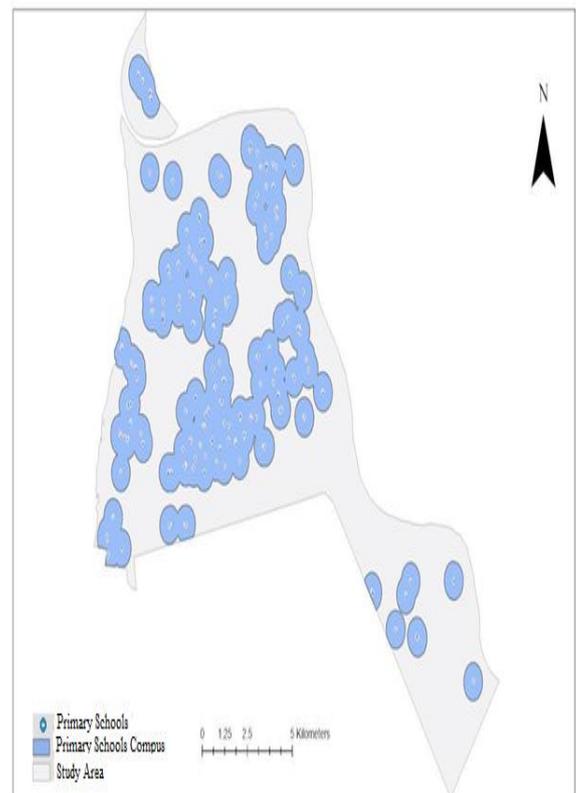


Figure 6: Primary Schools Campus



Figure 7: Secondary Schools Campus

### 3.2 Spatial Coverage

Spatial coverage refers to the geographical extent of a particular phenomenon. More simply, it is the extent of its spread. This is important in urban planning, predicting the best location for each service, distributing services appropriately to the infrastructure of each area, and avoiding the creation of unserved areas.

Within the context of our study, and to understand the areas benefiting from school educational services, the buffer tool was used to create a layer representing the coverage of primary schools with a radius of 500 meters and secondary schools with a radius of 1000 meters.

The areas located within the study area were then identified using the clip tool.

It was found that the total area of the study area, 158,110,511.274,082 square meters, had secondary school campuses comprising 50.58% and primary school campuses comprising 38.17% of the total study area

### 3.3 Spatial Suitability

Spatial suitability is the crucial step and the culmination of the work. After data was collected and processed using ArcGIS software, where data classification was performed and a weight was assigned to each factor, suitable locations were

identified. Different results can be obtained for the same data simply by changing the weight of each factor. This opens opportunities to assess the importance of each factor. With the possibility of combining the results with satellite imagery and remote sensing techniques, even more factors can be identified. The best location for establishing a school was reached using ArcGIS in three stages: classification of all influencing factors, weighting, and then using weighted overlay analysis to combine the different factors and produce a map showing the most suitable locations for establishing schools. This contributes to improving urban planning. The results are as follows:

### 3.4 Roads Layer

After placing the roads in a separate layer, a distances layer was created for the roads (250-500-750). This layer was then reclassified into four categories, ranked from 4 to 1. The best value was assigned to the longest distance as follows:

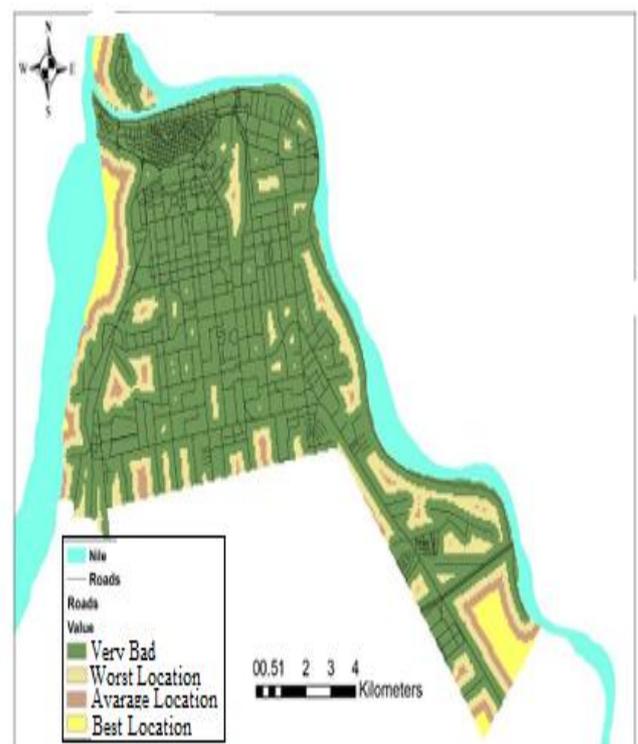


Figure 8: Road layer Classification

### 3.5 Airport Layer

The airport was placed in a separate layer, and a distance layer was created from the airport (at distances of 1000-1500-2000). The airport layer was then reclassified into four categories from 4 to 1, and the best value was assigned to the furthest distance as follows:

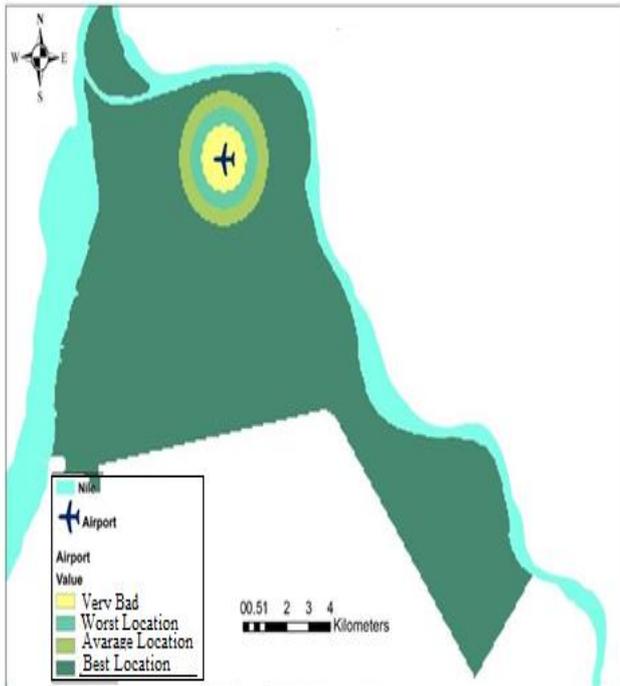


Figure 9: Airport Layer Classification

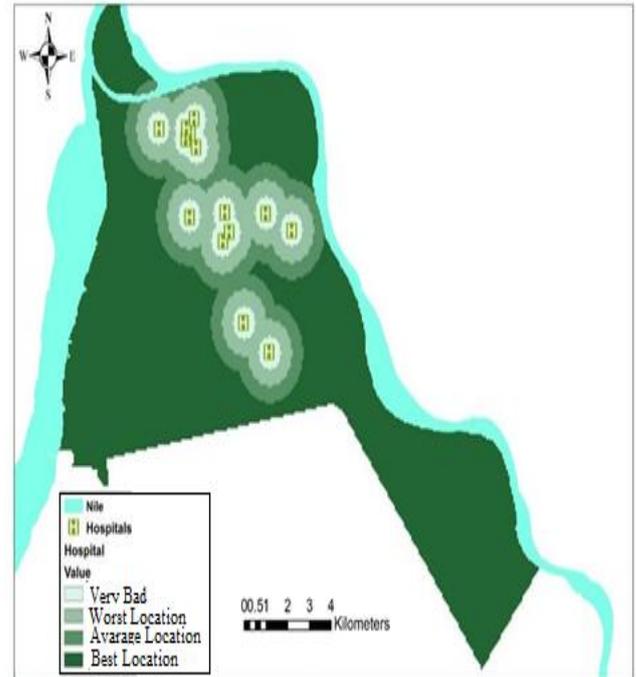


Figure 11: Hospital Layer Classification

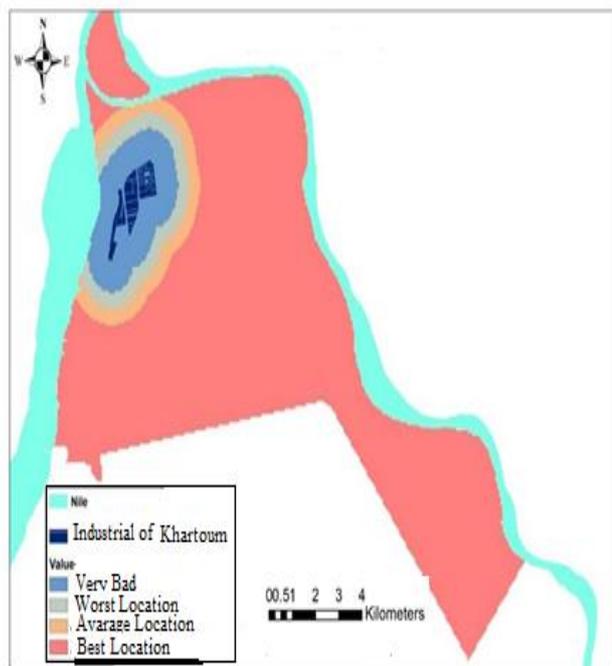


Figure 10: Location of Industrial Layer Classification

### 3.6 Hospital Layer

Hospitals were also placed in a separate layer, and a distance layer was created for hospitals with distances of 5000-1000-1500. Then, the same steps were performed to obtain a suitability layer for hospitals:

### 3.7 Primary School Layer

Primary schools were placed in a separate layer, and a distance layer was created for primary schools at distances of (500-1000-1500). The layer was then classified into four categories, ranked from 4 to 1, to obtain a suitability layer for primary schools.

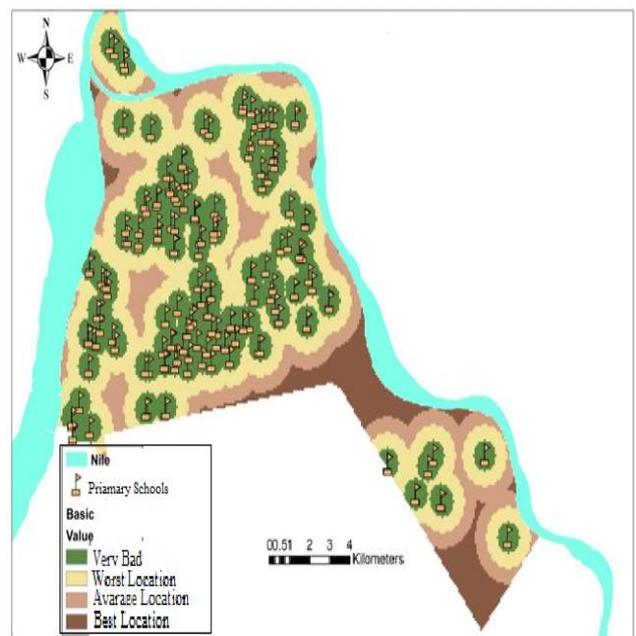


Figure 12: Primary School Layer Classification

### 3.8 Secondary School Layer

Following the same steps as before with distances of 1000-1500-2000, the suitability layer for secondary schools was obtained:

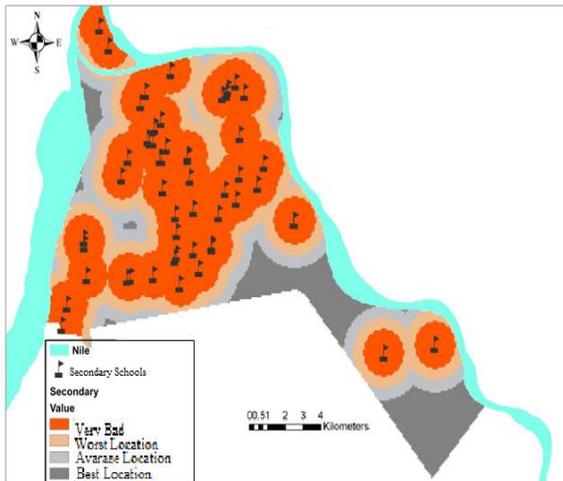


Figure 13: Secondary School Layer Classification

### 3.9 Weighted Overlay

Weights played a key role in the spatial suitability analysis, determining the extent to which each geographical factor influenced the selection of optimal school locations. The most important factors were given higher weights to ensure a fair and appropriate distribution of educational services. Subsequently, weighted overlay analysis was used to integrate the various factors and produce maps showing the most suitable locations for school construction, thus contributing to improved urban planning. The results are as follows:

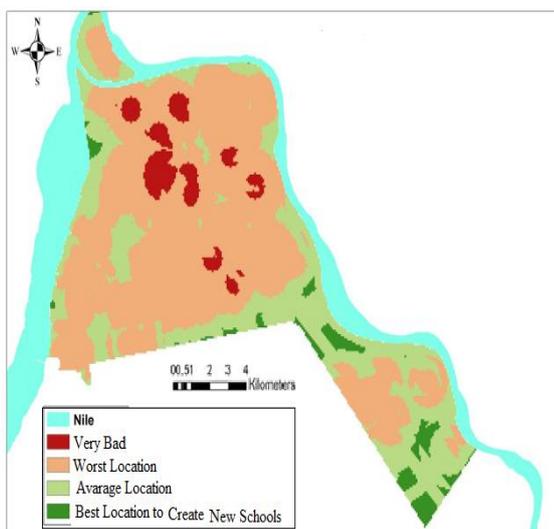


Figure 14: Final Proposal for the establishment of ne Primary Schools

The results showed that the most suitable locations for establishing new primary schools are concentrated in the areas of Al-Lamab, Jabra, and Suba, as these areas were characterized by high degrees of suitability according to the adopted criteria. In contrast, areas such as Burri, Al-Amarat, Al-Sahafa, Al-Shajara, and Al-Jeraif West showed low to unsuitable degrees, indicating a need to reconsider the distribution of schools.

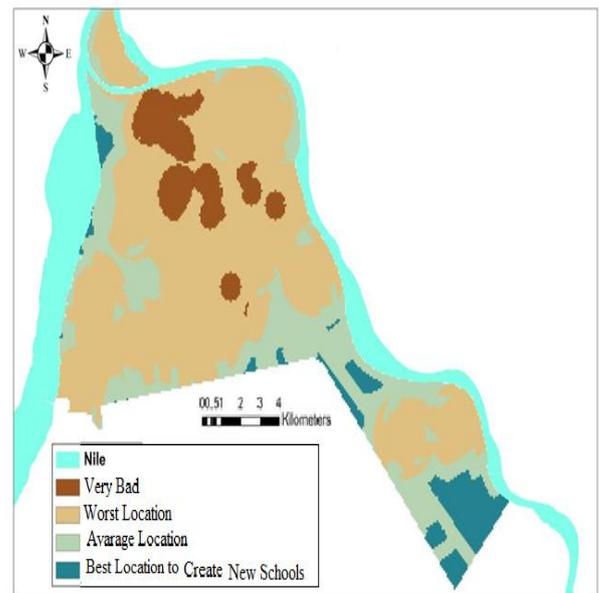


Figure 15: Final Proposal for the establishment of ne Secondary Schools

The study of secondary school segregation also showed a similar pattern in distribution, with the Al-Adab, Suba Al-Shajara, and Al-Harif West Kabir areas emerging as suitable locations for establishing new secondary schools, while the Al-Amarat and Burri areas showed lower degrees of suitability.

This similarity in results highlighted the need for integrated planning solutions that take into account the different educational stages, ensuring a more equitable and comprehensive approach.

## IV. CONCLUSION

This study demonstrates that the spatial distribution of primary and secondary schools in Khartoum locality is markedly unbalanced, resulting in unequal access to educational services. The application of GIS-based spatial analysis proved effective in identifying areas of concentration and service deficiency, revealing clear mismatches between school locations, population density, and planning standards. The findings emphasize that current school distribution patterns do not adequately support spatial equity, particularly

in underserved areas such as Al-Lamab, Al-Shajara, and Suba. Consequently, the study highlights the necessity of adopting data-driven, GIS-supported planning approaches to guide future school siting decisions, enhance accessibility, and promote equitable provision of educational services in rapidly growing urban areas.

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