A geospatial analysis utilizing AHP and GIS was conducted to assess the suitability of landfill sites for solid waste disposal in the province of Tangier-assilah, Morocco.

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Abstract. The objective of this study is to identify the most suitable areas for the implementation of a solid waste landfill in the province of Tangier-Assilah using geographic information systems (GIS). This approach aims to minimize pollution and its negative impacts on the environment and society. In this study, eight environmental, social and economic factors were considered, including residential areas, distance from roads, distance to water bodies, distance to forests, elevation, slope, aspect and parks. To determine the importance of each criterion, the Analytic Hierarchy Process (AHP) was used, based on a pairwise comparison matrix. In addition, a map was produced to indicate the most suitable and unsuitable areas for the solid waste landfill facility. This model can be used to help decision makers make informed decisions and develop effective planning strategies for selecting the most appropriate sites for the landfill.

1 Introduction

The management of solid waste poses a significant challenge for numerous developing nations[1, 2], particularly in urban regions that are experiencing rapid growth[3]. The inadequate management of solid waste has noteworthy ecological and health ramifications[4, 5], including but not limited to contamination of soil[6], air[4], and water[7], discharge of greenhouse gases[8], and propagation of illnesses[9]. Consequently, the determination of appropriate locations for landfills is of utmost importance in guaranteeing the secure and efficient handling of solid waste[10].

Geospatial analysis has been identified as a potent technique in the identification and assessment of appropriate landfill locations in recent times[11]. The utilization of Geographic Information System (GIS) technology enables the amalgamation of diverse strata of spatial data to pinpoint regions that satisfy particular standards for waste disposal. The Analytical Hierarchy Process (AHP) is a technique for multi-criteria decision-making that enables the identification of the optimal alternative by considering a set of criteria and their respective levels of significance[12].

The objective of this study is to assess and determine appropriate locations for solid waste deposition in the province of Tangier-Assilah, Morocco, through the utilization of a geospatial analysis methodology that incorporates AHP and GIS. The methodology used in this study involves four main steps: (1) defining the criteria and their weights using the AHP method, (2) collecting and processing the spatial data, (3) overlaying and analyzing the criteria layers using GIS, and (4) ranking and selecting the suitable landfill sites based on the results. The criteria used in this study include residential areas, road network, distance to water bodies, distance to forests, elevation, slope, aspect and parks.
The spatial data used in this study were obtained from various sources, including USGS (United States Geological Survey), DEM image, and OpenStreetMap. The data were processed and analyzed using GIS software. The analysis involved overlaying and integrating the criteria layers to identify areas that meet the selection criteria for landfill sites. The results of the analysis show that there are several potential sites that meet the criteria and are suitable for solid waste disposal in the province of Tangier-Assilah.

The paper concludes with a discussion of the implications and limitations of the methodology and suggests further research to improve the accuracy and reliability of the results. The study highlights the importance of considering environmental, social, and economic factors in the decision-making process and encourages the adoption of sustainable and integrated waste management practices. Decision-makers and planners in the province of Tangier-Assilah and other similar areas to identify and select suitable landfill sites for the sustainable and effective management of solid waste can use the results of this study.

2 Materiel and methods

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2.1 Study area

The geographical region under research in this study is the province of Tangier-Assilah, a province situated in the northern part of Morocco (**Fig. 1.**)[13]. The region encompasses a landmass of roughly 863,3 square kilometers[14], encompassing the urban centers of Tangier and Asilah, alongside various rural and peri-urban locales. Tangier, the most populous city in the province, serves as a significant economic center with a swiftly expanding populace. Asilah, conversely, is a comparatively diminutive urban settlement that harbors a noteworthy tourism sector. The province encompasses various rural settlements and hamlets, alongside arable land and ecological reserves. The region produces a substantial quantity of solid waste resulting from domestic, business, and manufacturing operations. The inadequate management of this refuse bears ecological and medical ramifications, including contamination of soil, atmosphere, and hydrosphere, discharge of greenhouse gases, and proliferation of illnesses. Hence, the identification of appropriate landfill locations is imperative to guarantee the secure and efficient handling of solid waste in the region. The research scope will encompass the complete Tangier-Assilah province, comprising both metropolitan and non-urban regions. The methodology of geospatial analysis, which incorporates the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS), will be employed to assess and pinpoint appropriate locations for solid waste disposal sites within the province. Regional policymakers and strategists to enhance solid waste management methodologies and tackle the ecological and health consequences of inadequate waste disposal may utilize the findings of this study.

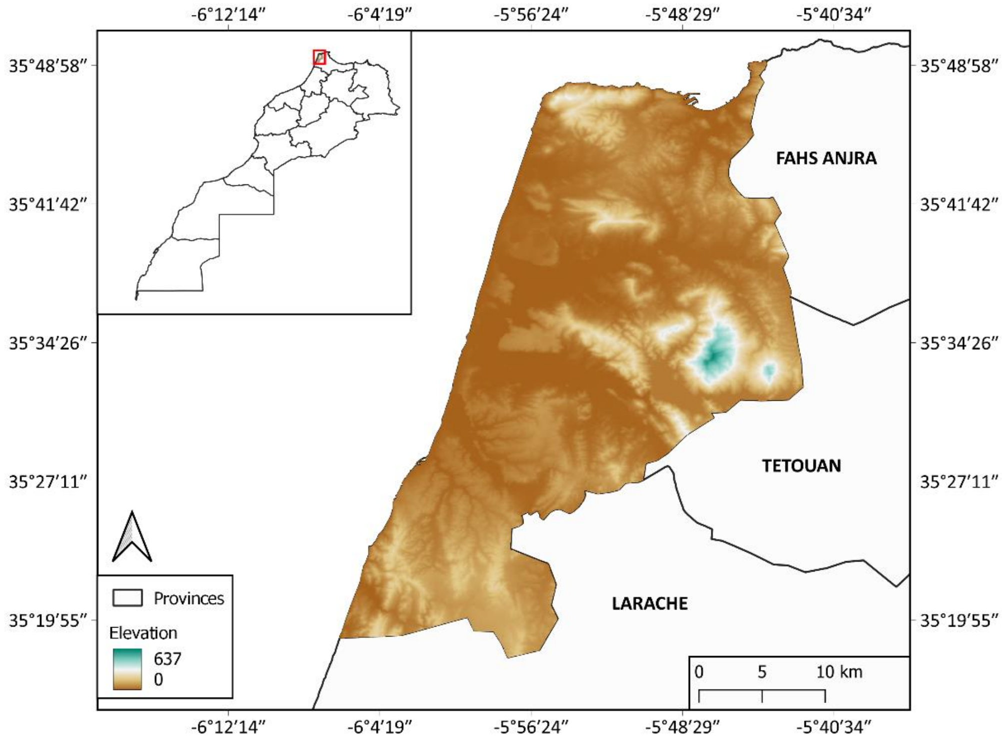

Fig. 1. Geographic location of the study area

2.2 Data Collection and Processing

In this research, the data collection procedure involved locating pertinent data sources and accumulating the data in a digital format. This research utilized a variety of data sources including OpenstreetMap and USGS. These data were obtained in raster and shapefile form in the GIS database after they were collected. In order to process the data, thematic maps highlighting potential landfill locations based on criteria such as slope, distance from water bodies and distance from residential areas were created using GIS software. In creating the thematic maps, multiple data layers were overlaid in a GIS program and spatial analysis tools were used to locate potential landfills. In addition to geospatial analysis, the Analytical Hierarchy Process (AHP) was used to rank potential landfills based on criteria such as accessibility, distance to population centers, and environmental impact. These factors were taken into consideration when ranking the potential landfills. The AHP was conducted using software developed specifically for the decision-making and ranking activities.

2.3 Methodology and Applications

The study's methodology (**Fig. 2.**) and its practical applications are detailed here. Geospatial analysis and the Analytical Hierarchy Process (AHP) are the two primary pillars of this methodology.

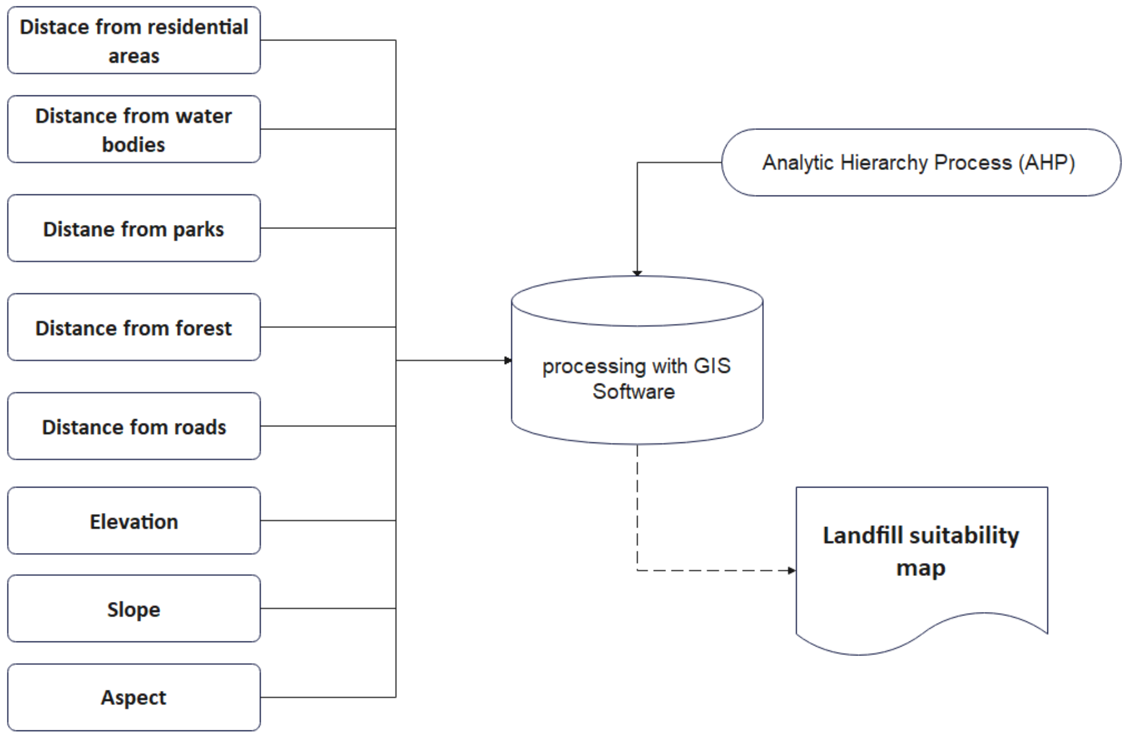

Fig. 2. The methodology used in this study

2.3.1 Geospatial Analysis

To process and analyze geospatial data, GIS software is used in geospatial analysis. This research used geospatial analysis to produce thematic maps that show potential landfill sites. The first step in the geospatial analysis was to create the map of each factor used in this study, followed by the reclassification of all factors to obtain all factors in raster reclassified format. From this digital base, a thematic map was generated to show potential landfill locations.

2.3.2 Analytical Hierarchy Process (AHP)

With the help of the Analytical Hierarchy Process (AHP), difficult choices can be broken down into more manageable chunks. In this analysis, the AHP was used to prioritize landfill locations based on criteria like ease of access, proximity to major population centers, and potential environmental impact. To use the AHP, a set of criteria and sub-criteria must be established in order to rank potential landfill locations. Each criterion and sub-criterion are given a weight that reflects its significance in making the final call. Each criterion is compared to every other criterion to establish its relative importance, and then weights are assigned based on the results of these comparisons. The AHP was performed with the aid of specialized software for making decisions and setting priorities. Potential landfill locations were ranked according to their AHP scores.

2.3.3 Applications

After data collection and preparation, the Analytic Hierarchy Process (AHP) was used to establish the weights of each criterion. To do this, the Saaty[15] scale was used to determine the relative importance of each criterion to the others (**Fig. 3.**). Using this scale, a pairwise comparison matrix was created and normalized to calculate the weights for each criterion. The more important a criterion is deemed to be, the higher its weight will be.

This research methodology can be used in other places with similar problems in solid waste disposal. Using a combination of geospatial analysis and AHP, we can locate potential landfill sites taking into account a wide range of factors. Local government agencies in Tangier can use the study's findings to pinpoint possible landfill locations and arrange them in terms of environmental impact, accessibility, and other criteria. As more information becomes available, the method can also be used to improve and update the selection of potential landfill sites.

The paper concludes with a detailed methodology for finding good landfill sites using geospatial analysis and the Analytical Hierarchy Process. We also talk about how this method can be used in other contexts with similar problems

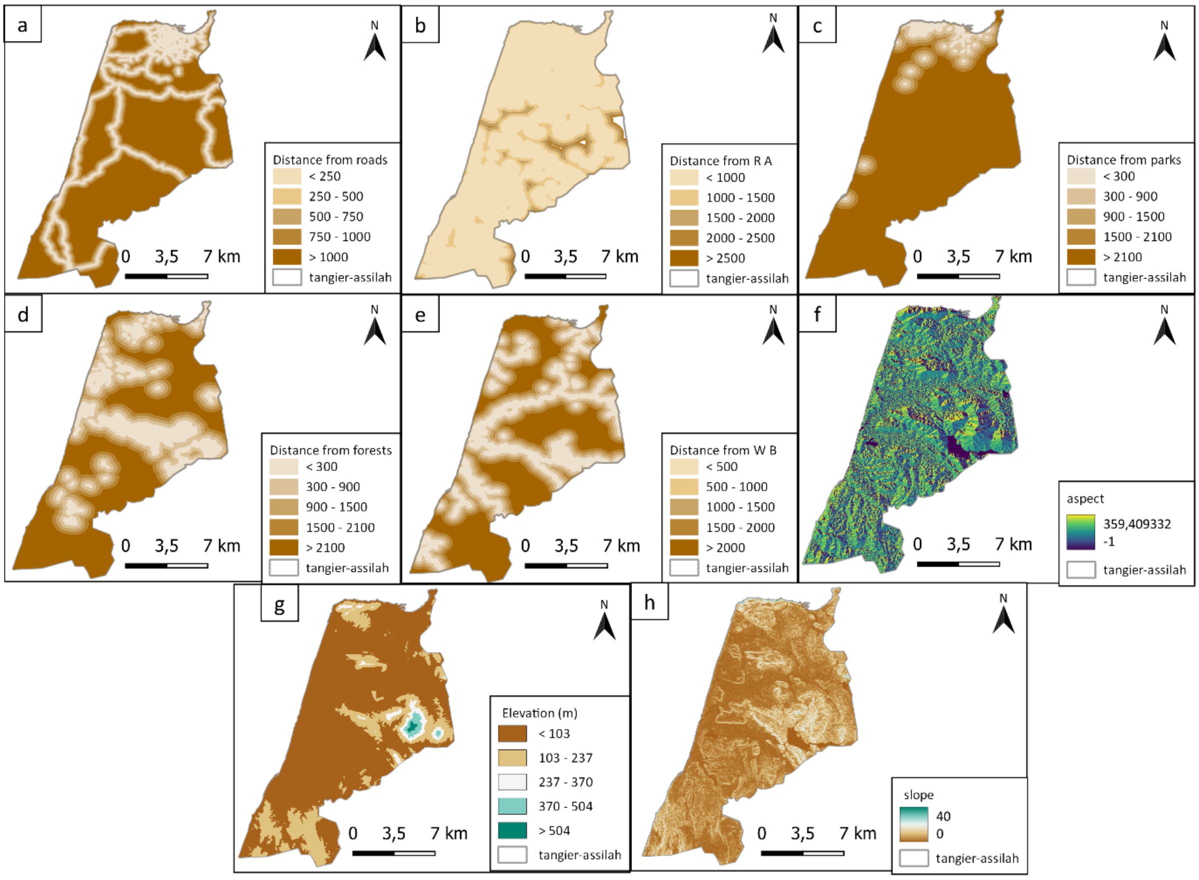

Fig. 3. Criteria considered in the study: distance from roads (a), distance from residential areas (b), distance from parks (c), distance from forests (d), distance from water bodies (e), aspect (f), elevation (g) and slope (h).

3 Results

The **Fig. 4.** illustrates the suitability map for locating a solid waste landfill in the province of Tangier-assilah. The weights assigned to each criterion in the study have been presented in **Table 1**, providing an indication of their relative importance in the decision-making process. The results reveal that distance to residential areas is the most important criterion, with a weight of 0.365, followed by distance to surface water, which has a weight of 0.229. In addition, distance to roads is also a crucial criterion for minimizing costs, with a weight of 0.165. Another important criterion is distance to parks, with a weight of 0.075; the other criteria have varying levels of importance. In sum, the weights assigned to each criterion provide information about their relative importance in the decision-making process.

Table 1 : Weights of criteria and sub-criteria.

Criteria	Criteria Weights	CR	Sub-Criteria	Weight	CR
Elevation (m)	0.063	0.0504	< 103	0.433	0.023
			103 - 237	0.271	
			237 - 370	0.158	
			370 - 504	0.092	
			> 504	0.046	
Slope (°)	0.058		0 - 3	0.433	0.023
			3 - 6	0.271	
			6 – 10	0.158	
			10 – 14	0.092	
			14 - 40	0.046	

Aspect	0.026	SW and flat	0.309	0.056
		NE	0.032	
		NW	0.161	
		SE	0.038	
		N	0.071	
		E	0.040	
		S	0.100	
		W	0.248	
Distance from water bodies (m)	0.229	<500	0.488	0.035
		500 - 1000	0.235	
		1000 - 1500	0.155	
		1500 - 2000	0.085	
		>2000	0.038	
Distance from roads (m)	0.165	<250	0.433	0.023
		250 - 500	0.271	
		500 – 750	0.158	
		750 - 1000	0.092	
		>1000	0.046	
Distance from residential areas (m)	0.365	<1000	0.488	0.035
		1000 – 1500	0.235	
		1500 - 2000	0.155	
		2000 – 2500	0.085	
		> 2500	0.038	
Distance from forests (m)	0.057	<300	0.488	0.035
		300 - 900	0.235	
		900 - 1500	0.155	
		1500 - 2100	0.085	
		>2100	0.038	
Distance from parks (m)	0.075	<300	0.488	0.035
		300 - 900	0.235	
		900 - 1500	0.155	
		1500 - 2100	0.085	
		>2100	0.038	

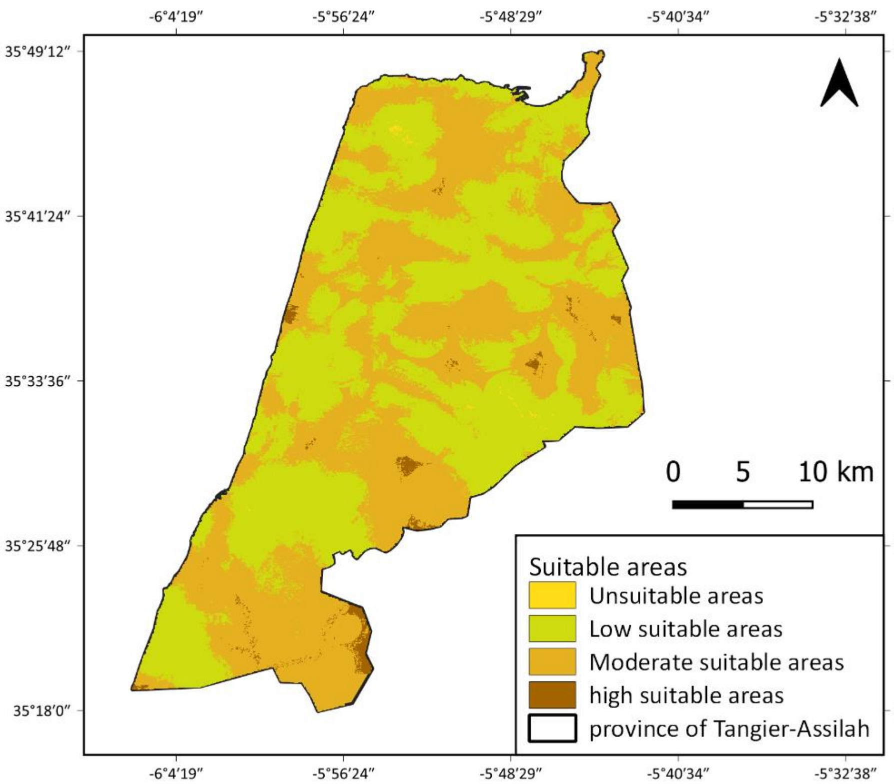

Fig. 4. Suitable areas for the implementation of a solid waste landfill

4 Discussion

The study's findings have significant bearing on how Tangier handles its solid waste. Local government agencies can better prioritize the development of landfill sites based on suitability once potential landfill sites have been identified. If landfill sites are ranked using the AHP, then only the best ones will be considered for construction. However, there are a number of things to keep in mind about the study's limitations. The reliability of the findings is contingent on the precision of the data used in the study. Social factors, such as public perception and acceptance of landfill sites, which can have a substantial impact on landfill site development, were not taken into account in the study. The study also failed to account for the potential impact of implementing non-landfill waste management strategies like recycling and composting. These non-traditional methods of waste disposal may have an effect on landfill viability, so they should be included in future research. Potential landfill sites were identified using geospatial analysis, and their rankings were determined using the AHP. The section also delves into the study's limitations and discusses the implications of the findings.

5 Conclusion

The association of GIS with AHP is an effective approach to landfill location. It allows spatial data to be visualized using GIS and criteria to be prioritized and their relative importance to AHP to be weighted. This method facilitates the identification of the most appropriate sites for landfills by taking into account various social, environmental and economic considerations. It thus contributes to minimizing the environmental and health impacts associated with solid waste landfills, by identifying sites that are farthest from residential areas, water sources and biodiversity.

It is important to note that assessment models based on the AHP method may be affected by the subjective judgments of environmental and socio-economic experts involved in the decision-making process. This subjective influence must be taken into account when interpreting the results and making final decisions.

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