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**PROJECT 2**

SECTOR : GEOGRAPHIC INFORMATION SYSTEMS AND LAND MANAGEMENT
(GIS-LM)

**Under the theme :**

# Integration of GIS and MCA for high school site selection in ESSAOUIRA city, MOROCCO

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## Abstract

Selecting suitable sites for high schools is crucial for effective educational planning. This research, conducted in Essaouira province, uses the Analytical Hierarchy Process (AHP) method to systematically evaluate and prioritize criteria for high school site selection.

We leverage Geographic Information Systems (GIS) tools to enhance decision-making by considering technical, economic, and environmental factors. By combining spatial data and decision criteria, we create a comprehensive framework to identify optimal high school locations.

This study addresses the limitations of traditional site selection practices and highlights the potential of GIS-integrated methods to avoid risks like unsuitable locations and overcrowding. The research findings offer valuable practical insights for educational authorities and policymakers regarding three sites, each covering at least two hectares.

These results highlight the importance of utilizing advanced spatial tools to select the optimal location for constructing high school infrastructure.

# Introduction

Much like how the entire world faces challenges with scarce land resources, Essaouira, a beautiful city in Morocco, grapples with the need for thoughtful urban development, particularly in education infrastructure. The increasing population and the migration of students from rural areas to Essaouira for better educational opportunities underscore the necessity of planning for new high schools in the region.

In recognizing the importance of suitable land use, just as it is a global concern, Essaouira aims to carefully plan the establishment of a new high school. The city's growing population, a blend of diverse ethnicities and cultures, highlights the need for comprehensive urban development that accommodates the influx of students. Much like a puzzle, selecting a suitable location involves weighing multiple criteria, such as technical, social, and environmental factors, with the help of decision-making tools like Multi-Criteria Analysis (MCA), the Analytical Hierarchy Process (AHP), Geographic Information Systems (GIS), and remote sensing.

Education holds a paramount role in Essaouira's development, and the creation of new high schools aligns with the city's commitment to providing quality education. The existing educational landscape has improved in recent years, yet challenges persist, especially in accommodating students from rural areas, leading to school overcrowding. Efforts to enhance education accessibility and literacy rates are ongoing, emphasizing the importance of investing in educational infrastructure.

In this study, we explore the complexities of selecting an appropriate site for a new high school in Essaouira. Drawing inspiration from decision-making methodologies like AHP and MCA, coupled with the capabilities of GIS and remote sensing, we aim to develop a robust approach for identifying and mapping suitable locations. As we embark on this journey, the goal is to create dynamic and active educational structures that not only responds to the existing population but also contribute to the cultural sustainability and overall development of Essaouira.

# Chapter I:

## The study area: Essaouira city

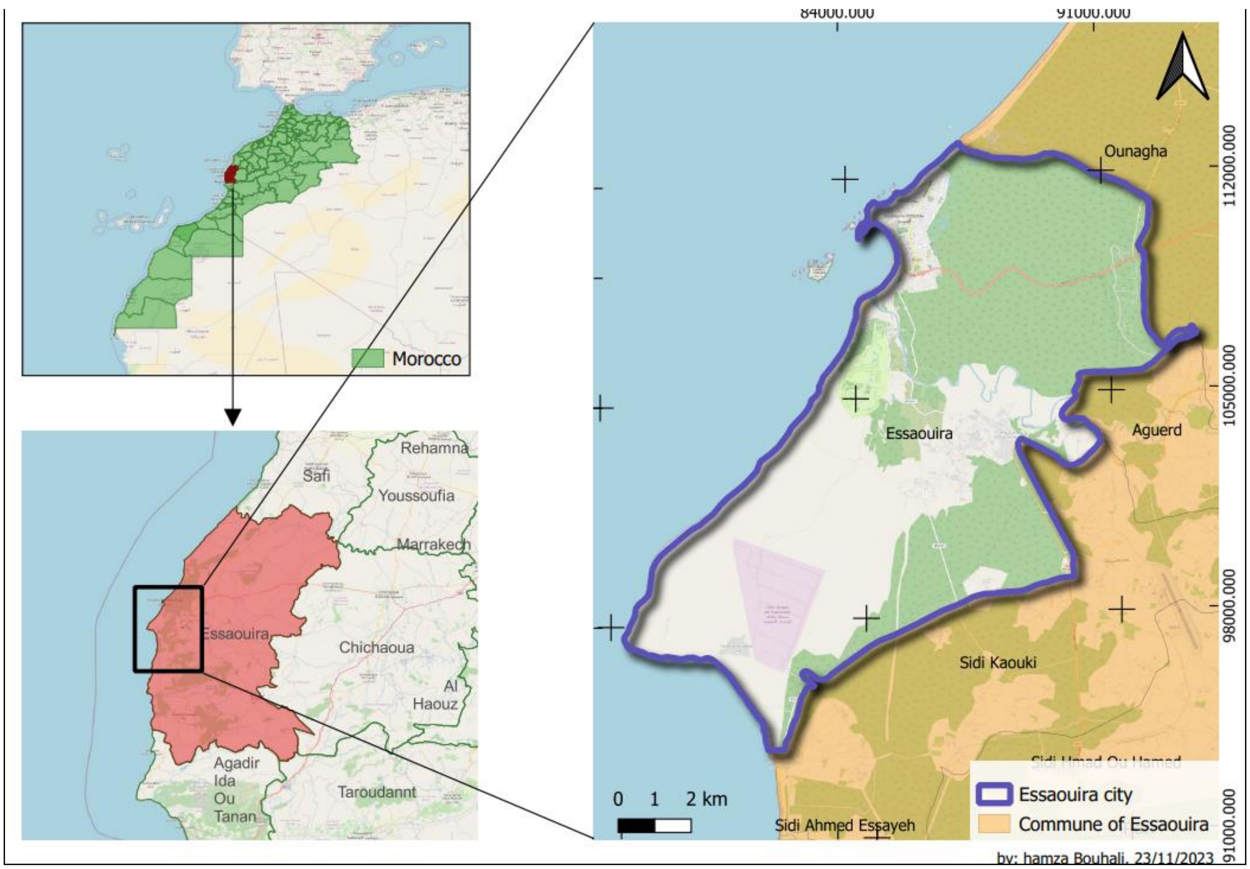
**Introduction:**

In this chapter we are going to explore the selected study area in bout geological and demographical aspect which will bring as to form a shaped understanding about Essaouira and it's need for a high school.

1. **Location and Geographical Description of Essaouira:**

The late-18th-centry town in the eastern Morocco, Essaouira is rugged terrain on the western slopes of the high Atlas Mountains meets the Atlantic Ocean on the west, bounded by Safi Province to north, Agadir Province to the south, and Chichaoua Province to the east (as mentioned in figure1).

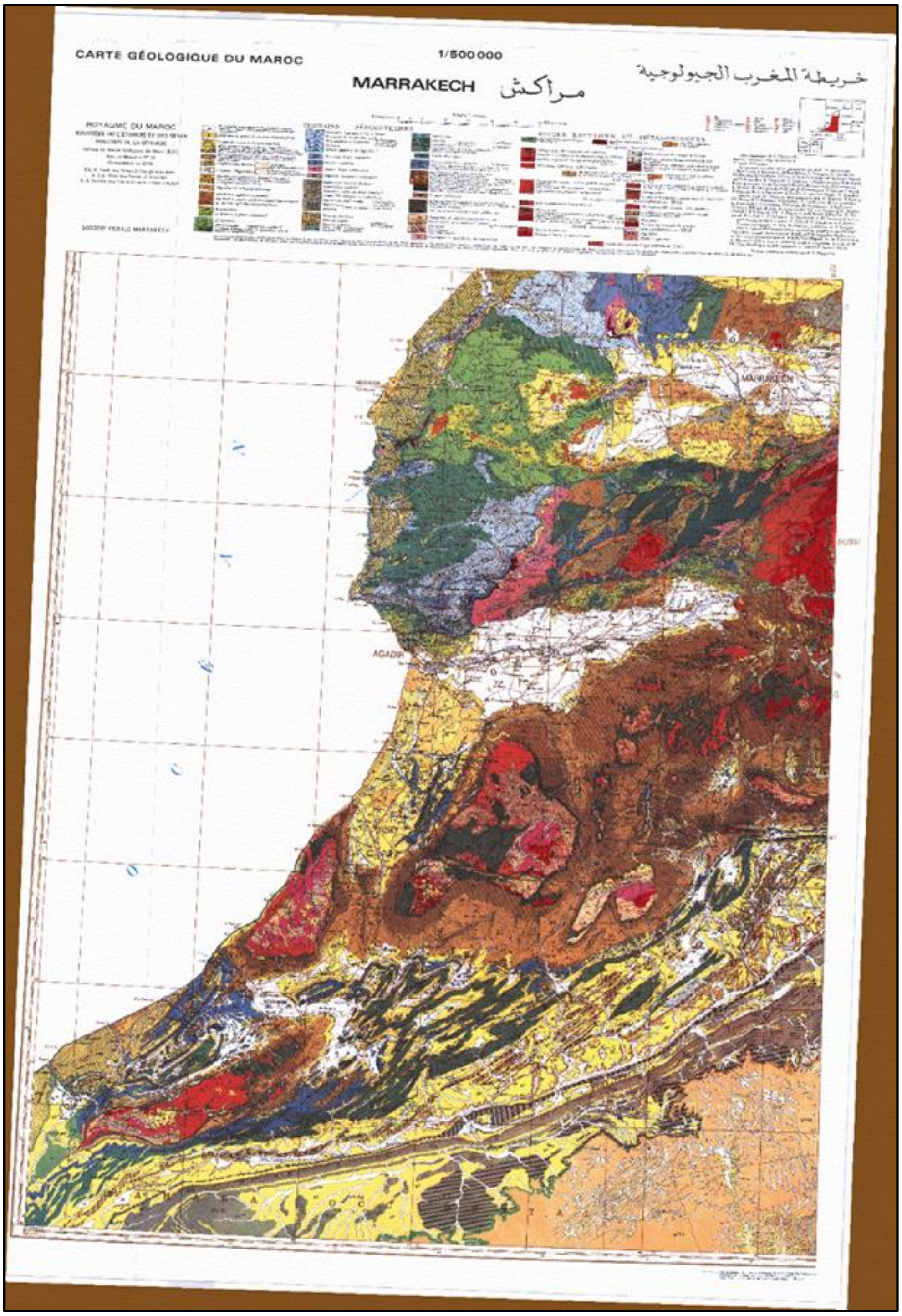
**Figure 1:Essaouira's location**




Geographically Essaouira lies on the Atlantic coast of Morocco, with coordinates 31º 31' North and 9º 46' west, this beautiful city covers an area of 18 sq Km, in the larger Essaouira province, which has an area stretched across 7,000 sq km.

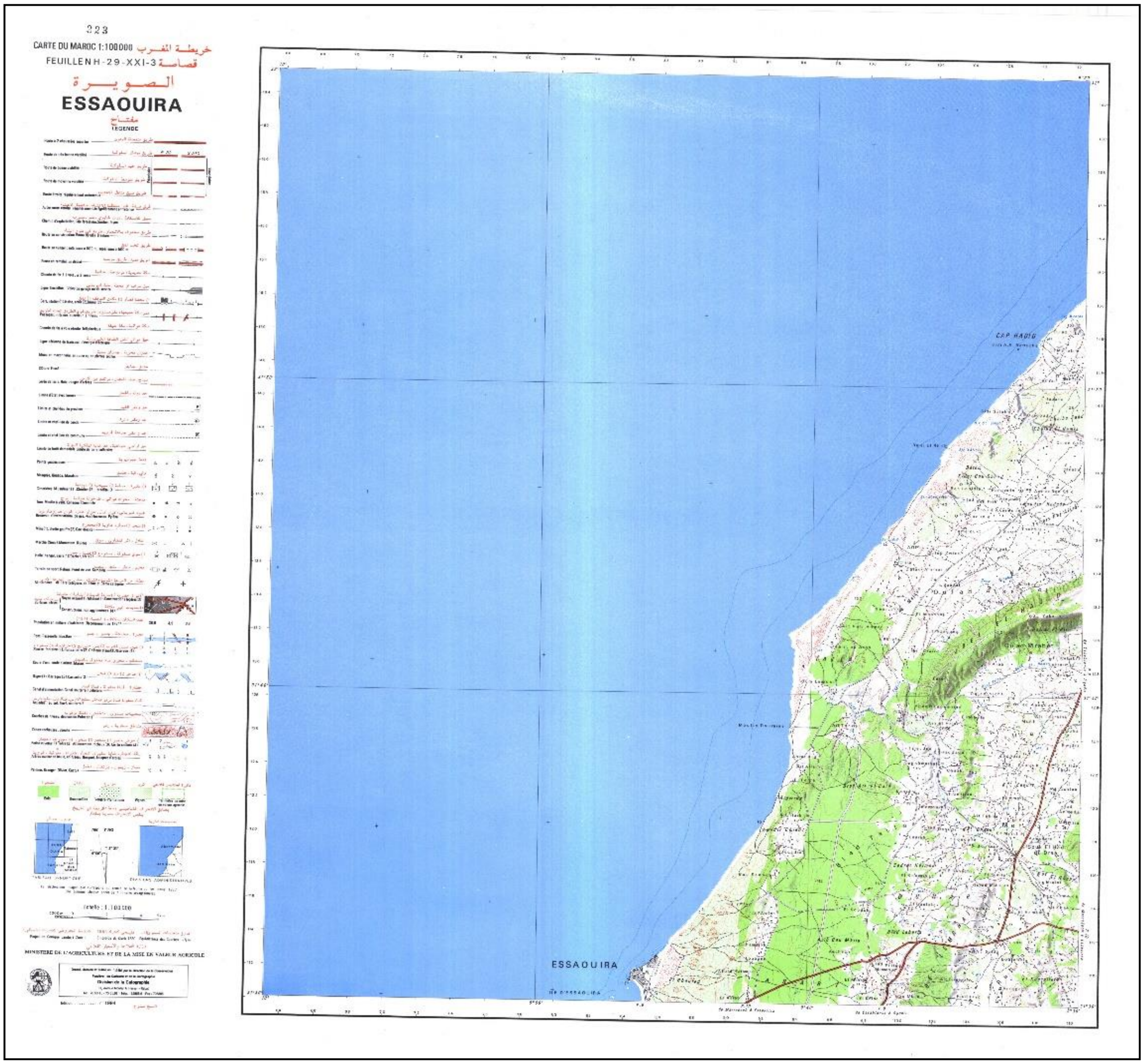
**The geological map of Essaouira:** are used to represent the distribution of rock formation, faults, folds, and other geological features, that often provide insights into the subsurface based on the age, type, and structure of the rocks at the earth's surface (as mentioned in figure 2).

**Figure 2: Geological map featuring Essaouira city within central Morocco.**



**Topographic map:** allows the understanding of the lay of the land, identify valleys, ridges, cliffs, and other topographical features, which is crucial for various applications like land-use planning, and infrastructure development, since it provides an accurate measurement of distance, areas, and slopes (as mentioned in figure 3).

**Figure 3: Topographic map of Essaouira city.**




## 2. Demographics of Essaouira:

### a. Population Size and growth:

Essaouira, with an estimated population of around 78,000, is a vibrant city in central Morocco, known for its rich cultural diversity. It serves as a melting pot, blending various ethnicities and cultures, including Arabs, Berbers, and individuals of sub-Saharan African descent. The majority of Essaouira's residents practice Islam, and Arabic is the official language, although French is also widely spoken.

In recent years, Essaouira has experienced substantial growth, partly due to an influx of people from the surrounding rural areas. These individuals are drawn to the city by the promise of better economic opportunities and, notably, improved educational prospects for their children. Many families from the outskirts of Essaouira have either relocated to the city or have sent their children there to pursue their educational aspirations.

Moreover, Essaouira has become increasingly popular among expatriates from Europe and other parts of the world. They are attracted to the city's unique charm, relaxed lifestyle, and cultural offerings.

### b. Age groups:

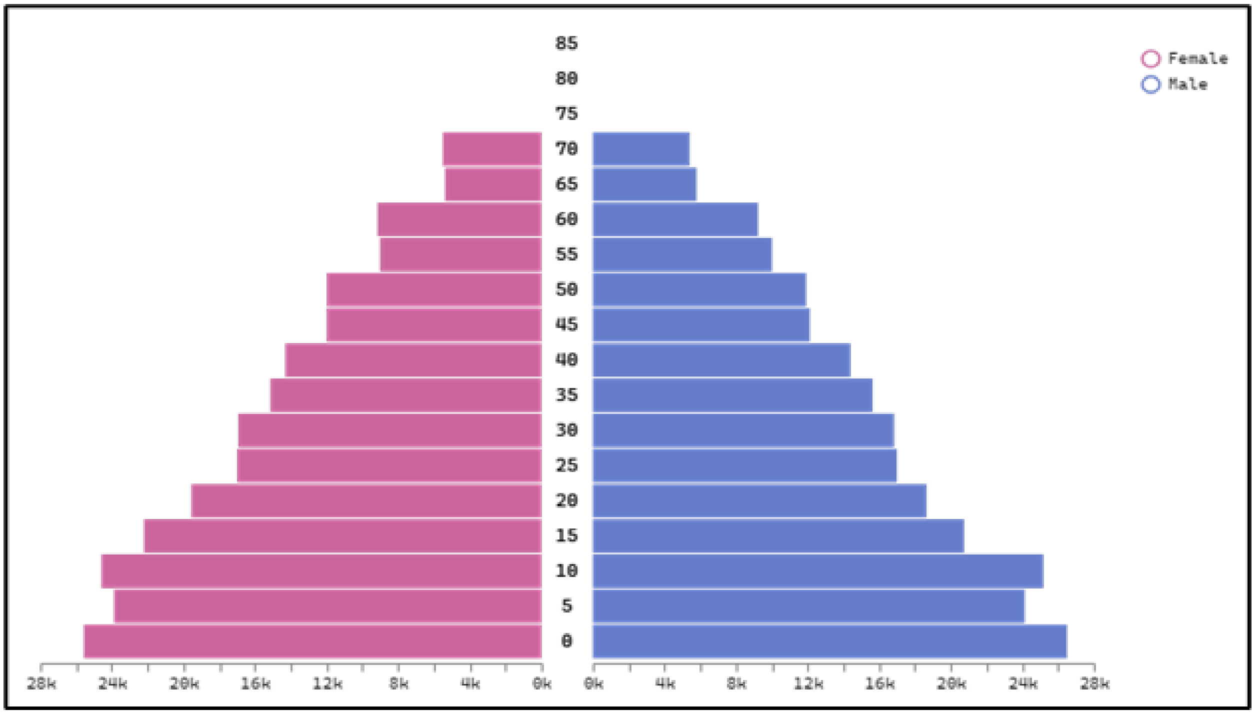
The population of Essaouira province is diverse in age groups, with a median age of 25.3 years. The age distribution shows a significant portion of the population in the younger age groups, which is important to consider when planning educational facilities like high schools.

In addition to Essaouira city, the rural areas of the province play a pivotal role in the overall population and distribution of resources. These areas often have specific needs and characteristics that should be considered when planning educational facilities. The population distribution in rural areas may differ from that of urban areas, and accessibility to educational facilities can be a significant factor for residents in these areas.

- **Age Group 10-14:** The total population in this age group is 49,755, with 25,186 males and 24,568 females.
- **Age Group 15-19:** There are 42,930 individuals in this age group, consisting of 20,739 males and 22,190 females.
- **Age Group 20-24:** In this age group, there are 38,201 individuals, with 18,646 males and 19,555 females.
- **Age Group 25-29:** The total population in this age group is 33,996, with 16,992 males and 17,004 females.

- **Age Group 30-34:** There are 33,758 individuals in this age group, consisting of 16,841 males and 16,917 females.

**Figure 4: Essaouira Province Population Tree.**




### c. Education and literacy:

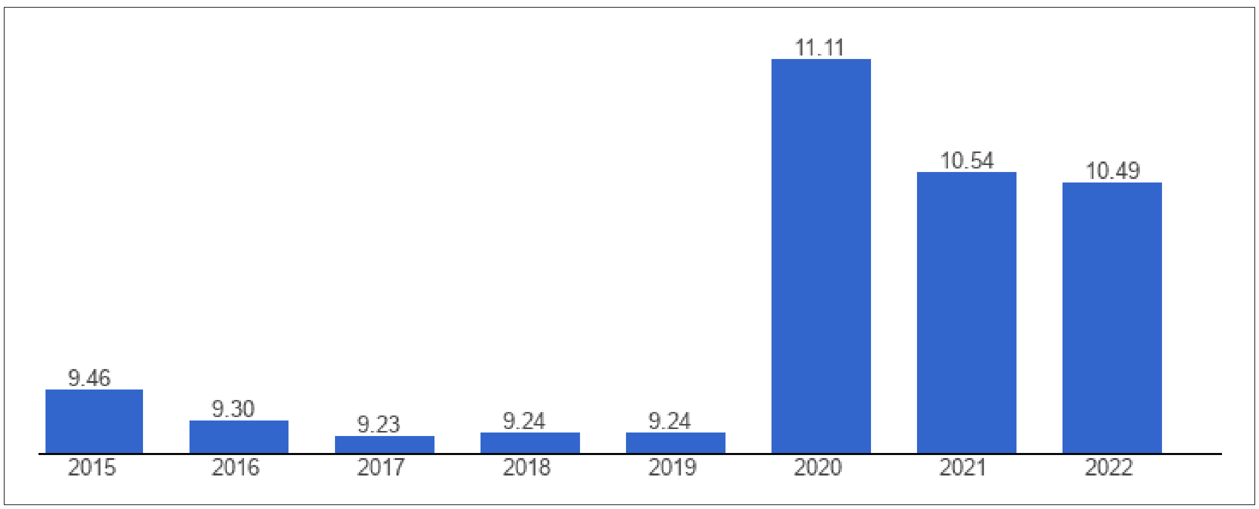
Essaouira's education and literacy rates have greatly improved in recent years. There are various basic and secondary schools in the city, as well as several vocational and technical training facilities. The city also is a home for the University Caddi Ayyad - Higher School of Technology. Essaouira's literacy rate is believed to be approximately 73%, which is higher than the national average. However, more effort has to be done to enhance access to school and boost literacy rates, especially in rural regions and among disadvantaged populations. Efforts are being made to address these difficulties, including measures to increase school resources and assistance, as well as to encourage adult literacy programs.

### d. Activity and Employment:

The city has a variety of industries and sectors that contributes to its economy, such as fishing, crafting, and mainly tourism, these are the city's key economics drivers.

Hotels, restaurants, transportation, and tour operators, these services are provided by a wide range if not the vast majority of the companies, with a booming visitor number only in 2023 Essaouira tripled it compared to previous summers, welcoming only in July over 26,000 tourists with an increase 42% compared to 2019. Fishing also employs a sizable section of the local population, from exporters to fishermen. The crafts industry is supported by many craftsmen and small enterprises. There are also other industries that contributes to the city’s economy such as commerce, and construction. Having an expanding infrastructure and strategic position that makes it appealing to firms and investors especially in the renewable energy industry. Although the unemployment rate and the underemployment continue to rise (as shown in figure 5), particularly for the youth.

**Figure 5: Chart of the unemployment rate**




**Conclusion:**

The influx of people from surrounding rural areas to Essaouira, driven by a desire for better economic opportunities and enhanced educational prospects, has led to significant population growth in the city. This trend has resulted in a strain on existing high schools, leading to issues of overcrowding. The city's ability to provide quality education and accommodate the educational needs of its growing population is a critical challenge that needs to be addressed. Efforts to expand educational infrastructure and improve access to quality education are essential to alleviate the issue of overcrowding in Essaouira's high schools and ensure that all students have the opportunity to pursue their educational dreams.

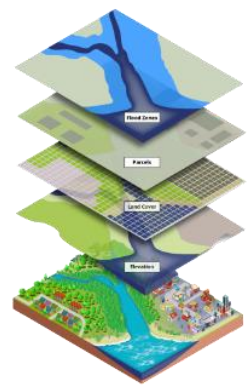
# Chapter II:

## Materials and Methods

**Introduction:**

This chapter dig into our analytical approach and methodology employed to attain the project's objectives. It involves an exploration of the data utilized, materials employed, methods adopted, and an analysis that is pivotal in generating the desired maps.

## 1. Materials used:

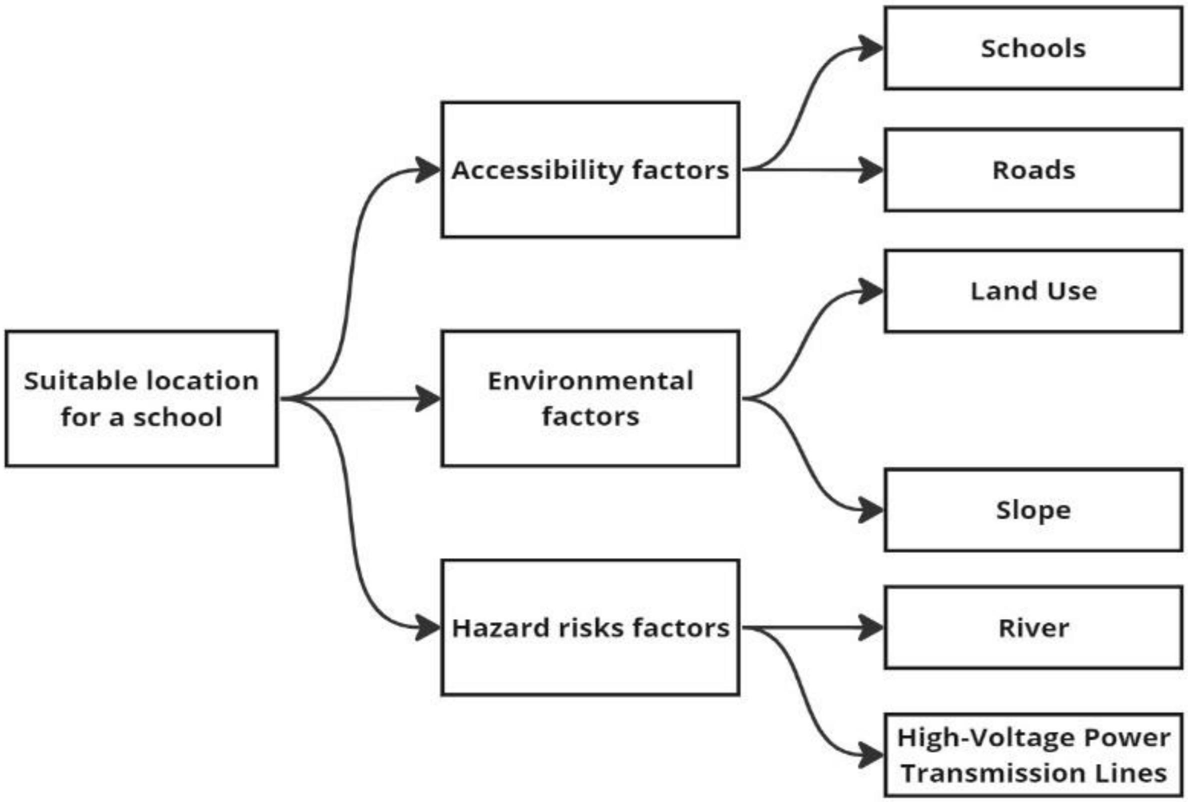
| | |
|---|---|
| GIS stands for **Geographic Information Systems** and is a computer-based tool that examines spatial relationships, patterns, and trends in geography.<br>The 4 main ideas of Geographic Information Systems (GIS) are:<br>Create geographic data.<br>Manage it in a database.<br>Analyze and find patterns.<br>Display it on the map. | **Figure 6:Gis representation**<br> |
| OpenStreetMap (OSM) is a free, open geographic database updated and maintained by a community of volunteers via open collaboration. Contributors collect data from surveys, trace from aerial imagery and also import from other freely licensed geodata sources. Because OpenStreetMap is publicly licensed under the Open Database License, it is widely used to create electronic maps (Figure 10: OpenStreetMap), assist in humanitarian aid, and visualize data. | **Figure 7:Openstreetmap**<br> |

| | |
|---|---|
| QGIS (Quantum Geographic Information System) is a free, open-source software that allows users to create, edit, visualize, analyse, and publish geospatial information. There are many benefits to using QGIS. First, the software offers many free online resources and maps available to download. | **Figure 8:Qgis logo** |
| Google Earth Engine is a cloud-based geospatial analysis platform that enables users to visualize and analyse satellite images of our planet. | **Figure 9:Google Earth Engine logo** |
| ArcScene is a 3D visualization application that allows you to view your GIS data in three dimensions. 3D view of utility poles and power lines. | **Figure 10:ArcScene logo** |
| SketchUp is a premier 3D design software that makes 3D modeling and drawing accessible and empowers you with a robust toolset. | **Figure 11:SketchUp logo** |

## 2. Methods:

The proposed model begins by gathering information from various sources to understand the features of the study area. This involves collecting data from online resources like Google maps for DEM the OSM downloader and manually creating maps at a suitable scale. Once gathered, the information is carefully managed and prepared for analysis, organized in a way that facilitates in-depth study.

**Figure 12:Criteria levelling**

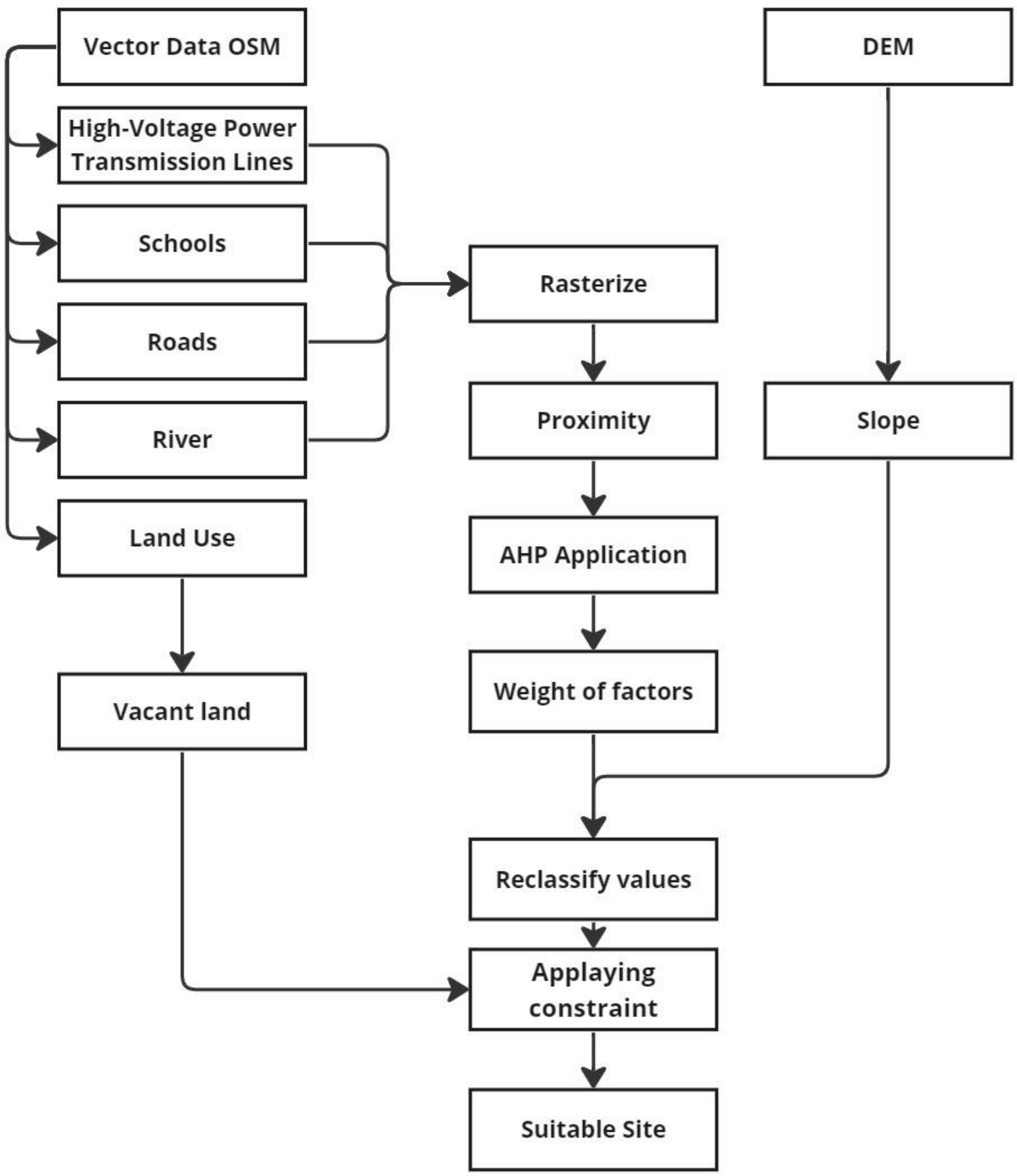



After this, the analysis goals and criteria are established for the subsequent stages. To determine the importance of each criterion, weights are assigned using the Analytical Hierarchy Process (AHP). These weights indicate the relative significance of each criterion in the analysis.

Moving ahead, the data analysis phase utilizes Geographic Information System (GIS) tools and methods to identify suitable locations for constructing a new high school. This comprehensive process ensures a thorough understanding of the study area, enabling well-informed decisions regarding the optimal sites for school construction.

In this segment, we outline the approach employed in our proposed model to pinpoint the best location for constructing a new high school in Essaouira city. The steps of our model are illustrated in Figure 14, providing a visual representation of the process.

**Figure 13:Global methodology**

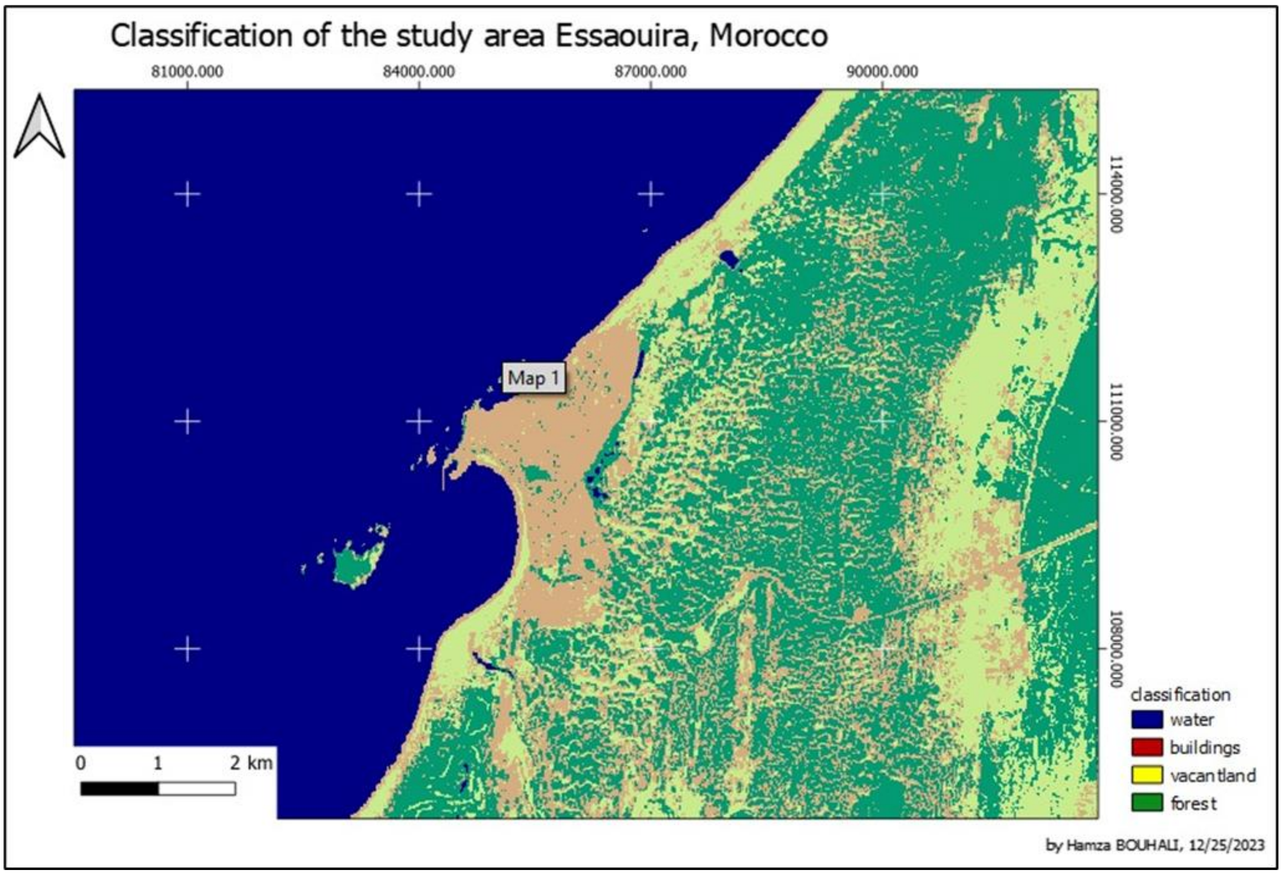


### 3. Data collection and preparation:

Data collection stands as a pivotal phase within GIS projects, as the ground upon which we build, and secure the project. The comprehensiveness of the data constructs our ability to meet project goals with reliability and efficiency.

The following parameters were identified and used for school location; distance from residential areas, distance from the main road, distance from river, distance to schools, distance from high voltage electrical transmission line, Data collected was from OSM Downloader, from DEM, and from the classified image (figure 15).

**Figure 14:classified image of Essaouira commune**




#### a. Road's factor:

The road is an important factor for constructing a school since it influences its accessibility. Easy access to roads makes it convenient for students, parents, and staff to commute to and from the school.

It also facilitates transportation services, such as school buses, ensuring that students from various locations can reach the school without much difficulty.

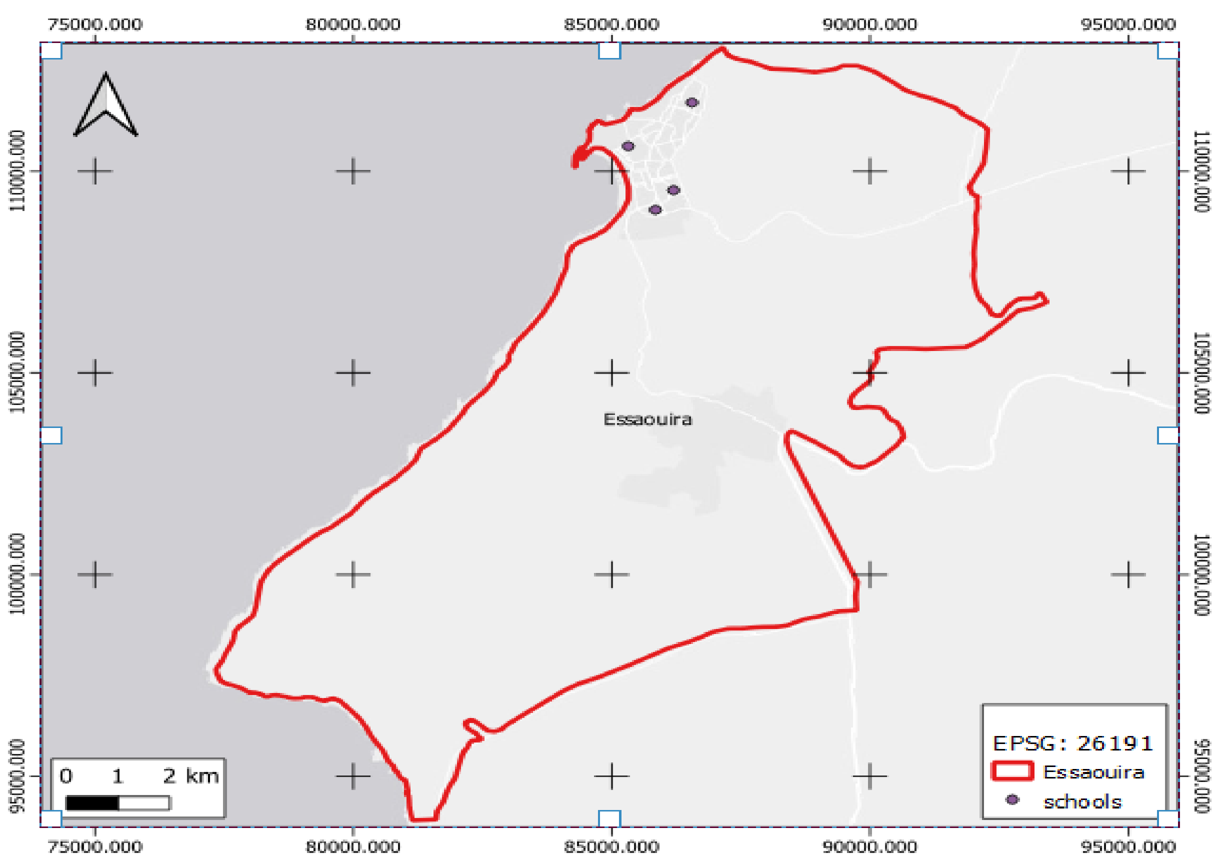
Also, in case of emergencies, having quick access to roads is crucial. Emergency services such as ambulances and fire trucks should be able to reach the school easily.

Being close to major roads ensures a faster response time in case of unforeseen incidents.

However, giving all these beneficial information it is advised that the roads should be at least 150 m far from school because of noise, air pollution Numerous research studies have addressed the health implications for students attending schools near extensive road networks.

These investigations consistently indicate that students in close proximity to such roads face elevated risks of heart and lung problems. However, the risk substantially diminishes beyond a distance of 150 meters.

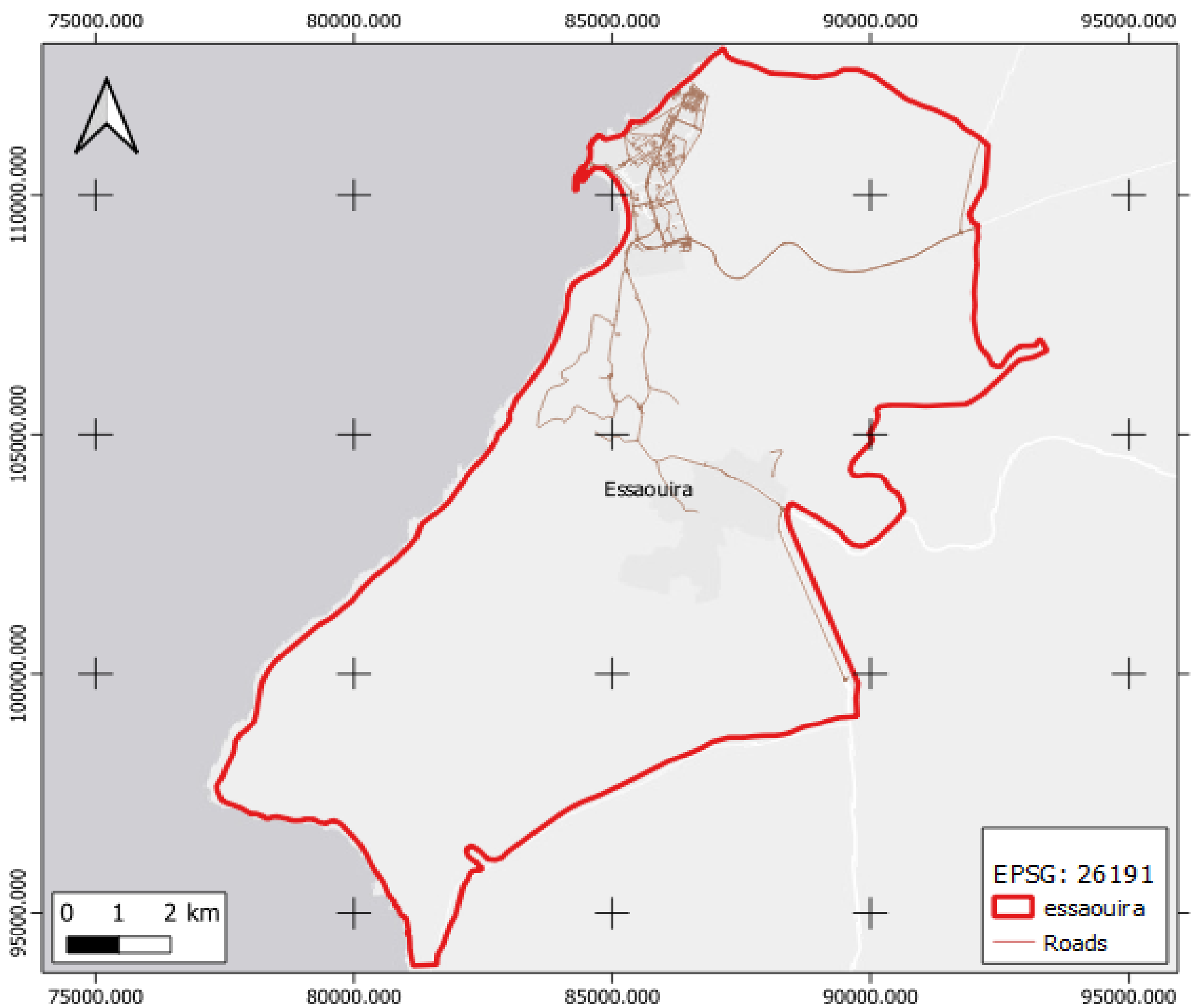
**Figure 15:Existing schools' data for the studied area.**



### b. Existing schools' factor.

One key factor we will consider in our analysis is how far students would have to walk to reach another school. The recommended walking distance in the literature is 1–2 km, but in the United States, it's suggested to be 2.4 km.

**Figure 16:Roads data for the studied area**

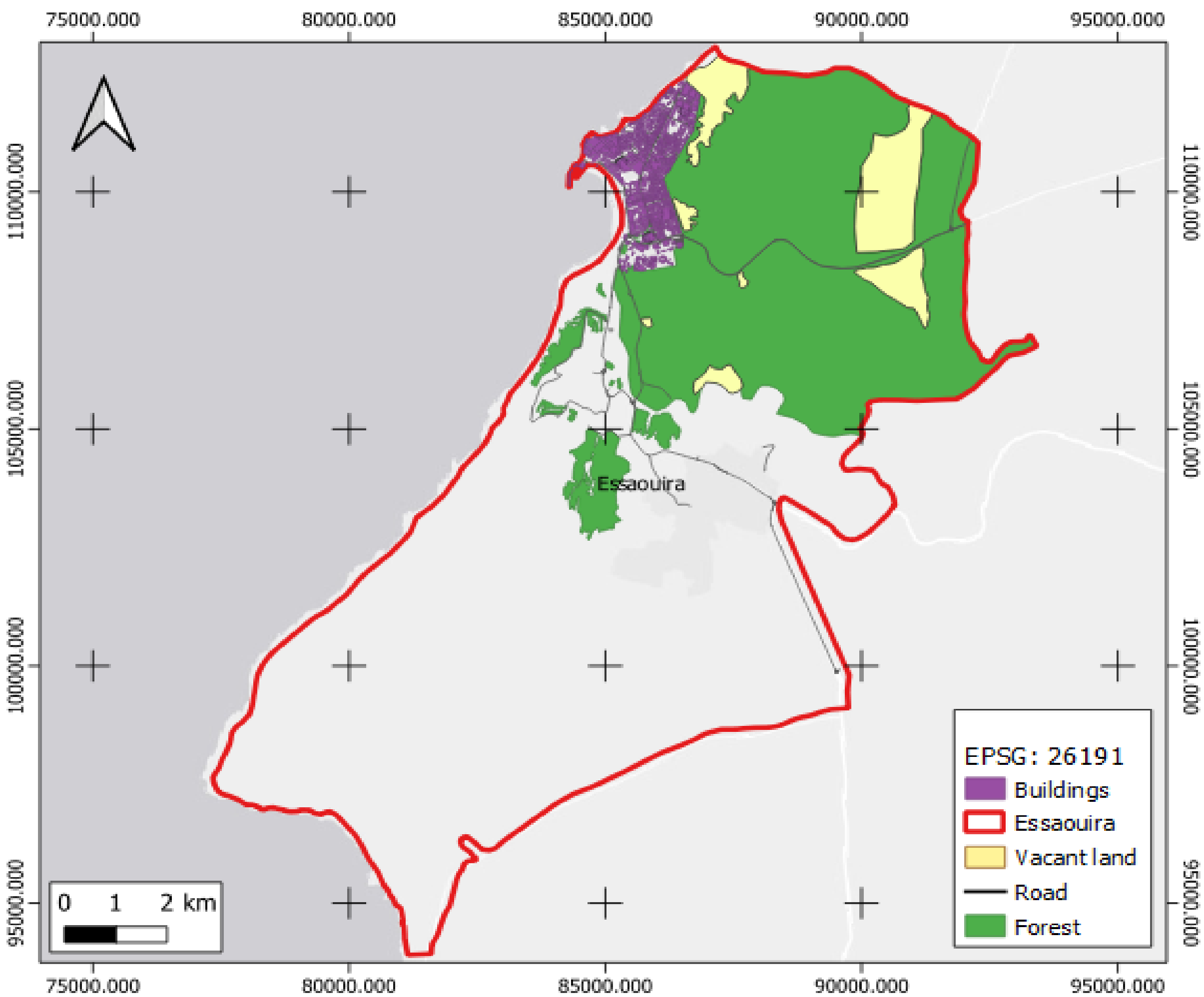



### c. Land use factor.

Land use plans play a crucial role in the formulation of zoning plans, influencing the selection of school sites. The process involves determining and evaluating sub-criteria based on various land uses such as dense forests, seasonal agriculture, agricultural areas, wetlands, rocky terrain, open spaces, and others, gathered from the geological map and the classified image. This comprehensive approach ensures that school site selection aligns with the overall zoning strategy.

Moreover, this factor ensures the harmony of school locations with the city's land use planning. The objective is to position schools within residential zones and in close proximity to parks and green spaces, fostering support for sports and outdoor activities.

**Figure 17:Roads data for the studied area**



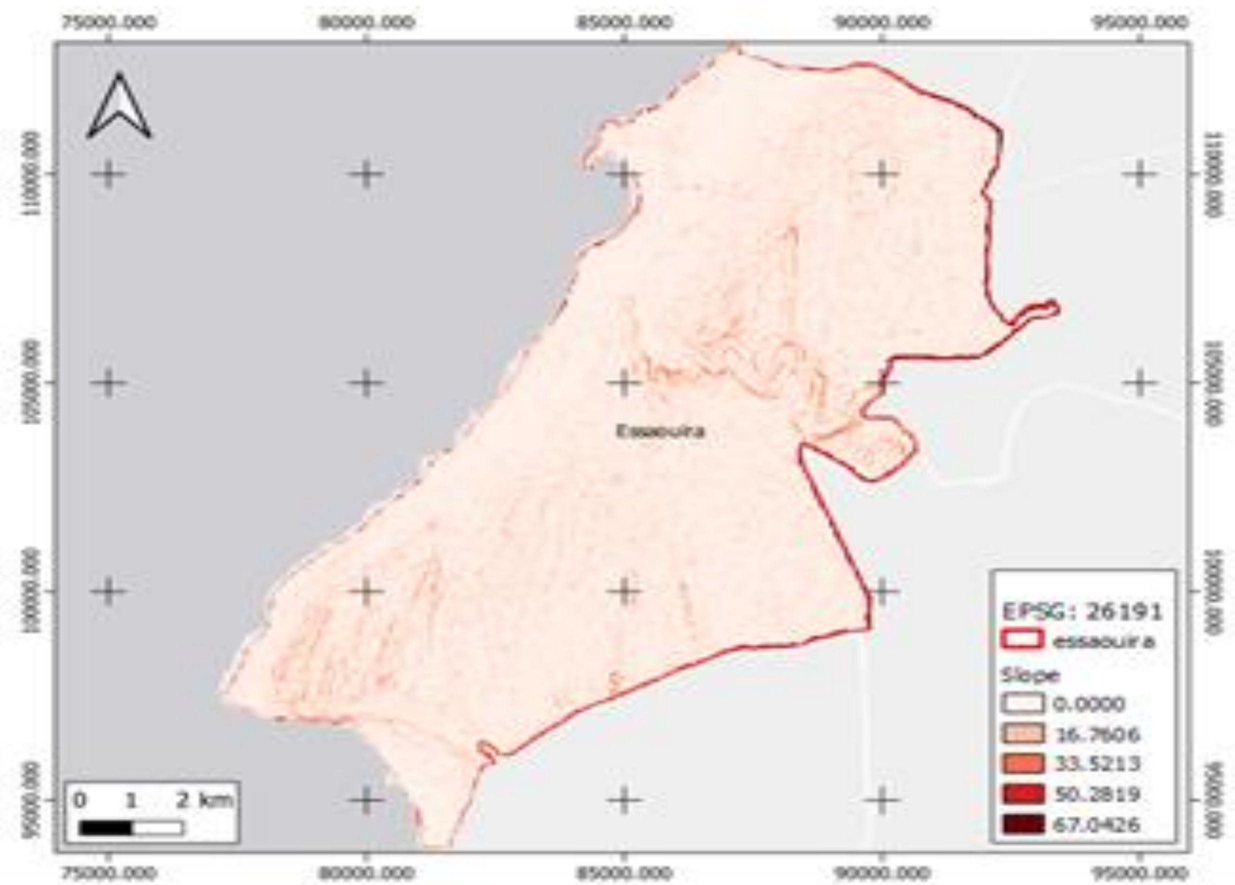

**d. Slope factor.**

Choosing the right location is crucial for a school. If a school is situated on a steep slope, it can lead to various problems. Steep slopes often face natural disasters like landslides, avalanches, and rock falls. Building schools on steep slopes is also challenging, especially in terms of cost.

Ideally, a good school site is on a fairly flat field. This ensures that children can play sports comfortably, have easy access to schools, and reduces construction costs. It's not advisable to have a slope steeper than 30 degrees.

To analyze this, we will use a digital elevation model (DEM) that will be transformed into a slope raster dataset. This will help us understand the terrain and make informed decisions about suitable school locations.

**Figure 18:Slope map of the studied area**



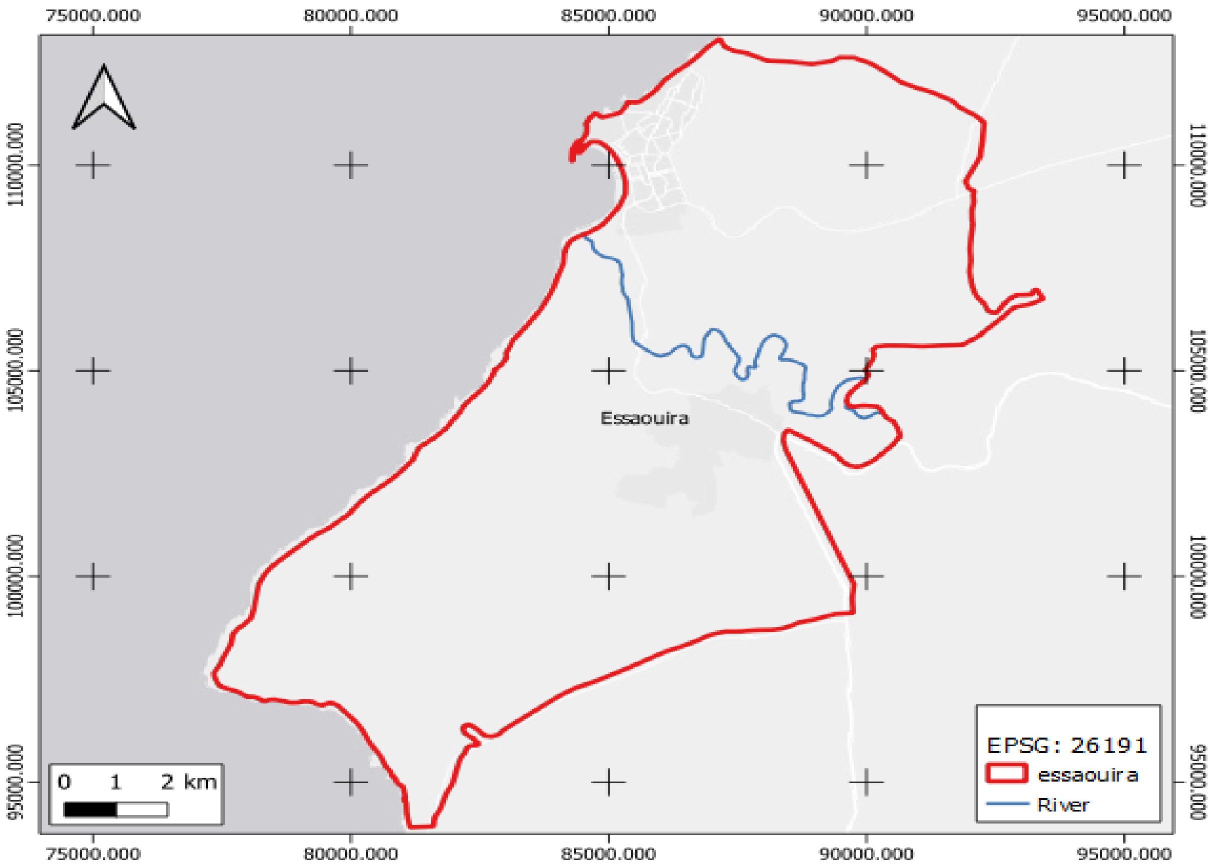

**e. River factor.**

Choosing a school location near rivers entails risks associated with potential flash floods and water pollution, posing potential harm to children. Experts advise maintaining a minimum distance of 150 meters from riverbanks to ensure safety.

Because placing schools within 100 meters of rivers heightens the risk of flooding, leading to potential personal injuries, loss of life, and substantial property damage.

However, beyond a distance of 2000 meters, the risk decreases. To mitigate these risks, it is recommended to position schools outside flood-prone areas.

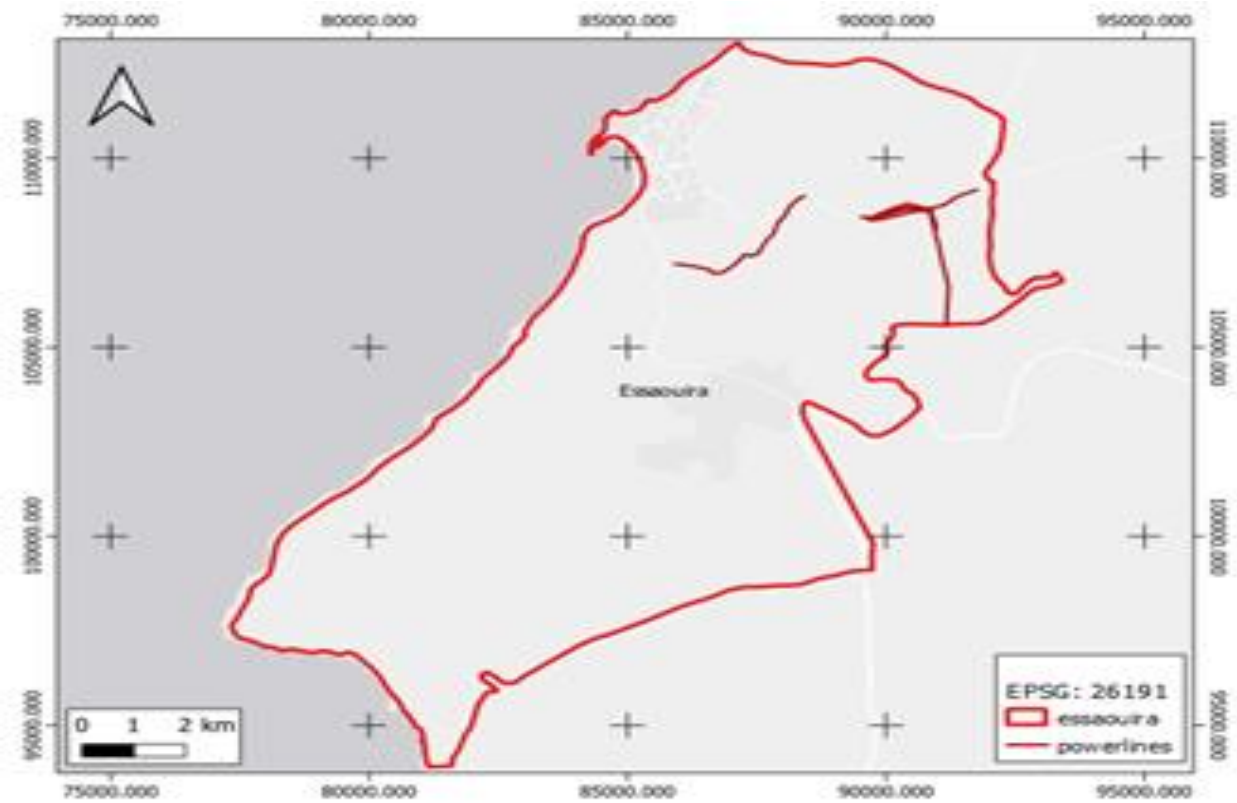
**Figure 19:River's data for the studied area**




### f. High-Voltage Power Transmission Lines factor.

The potential health hazards associated with electric power transmission lines, managed by power companies, are still under investigation, particularly concerning the impact of electromagnetic fields (EMF) on human health. Consequently, careful consideration should be given to health and safety aspects when selecting sites in proximity to overhead transmission lines. To safeguard the well-being of students and school staff from high-voltage electricity, most health departments advise maintaining a minimum distance of 107 meters from such lines. Therefore, establishing buffer zones of 150 meters is recommended for enhanced safety.

**Figure 20:High-Voltage Power Transmission Lines data**




## 4. Analytical Hierarchy Process:

We employed the Analytical Hierarchy Process (AHP) in our project of constructing a new high school for several key reasons. AHP's structured decision-making framework was crucial in handling the complexity of selecting an optimal site, considering multiple criteria such as accessibility, environmental impact, and community needs. The pairwise comparison process in AHP allowed us to systematically evaluate and prioritize criteria, making the decision-making process more rigorous and reliable. Additionally, AHP's consistency checking feature ensured the credibility of our judgments, enhancing the transparency and trustworthiness of our decision-making approach. Overall, AHP emerged as a valuable tool, contributing to a thoughtful and informed decision-making process in the construction of the new high school.

### a. AHP Ranking

The prioritization of criteria was determined by consulting information derived from articles and existing literature. In this process, we identified three distinct levels and pinpointed six specific sub-criteria. This approach allowed for a thorough examination of the factors influencing our decision-making process, enhancing the depth and precision of our analysis (table 1).

### b. Computation of weights

The process of handling data included turning it into vectors and then systematically building the model. This involved creating distances between points, cutting out specific areas, rearranging, and assigning different weights using a tool called weighted overlays to form an overall suitability score. Each layer was divided into four zones of suitability, from 1 to 9 in suitability values. A rating of 1 indicated the most suitable cells, and as the number increased, suitability gradually decreased, reaching 9 for cells in unsuitable regions (table 2).

**Table 1:Suitability tolerance**

| factor | value | | suitability | suitability value |
|---|---|---|---|---|
| Roads (m) | 0 | 150 | Not suitable | 8 |
| | 150 | 300 | Most suitable | 1 |
| | 300 | 450 | suitable | 4 |
| | 450 | 600 | Less suitable | 5 |
| schools (m) | 0 | 800 | Not suitable | 7 |
| | 800 | 1300 | Less suitable | 4 |
| | 1300 | 1800 | suitable | 2 |
| | 1800 | 2500 | Most suitable | 1 |
| landuse | Agricultural areas | | Most suitable | 1 |
| | Seasonal agriculture | | suitable | 2 |
| | Rocky areas | | Less suitable | 5 |
| | wet land | | Not suitable | 6 |
| slope | 0 | 10 | Most suitable | 1 |
| | 10 | 15 | suitable | 3 |
| | 15 | 20 | Less suitable | 6 |
| | 20 | >25 | Not suitable | 9 |
| river (m) | 0 | 150 | Not suitable | 8 |
| | 150 | 500 | Less suitable | 5 |
| | 1000 | 1500 | suitable | 4 |
| | 1500 | 2500 | Most suitable | 1 |
| High-Voltage Power Transmission Lines (m) | 0 | 150 | Not suitable | 8 |
| | 150 | 300 | Less suitable | 5 |
| | 300 | 450 | suitable | 4 |
| | 450 | 1000 | Most suitable | 2 |

**Table 2:Consistency check**

| AHP | | Consistency check |
|---|---|---|
| 0.095 | 9.50% | Consistency check 9% |
| 0.081 | 8.10% | |
| 0.293 | 29.30% | |
| 0.086 | 8.60% | |
| 0.316 | 31.60% | |
| 0.128 | 12.80% | |

**Procedures in Qgis program:**

In QGIS, the workflow involves rasterizing vector data, followed by the generation of proximity raster distances and reclassifying raster values. Initially, vector data is rasterized using tools like 'Rasterize (Vector to Raster)' to convert features into raster cells. Proximity raster distances are then computed using functions such as 'Proximity (raster distance)' to determine distances from specific features or layers. Reclassifying raster values is achieved using the 'Reclassify by value' tool, allowing for simple reclassification based on predefined criteria or thresholds. This step enables the replacement of values, grouping similar values, or setting specific values to No Data. Finally, weighted overlay analysis is performed using tools like 'Raster Calculator' or 'Raster Calculator (Grid)' to combine multiple raster layers into a single weighted raster layer. Each input raster layer is assigned a weight according to its significance or influence. The weighted overlay aggregates the factors using a common measurement scale, with each layer weighted based on its relative importance. The weights assigned to each layer represent a percentage influence.

**Conclusion:**

In conclusion, this chapter delved into the analytical approach and methodology used to achieve the project's objectives. It highlighted the importance of data exploration, materials, and methods employed in generating the desired maps. The chapter discussed the use of Geographic Information Systems (GIS) tools such as QGIS, Google Earth Engine, and ArcScene, along with the data collection and preparation process. The Analytical Hierarchy Process (AHP) was utilized for decision-making, prioritizing criteria, and selecting optimal sites for constructing a new high school in Essaouira city. Overall, the chapter emphasized the comprehensive approach taken to ensure informed decisions and the thorough analysis of the study area.

# Chapter III:

## Results and discussion

**Introduction:**

The reclassified layers play a crucial role in assessing the suitability of sites for schools. With six criteria identified and weighted using the Analytic Hierarchy Process (AHP), the reclassified raster layers offer a comprehensive representation of various factors influencing site suitability. These criteria, ranging from accessibility, environmental, and hazards factors, are translated into raster layers, each illustrating a specific aspect of suitability. By overlaying these layers using raster calculators, the weighted importance of each criterion is integrated into a single composite raster, providing a comprehensive perspective on potential school site locations. Visual representations of these reclassified layers, possibly depicted through thematic maps or color-coded overlays, offer intuitive insights into the spatial distribution of suitability across the study area.

Visual representations of these reclassified layers, offer intuitive insights into the spatial distribution of suitability across the study area.

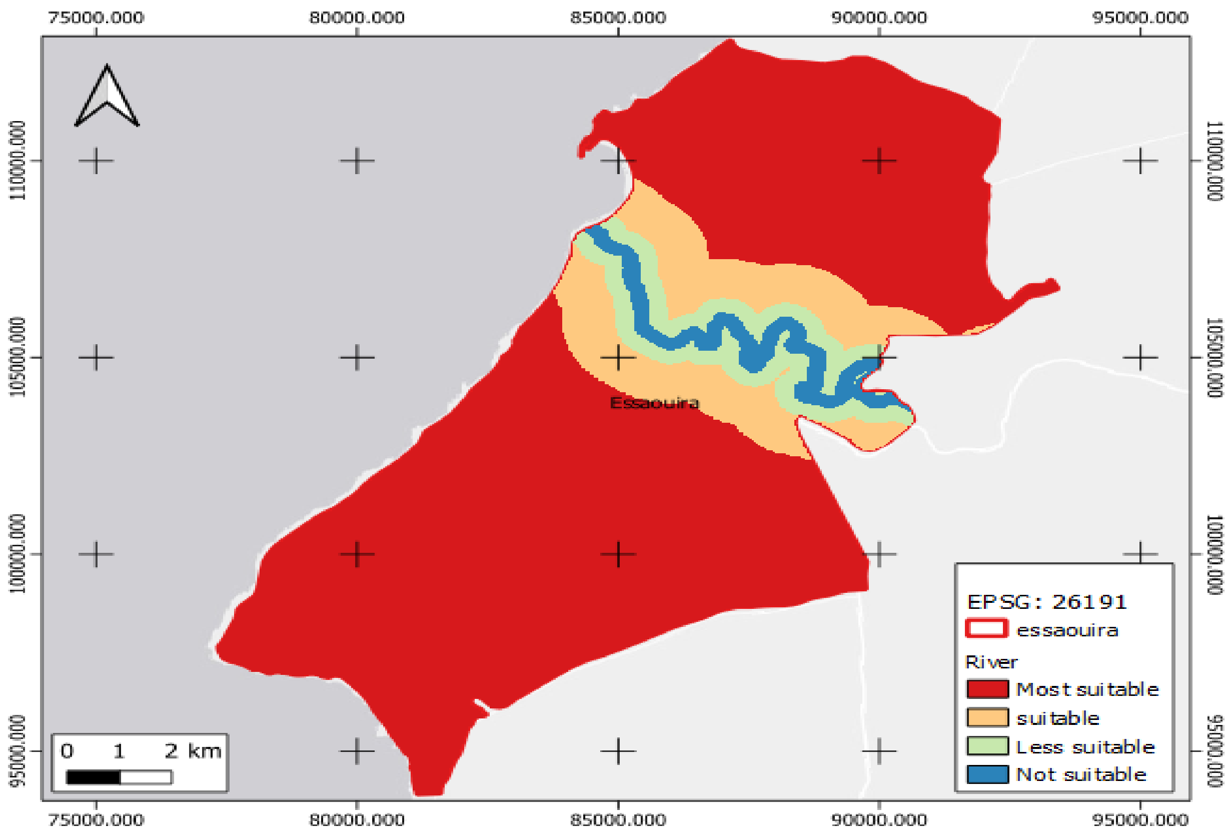
Such representations facilitate informed decision-making by decision makers, urban planners, and stakeholders involved in school site selection processes.

## 1. Reclassified criteria layers:

### a. River:

The proximity to rivers is considered, with suitability categorized from "Not suitable" (0-150 meters) to "The most suitable" (1500-2500 meters). Balancing the benefits of proximity to water bodies with potential flood risks, our assessment aims to identify locations that maximize environmental benefits while safeguarding against hazards associated with riverine environments.

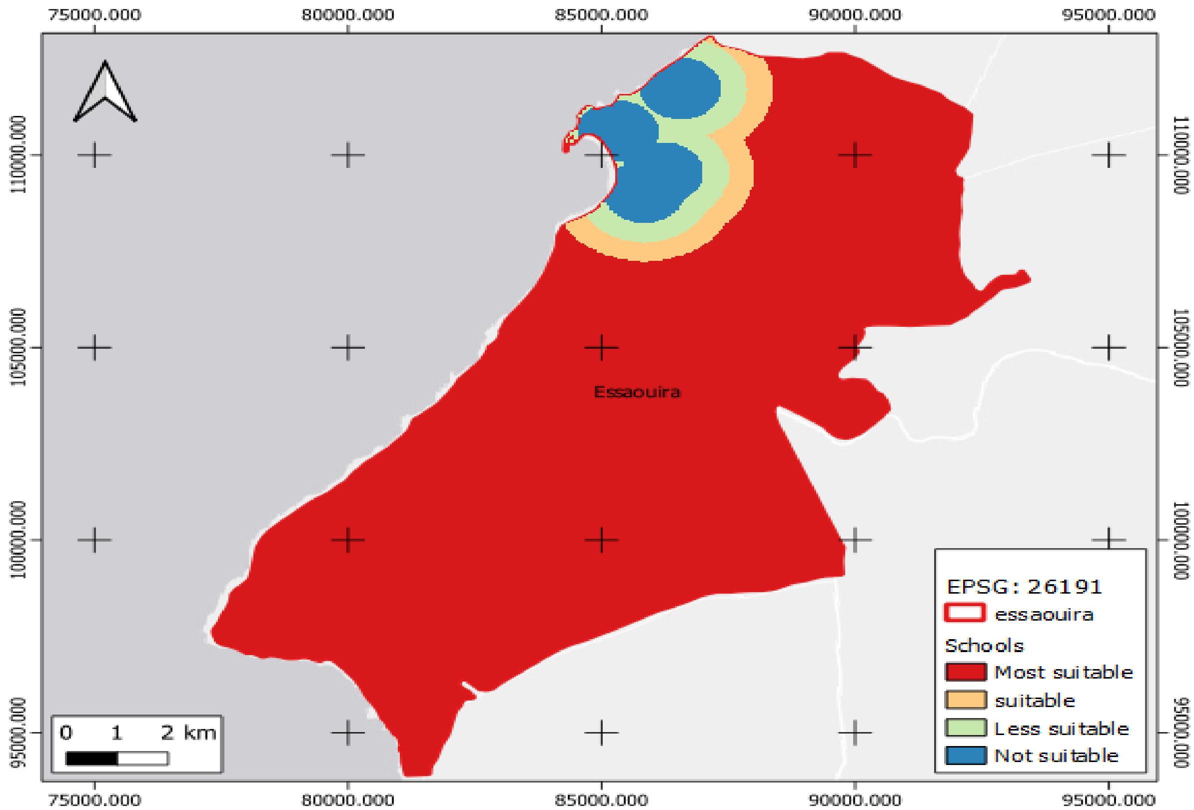
**Figure 21:River reclassified by distance**




### b. Distance from Existing Schools:

Evaluating the distance from existing schools helps ensure accessibility and convenience for families with school-aged children. Locations falling within the range of 0-800 meters are considered not suitable, while those situated within the range of 800-2500 meters are moderately suitable. However, the most favourable locations, falling within the range of 1800-2500 meters, strike a balance between proximity to schools and other desirable factors, offering an optimal environment for community engagement and educational opportunities (fig 12).

**Figure 22:Existing Schools Reclassified by distance**

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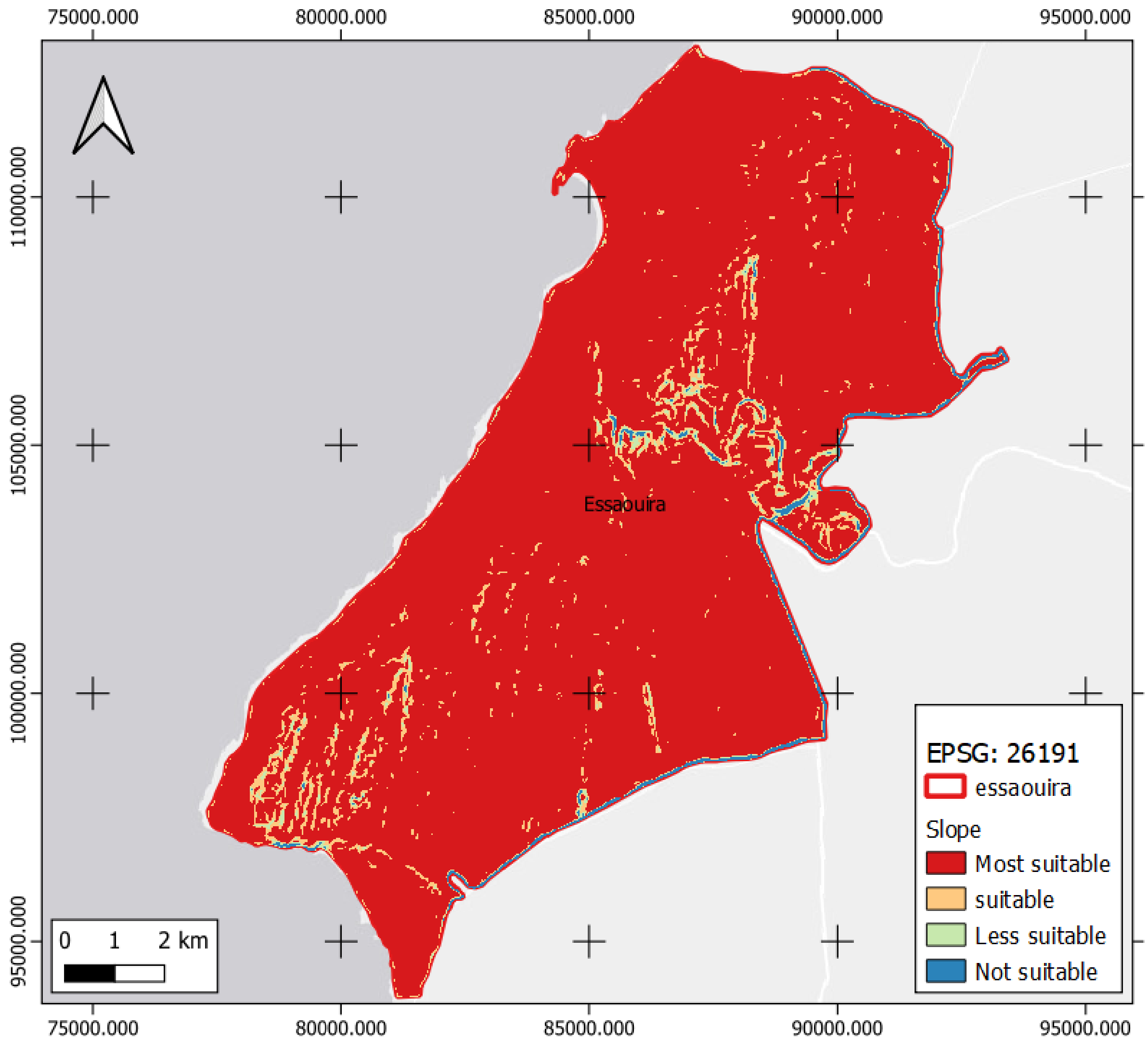
### c. Slope:

The terrain slope of potential sites is crucial for safe and sustainable development. Areas with slopes ranging from 0 to 10 degrees are considered most suitable, providing favorable conditions for construction and minimizing risks associated with erosion and land instability.

Conversely, sites with steep slopes exceeding 20 degrees are deemed not suitable, as they present significant challenges for development and may pose safety concerns (fig 13).

Figure 23:Reclassified slope

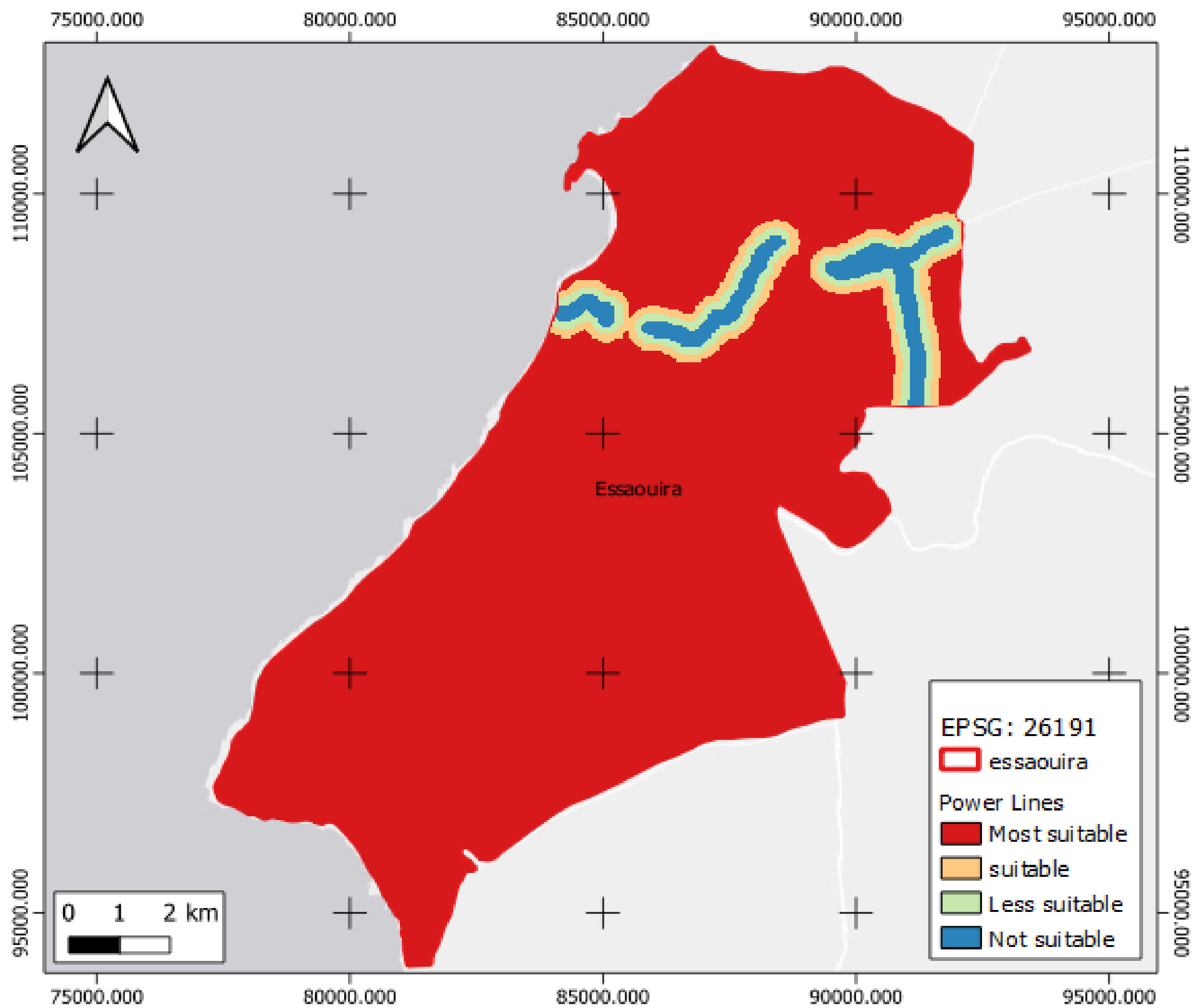



### d. High-Voltage Power Transmission Lines:

The distance from high-voltage power transmission lines is assessed to ensure safety and minimize exposure to electromagnetic fields. Sites falling within the range of 0-150 meters from transmission lines are considered not suitable, while those situated within the range of 450-1000 meters are moderately suitable.

The most favorable locations, falling within the range of 450-1000 meters, strike a balance between minimizing exposure to electromagnetic radiation and maintaining accessibility to essential infrastructure, promoting a safe and healthy environment for residents (fig 14).

**Figure 24:High-Voltage Power Transmission Lines Reclassified by distance**



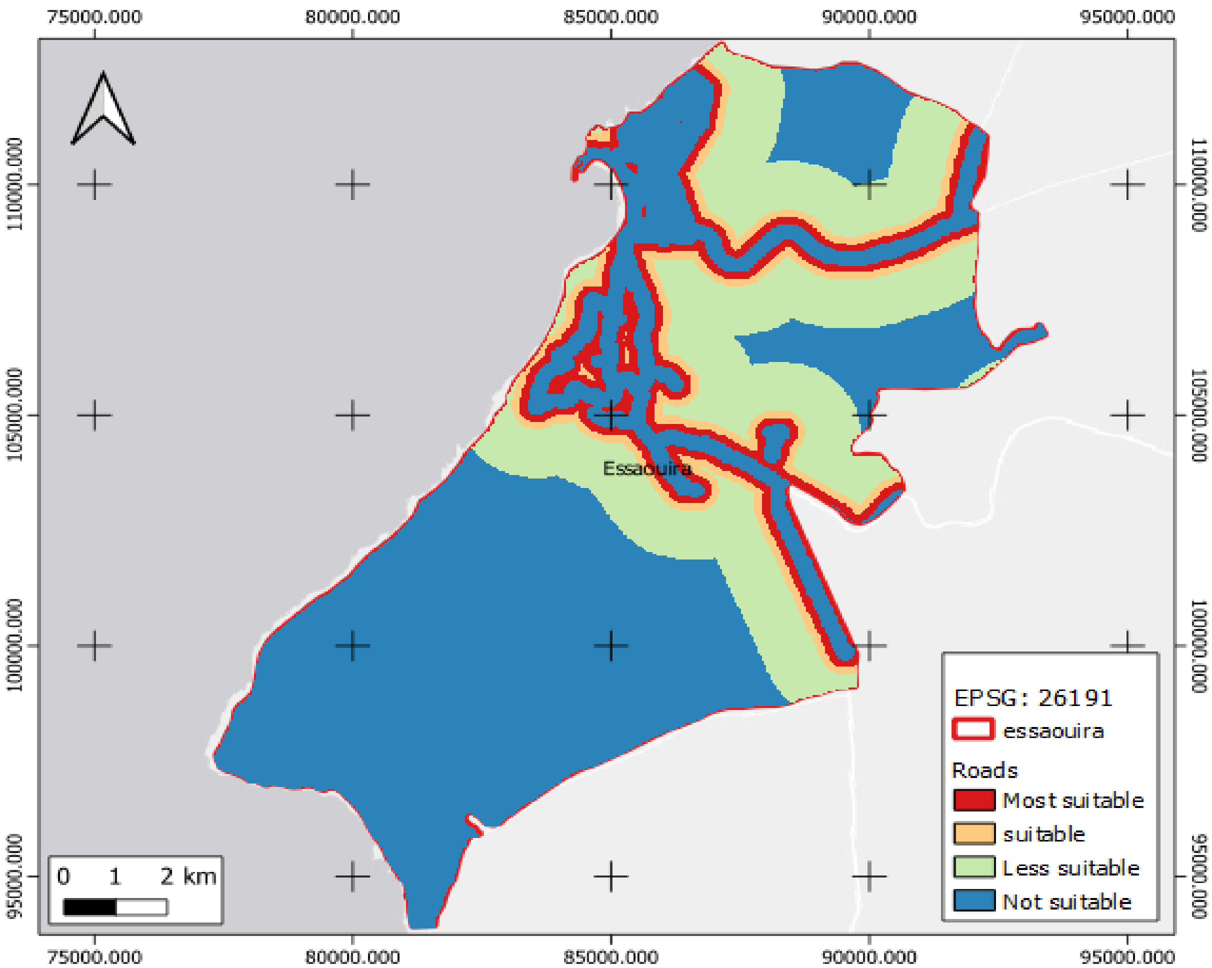

**e. Roads:**

The proximity of potential sites to existing road infrastructure plays a critical role in accessibility and transportation connectivity.

Sites falling within the range of 0-150 meters from roads are considered not suitable, while those situated within the range of 150-300 meters are deemed moderately suitable.

The most favorable locations, falling within the range of 300-600 meters, are highly accessible and prioritized due to their excellent connectivity to road networks, facilitating ease of travel for residents and emergency services alike (fig 15).

**Figure 25:Classified roads by the distance**



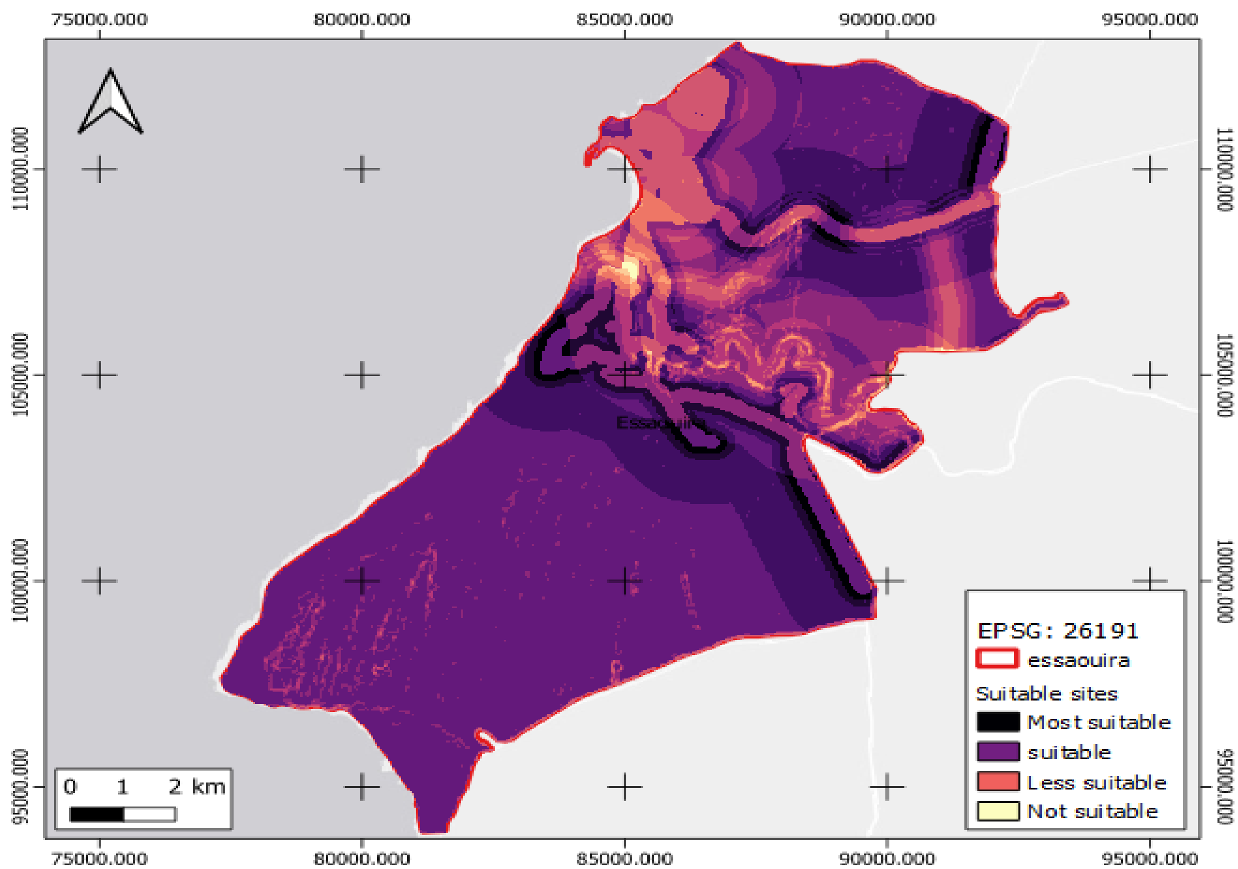

## 2. Overlaying reclassified layers and applying the constraint:

Our comprehensive analysis, supported by Geographic Information Systems (GIS), Multi-Criteria Analysis (MCA), and the Analytical Hierarchy Process (AHP), is visually depicted in the map illustrating the identified suitable sites for constructing a new school (Fig 16).

By meticulously evaluating various criteria and applying the vacant land constraint, we have successfully delineated areas that harmonize with our objectives of enhancing accessibility, ensuring safety, and enhancing the resilience of infrastructure.

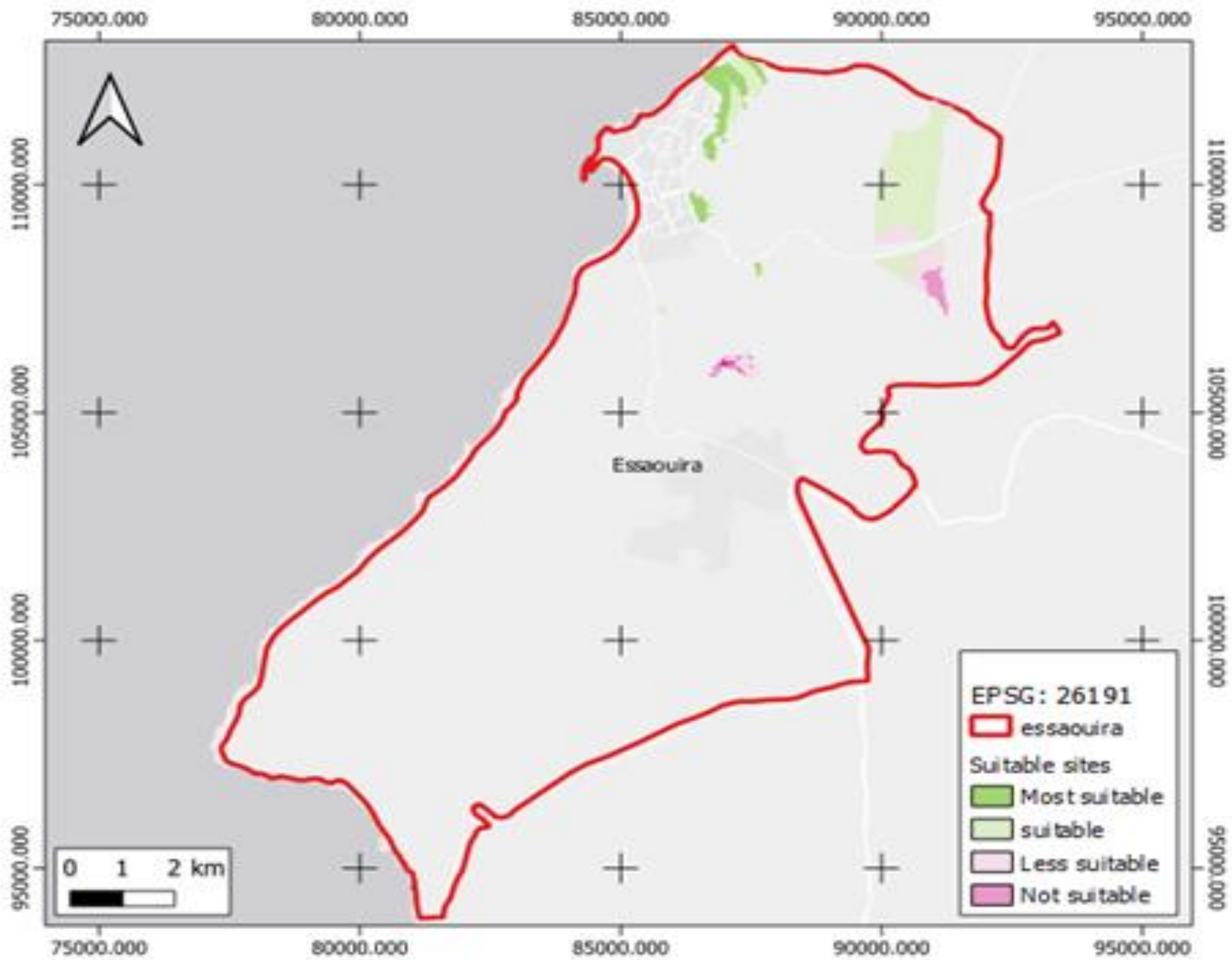
This map serves as a tangible representation of our efforts to identify optimal locations, demonstrating our commitment to informed decision-making and strategic planning in healthcare facility development.

**Figure 26:Suitable locations for a school before applying the vacant land constraint.**



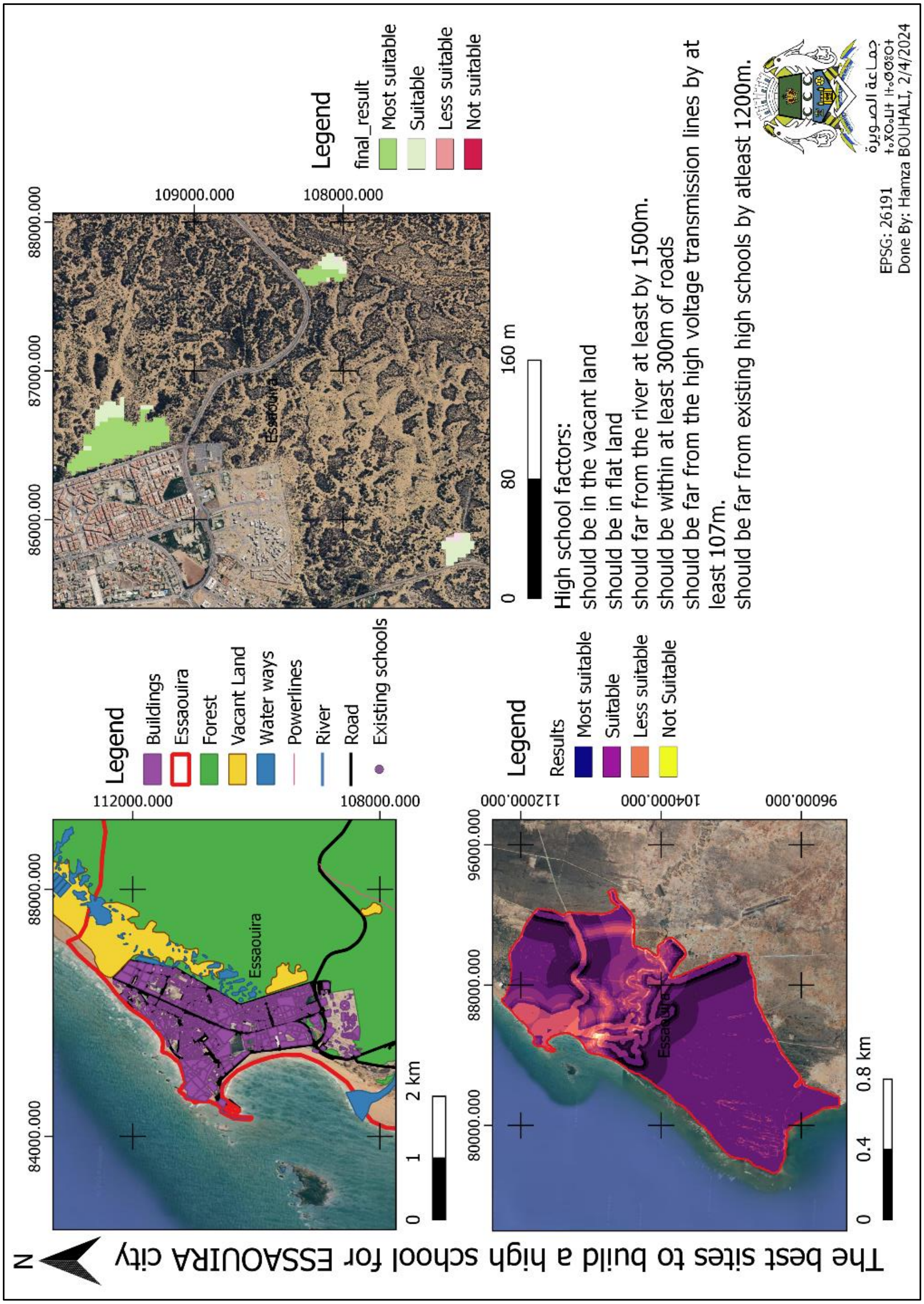

The map displays clusters of potential school sites strategically distributed across the region. These locations are chosen to optimize educational service coverage while minimizing exposure to natural hazards and urban traffic. Each identified site represents a careful balance between proximity to critical infrastructure like roads and emergency services, and distance from river and existing structures. This meticulous selection process ensures that the chosen sites offer a safe, accessible, and conducive environment for learning. In our analysis, we utilized a vacant land constraint to specify the exact area where suitable parcels intersect with the vacant land (fig 28).

**Figure 27:Suitable locations for a school after applying the vacant land constraint**




Our study identified three locations that meet our criteria, each exceeding 2.2 hectares, suitable for schools with an average of 24 to 32 classrooms, and conveniently located near the city. One site, located in the east adjacent to National Road R207, spans 5 hectares. Another site, also in the east, is situated right next to Av. Attaîf and covers 20 hectares. The third site, with a surface area of 3 hectares, is positioned in the south of the city along Road Number P2201 (fig 29). These findings demonstrate the effectiveness of our approach in identifying viable school site locations based on scientific analysis and criteria.

**Figure 28:the finale map that shows the best sites for building a high school**



### 3. Result in 3D:

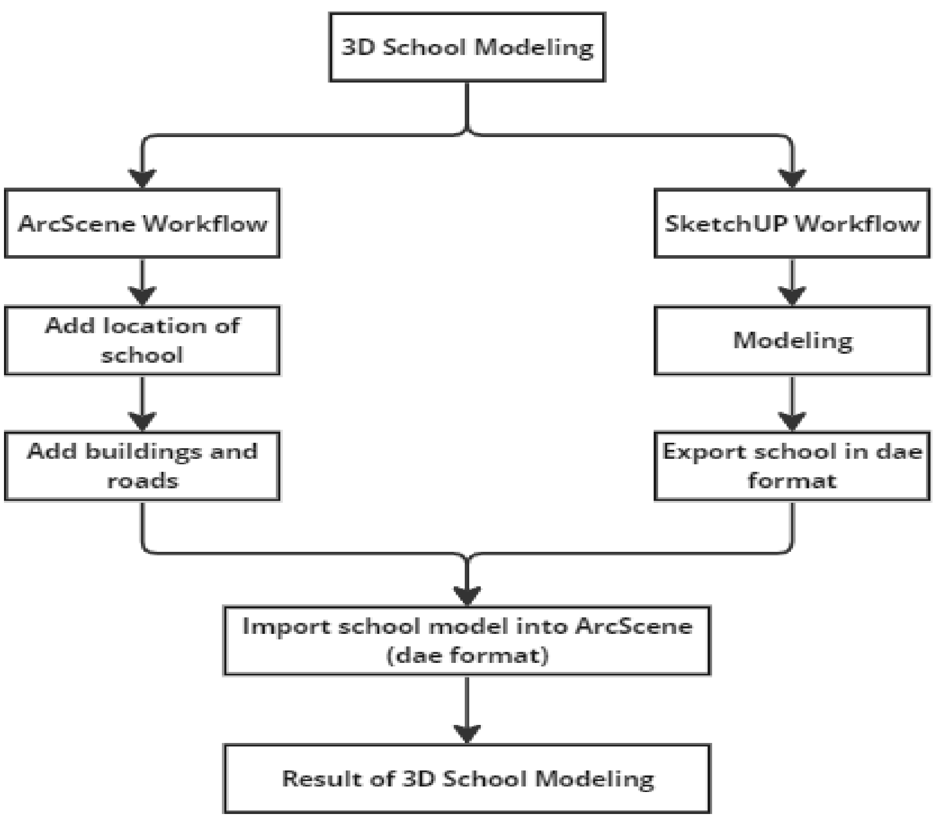
In our pursuit to determine the optimal location for a new school, we employed advanced 3D modeling techniques using ArcScene and SketchUp.

ArcScene allowed us to integrate spatial data and visualize various geographical and environmental factors influencing school placement. SketchUp enabled us to create and use detailed and accurate 3D models of the school.

Through our analysis, we identified the best site situated to the east of Essaouira city, right next to Av. Attaîf, covering an area of 20 hectares. By combining these tools, we were able to conduct a thorough analysis, considering factors such as accessibility, safety, and environmental impact. The 3D models effectively illustrated the potential scenarios, aiding in the decision-making process and ensuring that the chosen location meets all necessary criteria for the best educational environment.

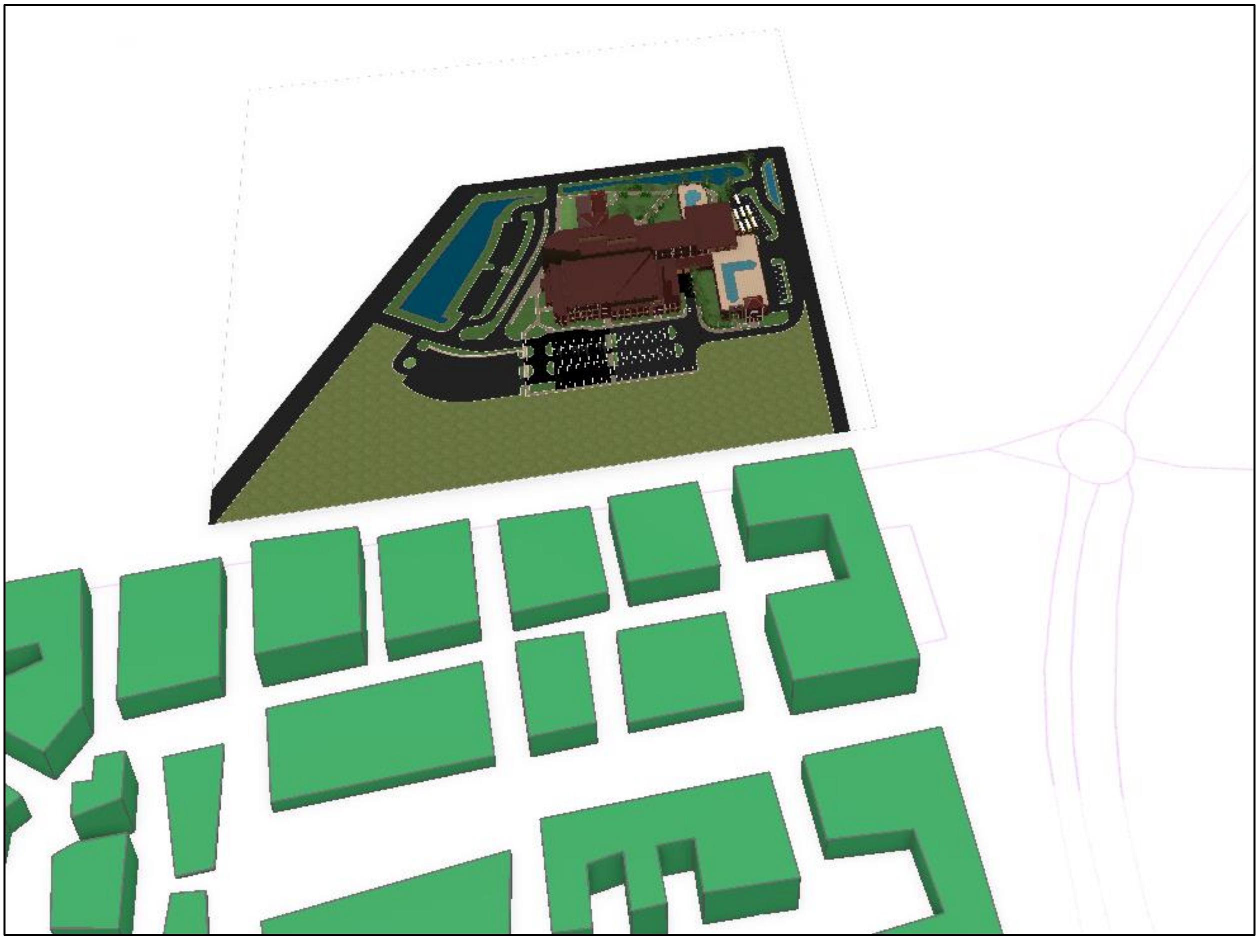
**3D modelling methodology:**

**Figure 29: methodology for creating a 3D model of the school**



The methodology for creating a 3D model of the school (fig 30) integrates the use of ArcScene and SketchUP to ensure a comprehensive and accurate representation. The process begins with detailed modeling in SketchUP, followed by exporting the school model in the COLLADA (dae) format. Simultaneously, ArcScene is employed to add the precise location, buildings, and roads surrounding the school. The final step involves importing the dae format model into ArcScene to merge all elements seamlessly, resulting in a detailed and realistic 3D model of the school (fig 31).

**Figure 30:school 3d model**



**Conclusion:**

In this chapter, we identified optimal school sites using the Analytic Hierarchy Process (AHP) and Geographic Information Systems (GIS). By evaluating six key criteria, we created a comprehensive suitability model. The analysis produced thematic maps, aiding decision-making for urban planners. We identified three prime locations, each over 2.2 hectares, ensuring safety, accessibility, and excellent connectivity.

Advanced 3D modeling provided detailed visualizations, supporting precise planning. The combination of AHP, GIS, and 3D modeling demonstrates an effective, data-driven approach to school site selection, promoting strategic urban planning.

# General conclusion:

The comprehensive analysis and multi-criteria evaluation conducted in this study have successfully identified optimal sites for new school construction. By leveraging the Analytic Hierarchy Process (AHP) and Geographic Information Systems (GIS), we have meticulously assessed and integrated six key criteria—accessibility, environmental factors, hazard risks, proximity to existing schools, terrain slope, and infrastructure proximity—into a cohesive suitability model.

The resulting reclassified raster layers, combined through overlay and weighting processes, provide a robust framework for visualizing and evaluating potential school sites. The thematic maps and color-coded overlays derived from these layers offer clear, intuitive insights into the spatial distribution of site suitability across the study area, facilitating informed decision-making for urban planners and stakeholders.

Our findings highlight three prime locations, each exceeding 2.2 hectares, strategically positioned to maximize educational service coverage while ensuring safety and accessibility. The largest site, spanning 20 hectares, is located to the east of Essaouira city near Av. Attaîf, presenting an ideal environment for a new school with excellent connectivity and minimal exposure to hazards.

Furthermore, the integration of advanced 3D modeling techniques using ArcScene and SketchUp has enriched our analysis, providing detailed and realistic visualizations of the proposed school site. These models not only enhance our understanding of the spatial context but also support precise planning and development, ensuring that the selected sites meet all necessary criteria for creating a conducive learning environment.

In conclusion, this study underscores the effectiveness of combining AHP, GIS, and 3D modeling in educational infrastructure planning. The identified sites reflect a careful balance of critical factors, demonstrating a strategic approach to school site selection that prioritizes safety, accessibility, and community engagement. This methodology sets a precedent for future projects, contributing to the advancement of data-driven and scientifically informed urban planning practices.

# Bibliography

D. H. Prasetyo, J. Mohamad, and R. Fauzi, "A GIS-based multi-criteria decision analysis approach for public school site selection in Surabaya, Indonesia," *Geomatica*, vol. 72, no. 3, pp. 69–84, 2018, doi: 10.1139/geomat-2018-0017.

Y. Shimamura, S. Shimizutani, E. Yamada, and H. Yamada, "The Gendered Impact of Rural Road Improvement on Schooling Decisions and Youth Employment in Morocco," *Journal of Development Studies*, vol. 59, no. 3, pp. 413–429, 2023, doi: 10.1080/00220388.2022.2139608.

V. Baser, "Effectiveness of school site decisions on land use policy in the planning process," *ISPRS Int J Geoinf*, vol. 9, no. 11, Nov. 2020, doi: 10.3390/ijgi9110662.

Z. Bukhari, a. M. Rodzi, and a Noordin, "Spatial multi-criteria decision analysis for safe school site selection," *International Geoinformatics Research and Development Journal*, vol. 1, no. 2, pp. 1–14, 2010.

Aomar and J. Amaghouss, "THE PERFORMANCE OF EDUCATIONAL SYSTEM IN MOROCCO: A SPATIAL ANALYSIS IBOURK," 2014.

R. A. M, "Spatial multi-criteria decision analysis for safe school site selection," 2010.

Essaouira Province statistics: https://www.city-facts.com/essaouira/population

Essaouira Province climate: https://www.climatestotravel.com/climate/morocco/essaouira