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Research Article

A GIS-based multi-criteria evaluation of landfill site selection in the region of Hodna, Algeria

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Abstract

In Algeria, solid waste management (SWM) is considered a major problem; most of this waste is dumped in landfills without any control. The Algerian authorities have developed a national strategy for the integrated management of urban solid waste by 2035 by working on the implementation, development and equipping of technical landfill centers (TLC). Therefore, the aim of this study was to help local authorities in choosing the optimal locations for the completion of the proposed TLC between municipalities. This research used a combination of the multi-criteria decision aid (MCDA) and geographic information systems (GIS). It combines two aggregation methods: Linear Combination of Weights (WCL) and Criteria Weighting. The analytical hierarchy process (AHP) pair-wise comparison method was applied for assigning weights to the 11 criteria that were divided into environmental, social, and economic criteria according to previous studies in the field and the characteristics of the HODNA area. The results showed that 22.56% is the most suitable location for a landfill site, especially on the southeastern side, while 20.70% was suitable and 18.40% was moderately suitable. Finally, the process of assessing the spatial suitability of public emptying sites based on the results obtained in the final digital map,4.76% of the landfill sites are located in inappropriate areas, 14.29% are located in less suitable areas, 33.33% are located in suitable areas, 33.33% are located in moderately suitable areas and 14.29% are located in very suitable areas.

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Introduction

The disposal of municipal solid waste is a big challenge. Inadequate municipal solid waste management leads to significant environmental consequences (Cleary, 2009; Hoornweg and Bhada-Tata, 2012) and negative economic and social consequences (Cointreau, 2006; Scheinberg et al., 2010; Lohri et al., 2014). Generally, technical landfill centers (TLC) are the most effective way to dispose of most solid waste, but unstudied ones can adversely affect soil, groundwater, and air (Abderrahmane et al., 2014; Liu et al., 2021), in addition to unpleasant odors, smoke and volatile plastic waste (Thonart et al., 2005). It distorts the aesthetic character of the urban surroundings, especially the green spaces and coasts (Redjem et al., 2021). In African countries, less than half of urban solid waste is collected, and 95% is recycled through indiscriminate waste disposal (Badi and Kridish, 2020).

In third-world countries where 80% of the world's population lives, the problem of solid waste has become complex and severe, especially with the lack of financial resources (Chabuk et al., 2016), poor planning and urbanization, and lack of management skills (Nanda et al., 2022).

Algeria is experiencing significant organized and unregulated growth, driven by natural demographic growth (Redjem et al., 2021). This is what makes a third-world city stand out. Due to the phenomena of rural exodus, particularly following the security crises that Algeria suffered in a quest for stability and a better life, the cities absorbed this demographic growth (Dehimi and Hadjab, 2019). This is what has led to an increase in the production of urban waste offset by weaknesses and problems in the management and treatment of this waste, as evidenced by a survey conducted by the departments of the Ministry of Land Use Planning and Environment, where more than 3,000 uncontrolled landfills have been identified (Naghel et al., 2022). Algeria generates 13 million tons of municipal solid waste annually, treated in 191 waste treatment facilities, represented by 101 TLC, and 90 controlled landfills (ANW, 2020). Several factors and criteria must be taken into account to determine the appropriate location of the TLC since there are no common universal laws or formulas that regulate the conditions for choosing the right site (Nascimento et al., 2020).

Recently, there has been an increase in research that uses Geographic Information System (GIS) Combining at AHP application for analysis, evaluation and decision-making assistance (Barakat et al., 2017; Bilgilioğlu and Bilgilioğlu, 2017; Alkaradaghi et al., 2020; Osra and Kajjumba, 2020; Sisay et al., 2021; Ahire et al., 2022; Asori et al., 2022). Studies such as Sharholy et al. (2007), Sumathi et al. (2008), and Mohammedshum et al. (2014) described the role of GIS and AHP in solid waste management.

Several researchers use different methods for landfill site selection (Redjem et al., 2021) and combine AHP with GIS to obtain a map of the appropriate areas for landfill sites in the municipality of M'sila, Algeria. Gorsevski et al. (2012) have used a GIS-based multi-criteria decision analysis approach to assess landfill suitability in the Polog Region of Macedonia. Eskandari et al. (2012) have used an integrated approach to landfill siting based on conflicting opinions among environmental, economic and social-cultural experts. Wang et al. (2009) used the AHP and a hierarchical model to solve the Beijing solid waste landfill site selection problem. Gbanie et al. (2013) used an aggregation technique combining weighted linear combination and ordered weighted average to identify urban landfills in urban areas of southern Sierra Leone. Alavi et al. (2013) used AHP combined with GIS and field analysis to find an optimal solid waste disposal site in Mahshahr District, Iran, with the growing population and the related unsustainable activities in Iran. Population growth and associated unsustainable activities in Iran have significantly increased the amount and type of solid waste generated. Dolui and Sarkar (2021) used multi-standard decision-making methods (MCDM) integrated with geographic information systems (GIS) as an effective tool for the scientific selection of suitable sites for landfill completion to be economically effective, environmentally appropriate and acceptable in the general context. Nascimento et al. (2020) conducted a global systematic review of the standards used in 57 scientific articles to locate landfills using geographic information systems (GIS) and came up with the following results: despite the increase in recently published studies, they mainly focus on the environmental dimension, the economic dimension, and the social dimension.

Based on the above and recent interest and efforts by public authorities to encourage the establishment of inter-municipal technical landfill centers, this study combined the analytical hierarchy process (AHP) with the geographic information system (GIS) and focused mainly on the environmental dimension. This study adopted 11 criteria and obtained a digital map of spatial suitability consisting of 5 areas 1-Unsuitable, 2-Less suitable, 3-Suitable,4-Moderately suitable, and 5-Highly suitable. The second stage of the study was the process of assessing the spatial suitability, based on the results obtained from the first stage of household waste for the treatment of municipal solid waste, by locating the completed technical landfill centers (M'sila city center, Barika city center), public landfills studied. Finally, the random public dumps in the final work map (Gharehbaghi and Scott-Young, 2018) assisted local authorities in selecting optimal locations to complete proposed TLC between municipalities and assess the spatial suitability of existing public dumps.

Materials and Methods

Study area

The Hodna Region is located in Algeria between the Atlas Mountain range to the north and the desert atlas to the south, specifically in the northeastern part of the province of M’sila and the western part of the province of Batna, and consists of 18 municipalities belonging to the province of M'sila and 6 municipalities belonging to the province of Batna, i.e. consisting of 24 municipalities (Figure 1). The Hodna Region is an area with common natural characteristics, whether geographical, geological or climatic, and its urban centers are characterized by their linear expansion along the main axes of national roads. Central to the Chott of Hodna is a salt lake with an area of 1,002.34 km^2, into which many seasonal waterways (valleys, reefs) flow from the surrounding mountains north and south. The area of HODNA is located between the latitudes 35° 00′ and 35° 52′ north of the equator, and between the longitudes 4° 30′ and 5° 34′ east of the Greenwich Line, 250 km southeast of Algiers, with an area of 7699.49 km^2. The climate of the region of continental type is influenced by the desert area, summers are dry and very hot, and winters are very cold (Programming Directorate and Budget Monitoring, 2019).

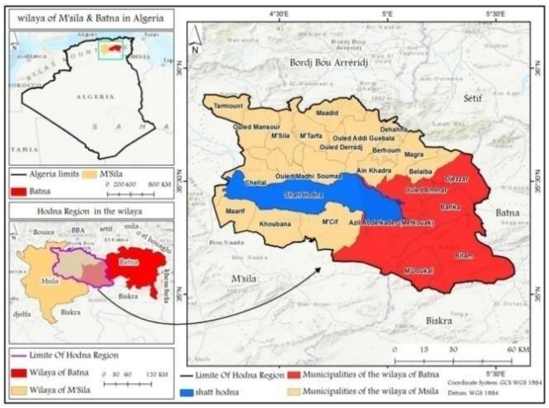

Figure 1. Location of the study area Hadna Region.

Methods

The best site for TLC for waste in the brood area is the site that reduces the negative effects on the environment (Badi and Kridish, 2020), and achieves economic efficiency, i.e., a lower completion cost. The site is exploited as a project that creates wealth and achieves public acceptance to avoid opposition from the population. The criteria for choosing the right place can be divided into environmental, social, and economic criteria, considering the characteristics of the brood area mentioned above (Thonart et al., 2005). Information on the standards adopted at the international level was identified and collected through previous studies and taking into account the characteristics of the study area (Nascimento et al., 2020). The research methodology used is shown in Figure 2.

Selection of suitability criteria

Information on the standards adopted at the international level was identified and collected through previous studies, and taking into account the characteristics of the study area, 11 standards were adopted into 5 areas: 0-Unsuitable, 1- Less suitable, 5-Suitable, 7-Moderately suitable, 10-Highly suitable. All the data and information obtained were converted into digital maps in QGIS to prepare base maps of environmental, social and economic parameters. Then the weights and domains of the criteria obtained from the AHP method were used. They were processed and analyzed to determine spatial suitability using QGIS to build a model builder. The model builder tool of the GIS program helps us to build a suitable model of place and convert the weights of the approved standards resulting from the AHP into digital maps, in our study, the outputs are the approved standards and using the model builder tool, become inputs to produce the final work map (Dehimi, 2021), which identifies us the appropriate places to complete the TLC, and produce the final map to suit the location (Redjem et al., 2021), to complete the TLC and divide them into 5 areas: 0-Unsuitable, 1-Less suitable, 5-Suitable, 7-Moderately suitable, 10-Highly suitable.

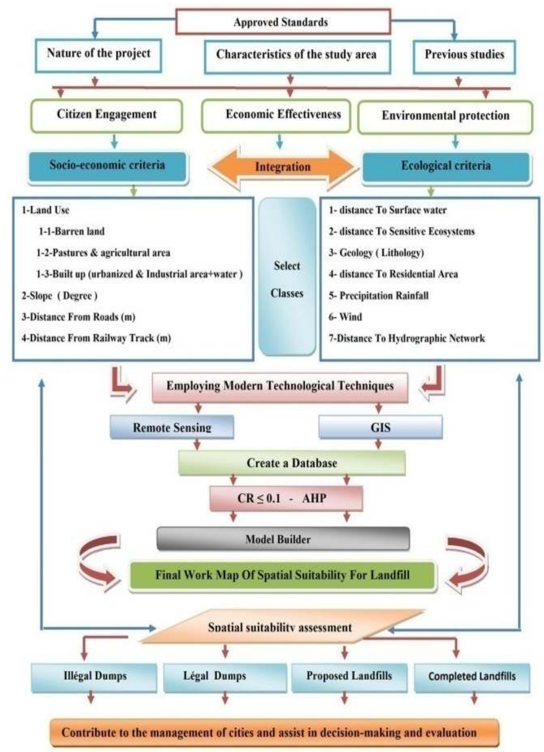

Figure 2. Research methodology used.

Hierarchical Analysis Process (AHP)

The sequential hierarchical analysis method was invented by mathematician Thomas L. Saaty (2008). This mathematical method is widely used in site selection, suitability analysis, territorial planning, routing modeling, and landslide susceptibility analysis (Bilgilioğlu and Bilgilioğlu, 2017). It is a system that enables us to rank selection criteria based on their importance, analyze the data collected, accelerate, organize and document the decision-making process, and is used to deal with multiple criteria and distinguish them from each other according to their importance (Barakat et al., 2017; Sk et al., 2020), and even in the evaluation of previously made decisions (Chabuk et al., 2016), where the adopted criteria are organized into a matrix, which is organized information arranged in rows and columns where each criterion has its own description column, and then the process of bilateral comparison between the criteria is done by converting the importance and preference between the criteria into numbers. The comparison is made using integers from 1 to 9, where each digit symbolizes how important each criterion is presented in Table 1.

Table 1. The AHP verbal scale ranges from 1 to 9.

Intensity of importance	Explanation
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very strong to extreme importance
9	Extreme importance
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3 (at sub layer level) can be used for elements that are very close in importance.	

Source: Pogarčić et al. (2008).

This results in determining the weights of the criteria by dividing the value in each column by the sum of these values in each column and then adding the sum of the division in each row and dividing it by the number of criteria used (11 criteria) We get the weight of each criterion (Dehimi et al., 2022). Which can be converted into a percentage that determines to us the degree of importance of the criterion, then the value of the obtained weights is multiplied by the value in each column, and then the addition process is done at the level of each row, and the resulting sum we divide by the value of the weights, and the rate of the sum of the values resulting from the division represents to us λ max, which enables us to determine the consistency index (CI) according to following equation :

$$CI = (\lambda \max - n) / (n - 1)$$

where: λ max denotes the largest eigenvalue of the precision matrix, and n is the number of criteria.

Accordingly, the value of RI is obtained as a random asymmetry index, and its value is determined by the following Table 2 developed by Saaty (2008).

Table 2. Random consistency index for values of N

N	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Source: Saaty (2008).

CR is then calculated as the final consistency ratio to confirm the binary comparison we have made, as the condition for the validity of the binary comparison is that CR is less than 10% according to the following equation:

$$CR = CI/RI$$

If CR is greater than 10%, the pair should be compared to improve consistency, and if CR is less than 10% the two-way comparison of the criteria was acceptable and logical (Dehimi et al., 2022).

Geographic Information System (*GIS*)

QGIS is an open-source geographic information system created in 2002 that it is used to display, process, and output data (Djouani et al., 2022). The Model Builder tool for QGIS helps us build a suitable model for the place and convert the weights of the approved standards generated by AHP into digital maps. The outputs are the approved standards, and by using the Model Builder tool, they become inputs to produce the final work map (Dehimi, 2021).

Results and Discussion

Description of criteria

After identifying and collecting information about the standards adopted at the international level through recent studies by taking into account the characteristics of the study area, the weights and areas of the criteria were then determined by the AHP method. After this, they were processed and analyzed by the QGIS program to produce a digital map of spatial fit.

Ecological criteria

Surface water: Surface water is an important criterion to be taken into account when choosing the right place to complete TLC (Nascimento et al., 2020) to avoid contamination of surface water represented by dams with juices resulting from fermentation and decomposition of waste (Thonart et al., 2005) where the study area contains 04 dams that are exploited in the provision of potable water and irrigation of agricultural land, where 5 areas were proposed with an increasing distance (Figure 3), places located at distances of less than 500 meters are not suitable, and places more than 3,000 meters are very suitable (Table 3) (Barakat et al., 2017; Redjem et al., 2021).

Sensitive ecosystems: The criterion of sensitive ecosystems has been given the same importance as the standard of surface water for the conservation of ecosystems, especially the wetlands represented by the Shatt al-Hadna, forests, green spaces, orchards and historical and archaeological areas. Accordingly, a 500-meter area has been placed around all sensitive ecosystems; places located at distances of less than 500 meters are not suitable, and places more than 3,000 meters are very suitable (Barakat et al., 2017; Dolui and Sarkar, 2021; Asori et al., 2022; Nanda et al., 2022) (Figure 4).

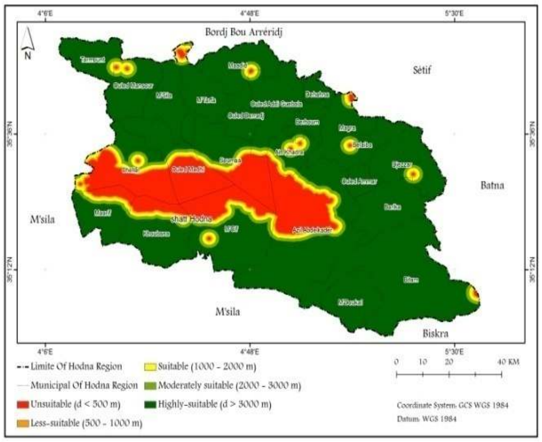

Figure 3. Map of distance to surface water.

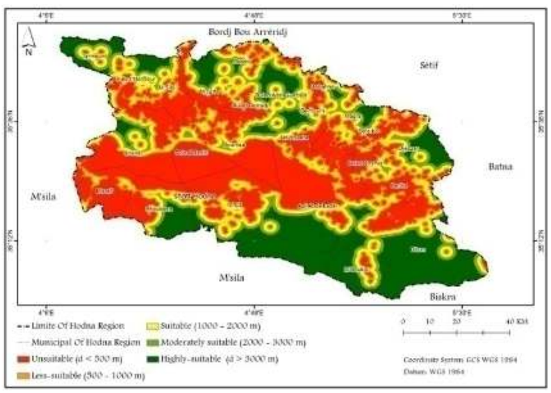

Figure 4. Map of distance to sensitive ecosystems.

Geology (lithology): The landfill must be carried out in the ground with impermeable soil to avoid contamination of groundwater with succulents resulting from the decomposition and fermentation of organic waste (Asori et al., 2022) The principle of work of the landfill depends on the soil in the landfill, where the types of breeding in the study area are divided into 7 types, Clay or calcareous soils are preferred for poor permeability (Barakat et al., 2017; Sk et al., 2020) (Figure 5).

Residential area: To avoid visual pollution and smell and affect the value of the land, future expansion and popular rejection, TLC should not be completed close to urban or residential centers; in this study 5 areas were adopted by placing a 500-meter area around all residential areas, places located at distances of less than 500 meters are not suitable and places more than 2,000 meters are very suitable (Babalola and Busu, 2011; Redjem et al., 2021) (Figure 6).

Precipitation rainfall (mm): Heavy rains affect the TLC of waste, which increases the likelihood of water leakage and mixing with succulents leading to an increase in its quantity and the likelihood of leakage abroad with floods, so the study area was divided into 4 areas, areas with precipitation of less than 25 mm are very suitable, areas with precipitation of 25 and less than 30 mm are suitable, Areas between 30 mm and 40 mm are less suitable, and areas with precipitation greater than 40 mm are not suitable (Osra and Kajjumba, 2020) (Figure 7).

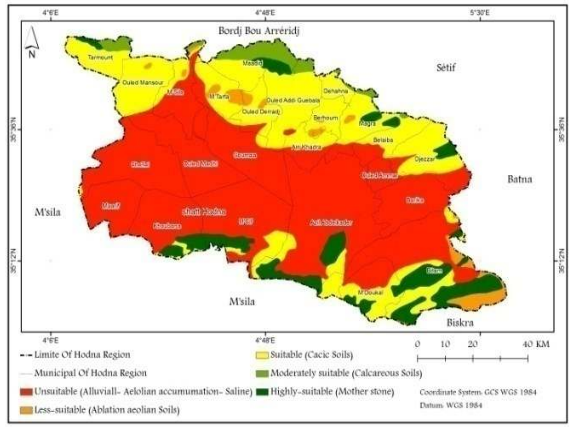

Figure 5. Map of geology (lithology).

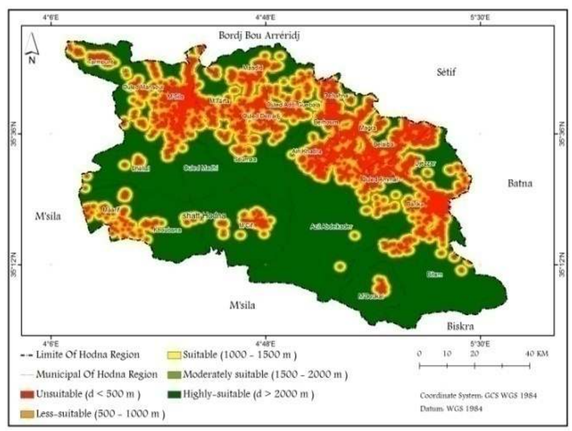

Figure 6. Map of distance to residential areas.

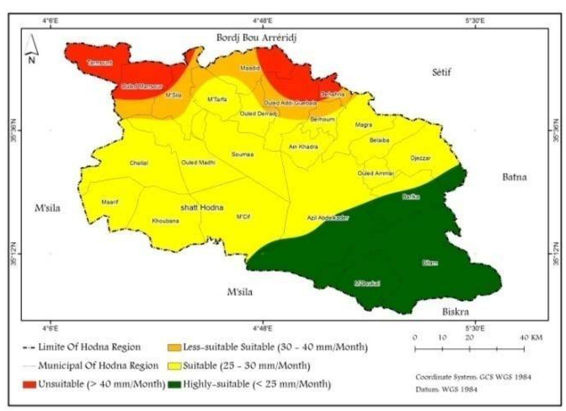

Figure 7. Map of precipitation rainfall.

Wind: The best location is one that is naturally protected from gusts of wind, or the wind direction is opposite to urban areas with the availability of heat and rainfall factors, gases and unpleasant odors leak and are transported by the wind to neighboring areas, whether residential areas or sensitive ecosystems (Barakat et al., 2017; Osra and Kajjumba, 2020) (Figure 8).

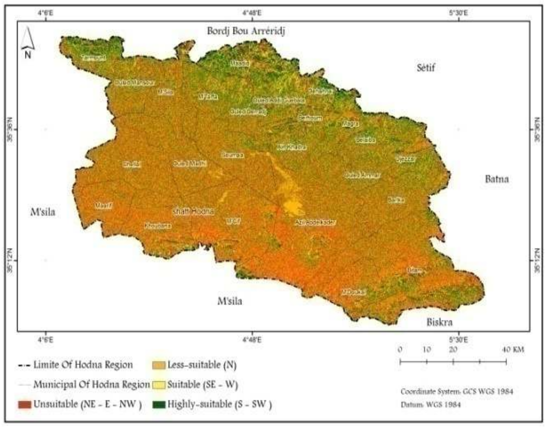

Figure 8. Map of wind.

Hydrographic network: The Hadna Region is characterized by a hydrographic network represented by the valleys, as it is seasonal runoff according to rainfall, especially the collapsing rains in the summer season, and its final estuary is the wet area represented by the brood Shatt, where TLC should not be completed near these valleys to avoid the transfer of juices and gases after rainfall and the occurrence of torrents to areas especially the sensitive ecosystems represented in the Shatt al-Hadna, where in this study 05 areas were adopted throughput a 100-meter field around all valleys, where places located at distances of less than 100 meters are not suitable, and places more than 1,000 meters are very suitable (Sisay et al., 2021) (Figure 9).

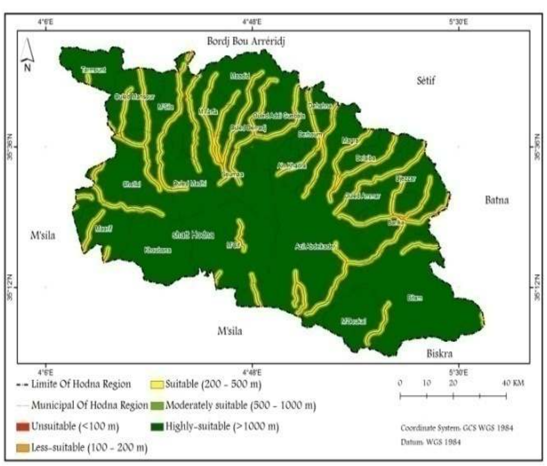

Figure 9. Map of distance to hydrographic network.

Socio-economic criteria

Land use: In order to achieve the goal of reducing the impact on the environment and the popular acceptance of the projects of TLC, the land uses in the field of study was divided into the first area, arid lands, which are very suitable and were given grade 10, the second area pasture and agricultural areas less suitable with degree 1, and the third area built-up land (urban and industrial area) is not suitable with grade 0 (Chabuk et al., 2016; Barakat et al., 2017; Redjem et al., 2021) (Figure 10).

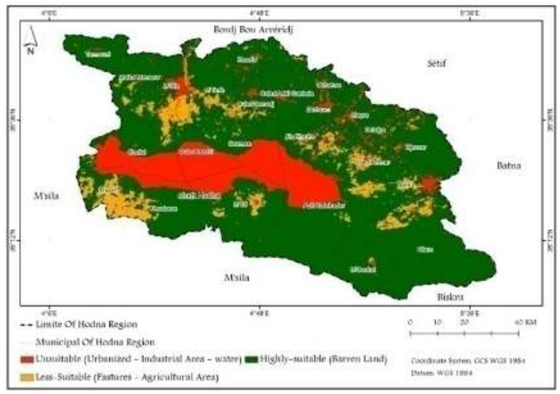

Figure 10. Map of distance to land use.

Slope: The regression criterion is an essential element in the choice of landfill site; when the slope is large, meaning when rainfall, the speed of runoff is large, which leads to the dredging of sedimentation basins for the treatment of juicer and the collapse of the TLC, in addition to the possibility of the exit of the internal juicer to the outside due to the large inclination, as well as economically such as the difficulty of access and the large completion costs resulting from the leveling of the floor and the opening of the paths (Bilgilioğlu and Bilgilioğlu, 2017). Since the area of the field of study is large the field of study area was divided into 5 areas, i.e., areas with a slope less than 7 degrees are very suitable, areas with a slope between 7 and 12 degrees are moderately suitable, areas with a slope between 12 and 25 degrees are suitable, areas with a slope between 25 and 45 degrees are less suitable, and areas with a slope greater than 45 degrees are not suitable (Barakat et al., 2017; Redjem et al., 2021). It is shown that the inappropriate areas were on the north side and the side Southern to the presence of mountain ranges (Figure 11).

Distance from roads: Distance from roads is an important economic criterion in choosing the location of a landfill to facilitate and reduce the cost of transporting waste from the source urban agglomerations to TLC without forgetting that technical backfill centers have become investment projects at the level of which the process of sorting resilient waste (paper, plastic... etc) (Nascimento et al., 2020), Where in this study 5 areas were adopted by placing a field of 200 meters around all roads, where places located at distances of less than 200 meters are very suitable, and places more than 2000 meters are not suitable (Redjem et al., 2021) (Figure 12).

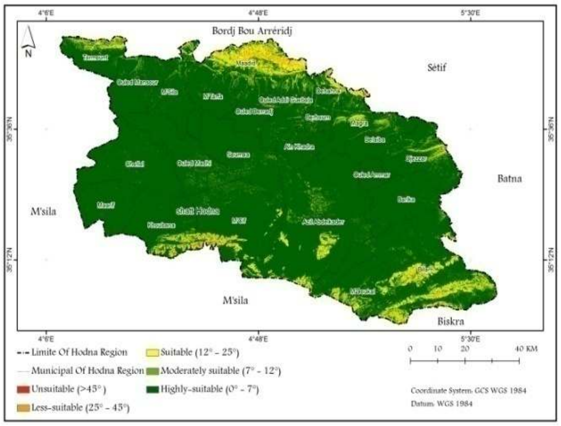

Figure 11. Map of slope.

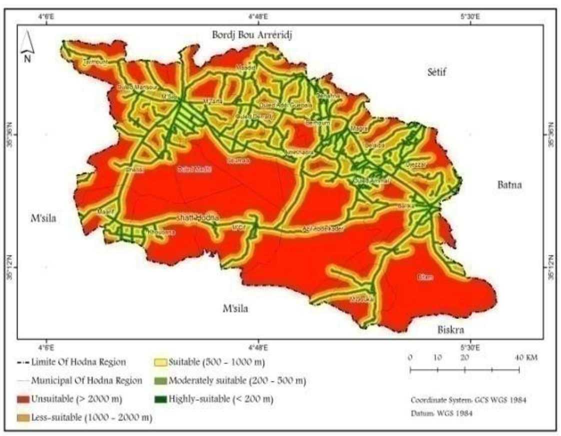

Figure 12. Map of distance to from roads.

Distance from railway track : Due to the presence of the railway line and passes through 9 neighboring municipalities from Barika in the east to M'sila in the west and its route along the national roads can be used to transport waste from the source of generation represented by urban centers to the treatment unit represented by the TLC, as well as exploited in the transport of materials resulting from recycling, to reduce pollution and the cost of transportation (Dolui and Sarkar, 2021), and even temporary waste warehouses can be completed around the railway line of each municipality, where in This study adopted 5 areas by placing a 500-meter area around the railway line, where places located at distances of less than 500 meters are very suitable and places more than 3,000 meters are suitable, extremely to avoid the smell and visual pollution (Barakat et al., 2017; Dolui and Sarkar, 2021; Asori et al., 2022; Nanda et al., 2022) (Figure 13).

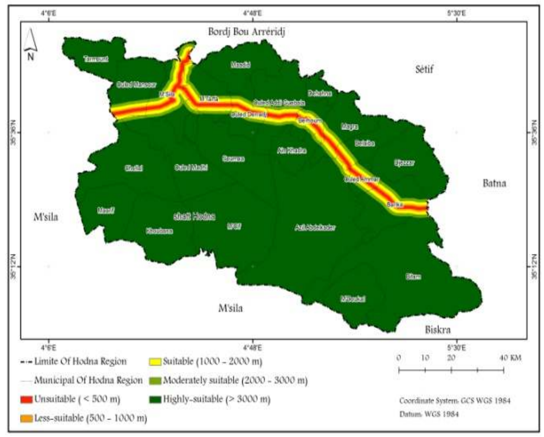

Figure 13. Map of distance to railway track.

The results obtained by the AHP method

If CR≥10%, pairs should be reevaluated and compared to improve (Saaty, 2008) consistency. In our study, the consistency rate was CR = 3.99%, which is less than 10%, which indicates that the preferential bilateral comparison between the criteria was acceptable and logical because the requirement for the validity of the binary comparison is that CR is less than 10%. In Table 3, the criteria are arranged according to weight and importance. The distance to surface water and distance to sensitive ecosystems standards, the two most important criteria in the process of determining spatial suitability by 24.17%, came to achieve the goal of environmental protection, followed by the criterion distance to residential area by 12.52%, then the standard of distance to land use and distance to hydrographic network by 8.92%, and then the criterion of wind by 6.11%. Then the geology (lithology) standard by 4.71%, then the precipitation rainfall criterion by 4.14%, then the slope (degree) criterion by 2.84%, followed by distance from railway track by 1.53% and finally by distance from roads by 1.53%, in order to achieve the goal of economic efficiency and popular acceptance.

Result of using the QGIS program

The weights and domains of the criteria obtained from the AHP method were used to extract the final digital map of spatial fit. Division of adopted standards (11 standards) into five areas (Table 4). The base map for each criterion was obtained using QGIS and using the structural model builder, where the program simplifies the basic problem and formulates a way to solve it by analyzing and collecting the previous basic maps in one map, which is the spatial suitability map for the completion of TLC and consists of 5 areas: 0-Unsuitable,1-Less suitable, 5-Suitable,7-Moderately suitable,10-Highly suitable (Table 5). The results obtained in a final digital map of spatial suitability were used to determine the appropriate places for the completion of TLC (Figure 14).

Table 3. Results of AHP comparison between standards.

Criteria	(C1)	(C2)	(C3)	(C4)	(C5)	(C6)	(C7)	(C8)	(C9)	(C10)	(C11)	Weight (%)	Rank
Surface water	1	1	6	3	6	5	4	4	7	9	8	24.17	1
Sensitive ecosystems	1	1	6	3	6	5	4	4	7	9	8	24.17	2
Geology (lithology)	1/6	1/6	1	1/4	1	1/2	1/3	1/3	2	4	6	4.71	7
Residential area	1/3	1/3	4	1	4	3	2	2	5	6	5	12.52	3
Precipitation rainfall	1/6	1/6	1	1/4	1	1/2	1/3	1/3	2	4	3	4.14	8
Wind (m/s)	1/5	1/5	2	1/3	2	1	1/2	1/2	3	5	4	6.11	6
Hydrographic network	1/4	1/4	3	1/2	3	2	1	1	4	6	5	8.92	5
Land use	1/4	1/4	3	1/2	3	2	1	1	4	6	5	8.92	4
Slope (degree)	1/7	1/7	1/2	1/5	2	3	1/4	1/4	1	3	2	2.84	9
Distance from roads	1/9	1/9	1/4	1/6	4	5	1/6	1/6	1/3	1	1/2	1.53	11
Distance from railway track	1/8	1/8	1/6	1/5	3	4	1/5	1/5	1/2	2	1	1.97	10
Total	3.75	3.75	26.92	9.40	27.08	19.73	13.78	13.78	35.83	55.00	47.50		
	λ max = 11.6019					**CI= 0.0602**			**R.I = 1.51**		**C.R = 3.99%**		

Table 4. Grading values and description of selected criteria.

Criteria	Classes	Description	Scores	AHP W	Selected criteria of previous studies and characteristics of the study area	Source
Ecological criteria						
C1 Surface water (m)	d<500 500<d<1,000 1,000<d<2,000 2,000 <d<3,000 3000<d	Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 1 5 7 10	24.17	(Thonart et al., 2005; Barakat et al., 2017; Nascimento et al., 2020 ; Redjem et al., 2021)	National Spatial Planning Agency (NSPA) + OSM
C2 Sensitive ecosystems (m)	d<500 500 <d<1,000 1,000<d<2,000 2,000<d<3,000 3000<d	Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 1 5 7 10	24.17	(Barakat et al., 2017; Dolui and Sarkar, 2021; Asori et al., 2022; Nanda et al., 2022)	ESRI Land Use 2020 https://www.arcgis.com/home/item.html?id=
C3 Geology (lithology)	-Alluvial soils -Aeolian accumulation soils -Saline soils (solonchak) -Ablation of aeolian soils -Cacic soils -Calcareous soils -Mother stone	Unsuitable Unsuitable Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 0 0 1 5 7 10	4.71	(Barakat et al., 2017; Sk et al., 2020; Dolui and Sarkar, 2021; Asori et al., 2022)	Drawn, gravure and published by the Geographical Service of the Army in 1927
C4 Residential area (m)	0<d<500 500<d<1,000 1,000<d<1,500 1,500<d<2,000 2,000<d	Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 1 5 7 10	12.52	(Babalola and Busu, 2011; Redjem et al., 2021).	ESRI Land Use 2020 https://www.arcgis.com/home/item.html?id=

Criteria	Classes	Description	Scores	AHP W	Selected criteria of previous studies and characteristics of the study area	Source
C5 Precipitation rainfall (mm)	<25 25-<30 30-40 >40	Highly suitable Suitable Less suitable Unsuitable	10 5 1 0	4.14	(Osra and Kajjumba, 2020; Asori et al., 2022; Jothimani et al., 2022)	https://power.larc.nasa.gov/data-access-viewer
C6 Wind (m/s)	The best location is one that is naturally protected from gusts of wind, or the wind direction is opposite to urban areas.	S+SW Highly suitable SE+W Suitable N Less suitable NE+E+NW Unsuitable	10 5 1 0	6.11	(Barakat et al., 2017; Bilgilioğlu and Bilgilioğlu, 2017; Badi and Kridish, 2020; Osra and Kajjumba, 2020; Asori et al., 2022)	https://power.larc.nasa.gov/data-access-viewer
C7 Hydrographic network (m)	0<d<100 100<d 200 200<d<500 500<d<1000 1,000<d	Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 1 5 7 10	8.92	(Sisay et al., 2021)	National Spatial Planning Agency (NSPA) + OSM
Socio-economic criteria						
C8 Land use	Barren land Pastures and agricultural areas Built up (urbanized and industrial area+water)	Highly suitable Less suitable Unsuitable	10 1 0	8.92	(Chabuk et al., 2016; Barakat et al., 2017; Redjem et al., 2021)	ESRI Land Use 2020,https://www.arcgis.com/home/item.html?id=
C9 Slope (degree)	0°<α <7° 7°<α<12° 12°<α<25° 25°<α<45° 45°<α	Highly suitable Moderately suitable Suitable Less suitable Unsuitable	10 7 5 1 0	2.84	(Bilgilioğlu and Bilgilioğlu, 2017; Barakat et al., 2017; Redjem et al., 2021).	earth explorer - usgs - dem https://earthexplorer.usgs.gov /
C10 Distance from roads (m)	0 <d<200 200<d<500 500<d<1,000 1,000<d<2,000 2,000<d	Highly suitable Moderately suitable Suitable Less suitable Unsuitable	10 7 5 1 0	1.53	(Nascimento et al., 2020 ; Dolui and Sarkar, 2021; Redjem et al., 2021).	Open street map + Official website of the Ministry of Public Works (Route Map)
C11 Distance from railway track (m)	0<d<500 500<d<1,000 1,000<d<2,000 2,000<d<3,000 >3,000	Unsuitable Less suitable Suitable Moderately suitable Highly suitable	0 1 5 7 10	1.97	(Dolui and Sarkar, 2021; Sisay et al., 2021).	Open street map + Official website of the Ministry of Public Works (Route Map)

Highly suitable: It is located on the southeastern side where the Barren land and some central and northern areas of the study area with an area of 1,737.18 km^2 and represents 22.56% (Figure 14).

Moderately suitable: Located next to Highly suitable areas with an area of 1,416.55 km$^{2.}$ It represents 18.40% (Figure 14)

Suitable: Located next to suitable areas with an area of 1,593.59 km^2 representing 20.70% (Figure 14)

Less suitable: Distributed adjacent to urban centers, i.e. in areas of the future expansion of urban agglomerations, representing an area of 1,701.28 km^2 and by 22.10% (Figure 14).

Unsuitable: It is represented in urban agglomeration areas and sensitive ecosystems, with an area of 1,250.89 km^2 and a rate of 16.24% (Figure 14).

This study can be relied upon by the public authorities in determining the appropriate places for the completion of TLC, especially between municipalities, to achieve the general goal of environmental protection, economic efficiency and popular satisfaction.

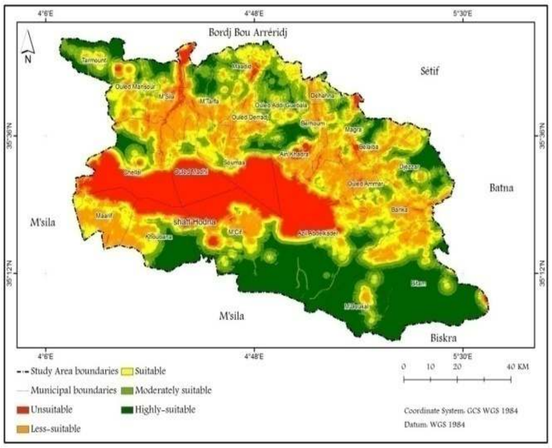

Figure 14. Final landfill suitability map.

Table 5. Results of the binary comparison criteria.

Selected Priorities	Area (km^2)	Area (%)	Rank
Highly suitable	1,737.18	22.56%	**01**
Moderately suitable	1,416.55	18.40%	**04**
Suitable	1,593.59	20.70%	**03**
Less suitable	1,701.28	22.10%	**02**
Unsuitable	1,250.89	16.24%	**05**
Sum of suitability	**7,699.49**	**100%**	

Finally, the results of the study were adopted in the process of assessing the spatial suitability of the existing public dump sites, where the results were, 4.76% of the public dumps are located in unsuitable areas, 14.29% are located in less suitable areas, 33.33% are located in moderately suitable areas, 14.29% are located in very suitable areas, 33.33% are located in moderately suitable areas, 14.29% are located in very suitable areas (Figure 15).

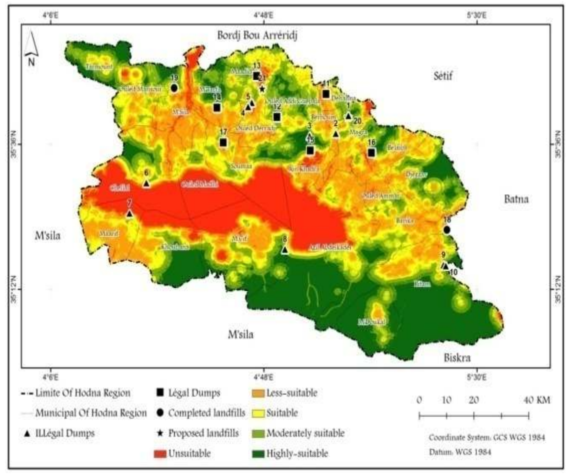

Figure 15. Spatial suitability assessment.

Table 6. Spatial suitability assessment.

N on the map	Public landfill	Municipality	Spatial Fit	Grades
01	Illegal Dumps	Bitam	Moderately suitable	**07**
02	Illegal Dumps	Bitam	Moderately suitable	**07**
03	TLC	Barika	Moderately suitable	**07**
04	Legal Dumps	Belaiba	Suitable	**05**
05	Illegal Dumps	Magra	Highly suitable	**10**
06	Proposed Landfills	Magra	Highly suitable	**10**
07	Legal Dumps	Dehahna	Suitable	**05**
08	Illegal Dumps	Berhoum	Suitable	**05**
09	Illegal Dumps	Berhoum	Highly suitable	**10**
10	Legal Dumps	Ain khadra	Suitable	**05**
11	Illegal Dumps	M'cif	Moderately suitable	**07**
12	Legal Dumps	Ouled Addi Guebala	Moderately suitable	**07**
13	Proposed Landfills	Ouled Addi Guebala	Suitable	**05**
14	Legal Dumps	Maadid	Less suitable	**01**
15	Illegal Dumps	Ouled Derradj	Moderately suitable	**07**
16	Illegal Dumps	Ouled Derradj	Moderately suitable	**07**
17	Legal Dumps	M'Tarfa	Less suitable	**01**
18	TLC	M'sila	Less suitable	**01**
19	Legal Dumps	Soumaa	Suitable	**05**
20	Illegal Dumps	Chellal	Suitable	**05**
21	Illegal Dumps	Maarif	Unsuitable	**0**

Conclusion

In this paper, the mathematical method called AHP was combined with GIS, In order to determine the appropriate places for the completion of TLC in the area of Al-Hodna, Algeria, especially since there are no laws or a common global formula that controls the conditions for choosing the appropriate site, as many studies and research have been completed, which have recently increased the importance of the subject and followed different methods to study and choose the appropriate place to complete technical filling centers, especially using modern technology and remote sensing such as geographic information systems. They agreed on the goal of environmental protection, economic efficiency and popular acceptance of these projects. This combination and integration resulted in a final digital map of the sites suitable for the completion of TLC divided into 5 areas: Inappropriate, 1-Less suitable, 5-Suitable, 7- Moderately suitable, and 10-Highly suitable. Accordingly, the study proved the effectiveness of integration between AHP and GIS in assisting public authorities in choosing the appropriate places for the completion of TLC, especially inter-municipal ones to achieve the desired goal of environmental protection, economic efficiency, and popular acceptance, and even assess the spatial suitability of existing public dumps used in the treatment of municipal solid waste to assist in decision-making. The importance of such studies is highlighted in the process of spatial planning and environmental assessment before the start of the completion of municipal solid waste treatment projects to reduce effort and time.

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