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SUITABILITY MAPPING FOR OPTIMAL LANDFILL SITE IN COASTAL MOUNTAIN MUNICIPALITIES. CASE STUDY: COLLO MASSIF (NORTHEASTERN ALGERIA)

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ABSTRACT

The management of Municipal Solid Waste (MSW) in coastal mountainous regions displays a significant challenge to sustainable development in Algeria, particularly in its environmental dimension. Local stakeholders face substantial difficulties in identifying appropriate sites for solid waste disposal in this area due to the fragility and complexity of their ecological systems and their potential to amplify the impacts of waste disposal. This affects directly the quality of life, sustainability of natural resources, and threatens the scenic beauty of this tourist destination. Therefore, developing a mechanism based on scientific knowledge to facilitate decision-making processes in these regions is imperative. This paper aims to underscore the importance of employing Cartographic Suitability Mapping for Optimal Landfill Site Selection in coastal mountainous regions as an effective tool to ensure precise results, focusing on the study case of Collo, Skikda state, Algeria. The results show four categories of land suitability: constraint (5.22-7.76) , unsuitable (3.25-4.26), and suitable area (1.21-3.24), with four candidate areas identified as the most suitable for landfill establishment. It is recommended that future studies incorporate social and economic dimensions to further enhance decision-making processes in this regard.

KEYWORDS:

Municipal Solid Waste (MSW), Landfill, Suitability Land, Coastal Mountain

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1. Introduction.

The management of Municipal Solid Waste (MSW) in light of sustainable development directives is relatively ancient in Algeria. The global awareness about environmental issues following the 1992 Rio de Janeiro Declaration (Earth Summit) has guided Algeria to adopt international treaties and protocols related to the environment and sustainable development (Basel Convention 1993). These agreements have provided Algeria with a policy framework to initiate effective measures and implement MSW projects. The Algerian government has maintained a consistent focus on this sector, over the recent years. This commitment finds its expression in legislative context that results of a series of Executive Decrees, come on the top the Executive Decree No. 84-378 dated December 15, 1984. Supervised by the Ministry of Territory Planning, Environment and Tourism (MLPET, 2003 and 2016; Djemaci, 2012), the MSW in Algerian is reinforced by Law Nº. 01-19 of 12/12/2001 relating to the management, control, and disposal of waste.

This law also provides for the creation of technical landfill centers and the establishment of national, regional and municipal waste management plans (National Plan of Planning and Management of Solid Waste NPPMSW (MERE, 2022); Plan of Municipal Solid Waste Management PMSWM), programs (The National Program for Integrated Municipal Solid Waste Management ProgDem), strategies (The New National Strategy for Integrated Waste Management NSIWM 2035) (MERE, 2023), and national and local institutions (AND, CNFE, MICL, CNTPP). The fiscal field is another framework enriched by eco-taxes (polluter pays). However, despite the government's long-term efforts the MSW awareness has not been translated into effective practices. The proliferation of landfills of solid waste (SW) is exacerbated by the amount of municipalities in Algeria (Naghel et al., 2022). The Sw estimated by 14.5 million tons (Hemidat S et al, 2022) against 10 million tons in 2016 (NDA, 2016). Urban areas in Algeria annually generate solid waste at a rate of 0.8 kg/person/day, while rural areas generate a rate of 0.65 kg/person/day (NDA, 2020). Household and similar waste (HSW) is considered the most voluminous of all types of municipal solid waste (Abdelli, 2017). This phenomenon can be explicated by several factors, including the growing population, accelerated urbanization, and changing consumer behavior of the inhabitants (Ouchene and Moroncini, 2018).

Additionally, the deficiency of material resources (transportation, collection, and elimination) and accurate data complicates efforts to control and regulator the issue (CNES, 1999; Morocco: Konrad-Adenauer-Stiftung E.V., 2015. These conditions threat seriously the quality of public health, effectiveness of economic activities and biodiversity suitability (Mayster and Duflon, 1994), especially in costal mountainous domain characterized by marginality, isolation, complexity of ecosystem and a high ecological sensitivity. Explore this long-standing problem and developed operational solutions adapted with these specific regions, became contemporary environmental challenges for planners, managers and stakeholders. *This* research paper initiated the original approach to Cartography the Suitability Mapping for Optimal Landfill Site Selection based on complementarity between several methods and technics. this synergy worth is applied to Collo Costal Mountain within the westerner of Skikda state, northeastern of Algeria. The Results helps the authorities (policy makers) and scholars to elaborate the original susceptibility land map.

2. Materials and Methods.

2.2.1. Study Area.

Withe along coastline of 250 km, the Collo mount, is located in the northeastern of Algeria, and constituted a portion of a large coastal chain of the Atlas Tellin.

It covers 4137.68 km² that represents the third part (1/3) of Skikda state area (Fig. 1).

This area having nearly 3798838 inhabitants in 2023 is organized into 13 municipalities and structured by two small cities, some villages and rural agglomerations. This region is characterized by a chaotic and airy topography resulting from brittle and folding tectonics affecting the entire region of Collo Mountain (Villa, 1980), with the highest peak reaches 1183 m (Djebel El Goufi), while the average altitude is around 700 m. This picturesque region, wooded with maritime pine, benefits from a relatively humid to sub-humid of Mediterranean climate. Humidity is higher in winter than in summer (80.5 %).The Collo Mountain is served by sufficient road network. Its economics is motivated by agricultural, forestry, agro-pastoral and tourism activities. Based to the ratio waste generated by DNA, 2016, a growth rate of 2.5% and an average household size of 6 persons (SNO, 2008), the daily quantity of Municipal solid waste in the Collo Mountain is estimated at 266 tones in 2023. The direct observation shows 20 open dumpsites of varying sizes scattered randomly around the towns and the main roads (fig.2).

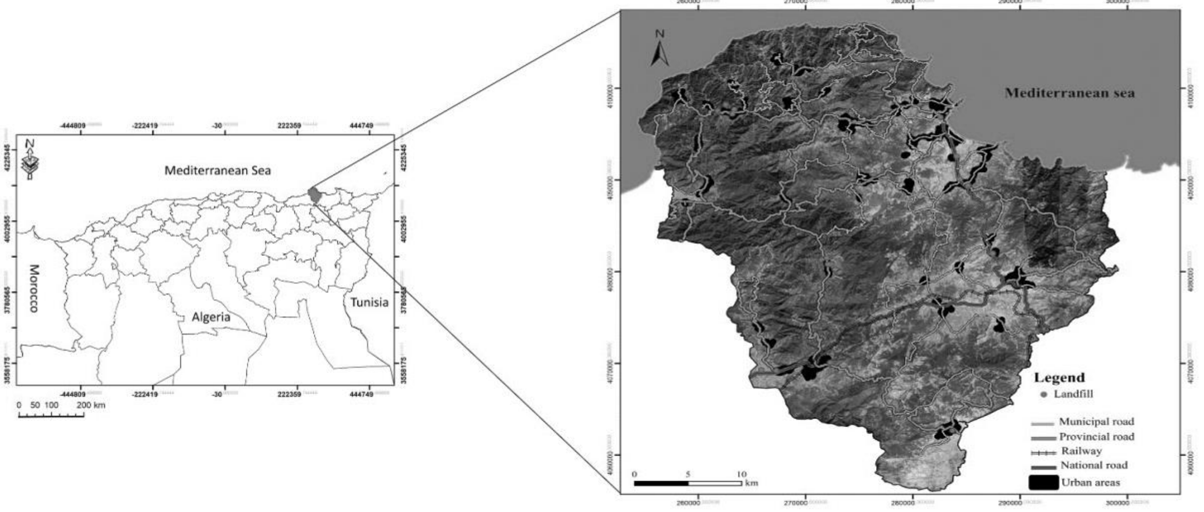


Fig. 1. Location map of the study area

Collo,2024

Bin El Ouidene, 2024

Bin El Ouidene, 2024

Bin El Ouidene, 2024

Kheng Mayoune, 2024

TLC in Tamalous, 2024

Fig. 2- Landfill sites and TLC in Collo Massif

Generally, the composition of waste is heterogeneous and its origins are manifold. The household waste represents a considerable part of total waste, most of wastes are the plastic (AND, 2016). The Collo Mountain has been benefited from a Technical Landfill Center (TLC) in Tamalous municipality, withe 20 hectares area that serves seven (7) municipalities, its storage capacity is estimated at 445,000 m^3. It managed by regional Public Institution of Technical Landfill Centers Management created in 2005 due to encourage local authorities to abandon "traditional disposal modes". However, it has been stopped because it stimulates social conflicts according the interview with local actors the Owenchip of land and overlapping responsibilities landscape distortion are the most problems.

2.2. Methodology.

The development of suitability mapping for optimal landfill site selection in mountainous coastal regions requires the integration of various methodologies. This study employs a descriptive and analytical approach, combining participatory territorial diagnosis, statistical methods, and advanced techniques for data collection, analysis, and result presentation.

The territorial diagnostic method assesses the current situation regarding waste dump distribution and its environmental impact, captures public opinion, and identifies specific problems. This analysis mechanisms provides detailed indicators for evaluating landfill suitability, integrating criteria derived from international and national literature and expert opinions, particularly in the absence of nationally approved standards and predefined criteria.

Multiple-criteria evaluation (MCE) techniques, utilizing the Analytic Hierarchy Process (AHP), are employed to assess and prioritize indicators, organizing criteria based on their significance and impact on the local environment.

Geographic Information Systems (GIS) technology and remote sensing (RS) facilitate the collection, processing, and mapping of large spatial and non-spatial datasets to assess potential landfill sites.

Integrating these methods and techniques aims to achieve more accurate and effective solutions tailored to the study area, thereby optimizing resource allocation and time efficiency.

2.2.1. Selection Criteria.

Since the absence of local reference indicators for the determination of suitable sites for Municipal Solid Waste (MSW) landfills, we availed ourselves of various preponderant and insightful principles and guidelines. We inspired by typical works: Principles of sustainable development (2001), French Law 09/1997, the European Union directive 1999/31/CE of 26/04/99 in its article 20 Annex I concerning discharge 2005, the Practical Guide to Household and Similar Waste Management and Landfill in the South (Thonart et al; 2005), environmental, health, and safety parameters defined by the World Bank (WBG, 2007), the US Environmental Protection Agency (EPA, 2021) and by authors' opinions after comparing their researchers done in field (Lox and Houtain,1999). These scientific researchers have been conducted to outline essential requirements that Municipal Solid Waste (MSW) landfills should predominantly meet:

- Avoided to expose to natural hazards.
- Prevented the alteration of human sensory and comfort including visual sensation, olfactory sensation, thermal comfort, and ash fires of dumps.
- Avoided to decrease gas distribution to the atmosphere
- Ensuring optimal accessibility to the landfill sites.

In this previous investigate, nine indicators have been proposed for evaluating MSW landfill suitability location. These criteria comprise slope, elevation, land cover, distance from rivers, roads, and residential areas, soil lithology, groundwater depth, and slope exposure. Each criterion proposed is associated with urban or environmental parameters, as depicted in Table 1.

Table 1.

Parameter	Sub parameter	Classification criteria	Qualification of criteria	Weight value	Weighting factor LPC
Urbanity	Urban and business zone	**A**- Distance (km)	< 1	1	**28%**
			1-2	2	
			2-3	5	
			3-4	6	
			4-5	7	
			5-8	8	
			8-10	9	
			> 10	10	
	Road Network	**B**-Distance (km)	< 0.5	1	**12%**
			0.5-1	2	
			1-2	3	
			2-3	4	
			3-4	6	
			4-5	8	
			> 5	10	
Environmental	Soil	**C**- soil lithology	Unsaturated soil	4	**20%**
			Podzolic soil	6	
			Alluvial soils	1	
	Geomorphology and climate	**D**-Slope (%)	0- 6	10	**3%**
			6-12	8	
			12-18	6	
			18-24	4	
			>24	1	
		E- Elevation (m)	< 100	10	**4%**
			100-250	8	
			250-500	4	
			>500	1	
		F- Slope direction	Plat standard	10	
			North	2	
			Suth-west	8	**7%**
			North-east	2	
			East	1	
			West	1	
			South east	8	
			North west	2	
			South	10	
	Biophysics	**G**-Land cover	Forest and dense	4	**5%**
			Clear scrubland	8	
			Beach	1	
			Bare soil	10	
			Agricultural land	1	
			Residential area	1	
			Open water	1	
	Water resources	**H**-Distance from river(m)	< 500	1	**12%**
			1000	2	
			1500	3	
			2000	4	
			2500	5	
			3000	6	
			3500	8	
			>4000	10	
		I-Groundwater depth (m)	< 0-20	1	**9%**
			20-50	2	
			50-100	4	
			100-150	6	
			>150	10	

2.2.2. Data Collection.

To evaluate the suitability land for municipal solid waste (MSW) landfill in the Collo costal mountainous, spatial and alphanumeric datasets were collected from various sources, including local institutions, municipalities, study reports, articles, online portals (USGS), cartographic documents (geological and topographical maps), satellite images (Landsat OLI/TIRS), and census statistics. In situ observations and investigations, such as photography, interviews, and conversations, were also conducted to fill information gaps and enhance the robustness of the research.

2.2.3. GIS-AHP.

Developed by Thomas Saaty in 1984, Analytic Hierarchy Process (AHP) is frequently employed in conjunction with Geographic Information Systems (GIS) to facilitate decision-making processes concerning geographic issues (Roy, 1985, Belton, 1998; Ben Mena, 2000; Chakhar, 2006, et al; 2011; Chevallier, 2016; Chabuk et al., 2017, Kamdar et al., 2019, Benkahoul et al; 2017, El Mordjani, 2003,Tanupriya Choudhury, et al 2024,). AHP consist to breaking down a complex decision problem into a structured tree of hierarchic criteria. Using the Multi-Criteria Evaluation (MCE) technique, deal with statistical tests (Saaty, 1977; Olmedo et al., 2007) permit to determine the weights assigned to each criterion (Rezaei-Moghaddam and Karami, 2008). The comparison of these criteria is done pairwise square comparison matrix (NxN) according to a scale of values chosen. This process is designed to articulate the degree of significance of one indicator relative to another, assigning corresponding scores. Within Analytical Hierarchy Processes, the numerical rank of 9 weights established by T.Saaty (1993) is adapted in our specific case study (Table 2).

This phase involved the following calculations was explained by Coyle (1989, 2004). Initially, it commences with calculating the sum of values in each column of pairwise matrix, whilst the second step involves normalizing the matrix by dividing each element by the total of its corresponding column. The last step tends to compute the average of the elements in each row of the normalized matrix. The Consistency Ratio CR is determined using Equation (1) and Equation (2).

$$CI = \frac{\lambda max - n}{n-1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

Where: λ max principal represent eigenvalue, n is the matrix size in a pairwise comparison.

CI: Consistency Index and RI is the Random Inconsistency Index.

If the Consistency Index *CI* is greater than 0, 1, the consistency of the pairwise comparisons are lacking and the matrix needs to be re-evaluated (Saaty, 1990).

These are in subsequently subdivided into a numerous criterion, each of which have been normalized to common range of 1 to 10 (Table 3).

The comparison of different criteria selected from 1 to 9 per pair, lids to a square matrix, which will be standardized and weighted through the linear weight comparison method. The results give the following matrix (Table 4):

The Consistency Ratio CR values for all comparisons were calculated using the methodology suggested by Saaty and Virgel (2001), revealing values were concisely founded less than 0.1. Then this outcome suggests that the application of weights was executed appropriately, as noted by (Eastman 2003). The weights assigned to different criteria, were combined with the Weighted Linear Combination (WLC) method based on Multiple Criteria evaluation (MCE) using AHP extension in ArcGIS soft word. The suitability of Collo land was calculated by aggregating the weights of the different criteria through the application of the following mathematical Equation.

$$SI = \sum_{n}^{i=1} Wi \times Si \quad (3)$$

Where: *Wi*; criterion weight, Si; criterion standardized, and *SI* is the suitability index.

Table 2.
Fundamental scales for pairwise comparisons, (Saaty, T.L., 1984)

Scales	Degree of preferences	Descriptions
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2,4,6,8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7 and 9

Table 3.
Random consistency index (RI), (Saaty, T.L., 1984)

Number of criteria (n)	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0,0	0,0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

Table 4.
Square matrix of the pair-wise comparisons of various criteria

Criteria	A	B	C	D	E	F	J	H	I	WEIGHT, %
A	1	2	4	7	6	4	5	3	2	28%
B	1/2	1	2	2	6	1/4	2	1/5	1/2	12%
C	1/4	1/2	1	6	4	3	6	9	2	20%
D	1/7	1/2	1/6	1	1/4	1/4	2	1/4	1/3	3%
E	1/6	1/6	1/4	4	1	1/2	1/2	1/5	1/4	4%
F	1/4	4	1/3	4	2	1	2	1/4	1/2	7%
J	1/5	1/2	1/6	1/2	2	1/2	1	1/2	2	5%
H	1/3	5	1/9	4	5	4	2	1	2	12%
I	1/2	2	1/2	4	4	2	1/2	1/2	1	9%
Hmax = 9.38, CI=0,048, IA= 1.45, CR= 0,033										

ArcGis 10.8 are used to digitalize, analysis (interpolation, buffering, aggregation, overly, union, intersection), and visualizing the various criteria maps. The resulting maps were transformed into Esri Grid format by incorporating the weighting values obtained from the Multi-Criteria Evaluation (MCE) technique. The standardized criterion layers in ArcGIS underwent aggregation through the Weighted Linear Combination (WLC) function, utilizing the "Map Algebra" operator in the Spatial Analyst toolbox of “reclassify”. The above methodology is summarized in the flowchart shown in Figure 4.

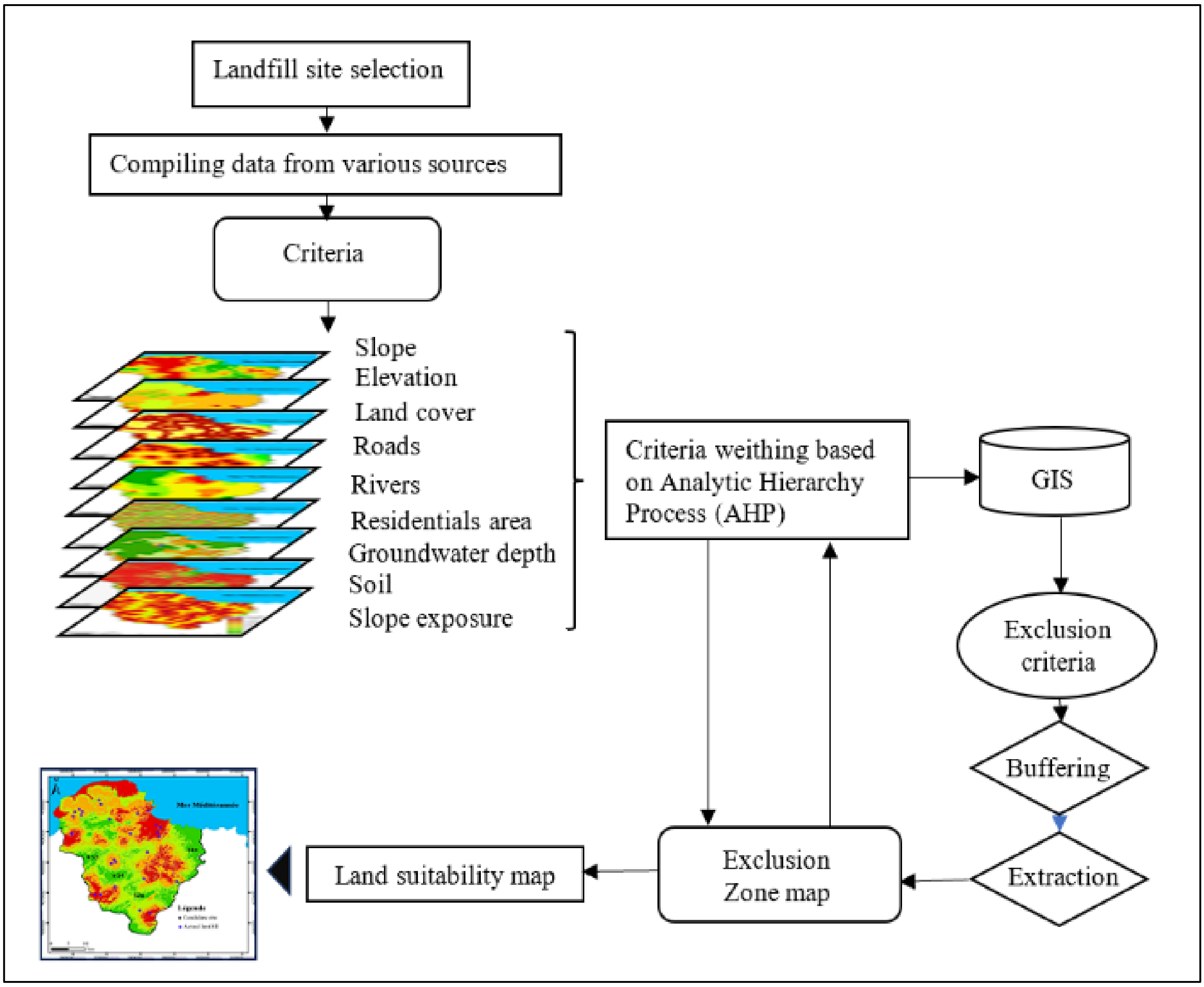


Fig.3. Flowchart of the methodology

2.3. Results and Discussion.

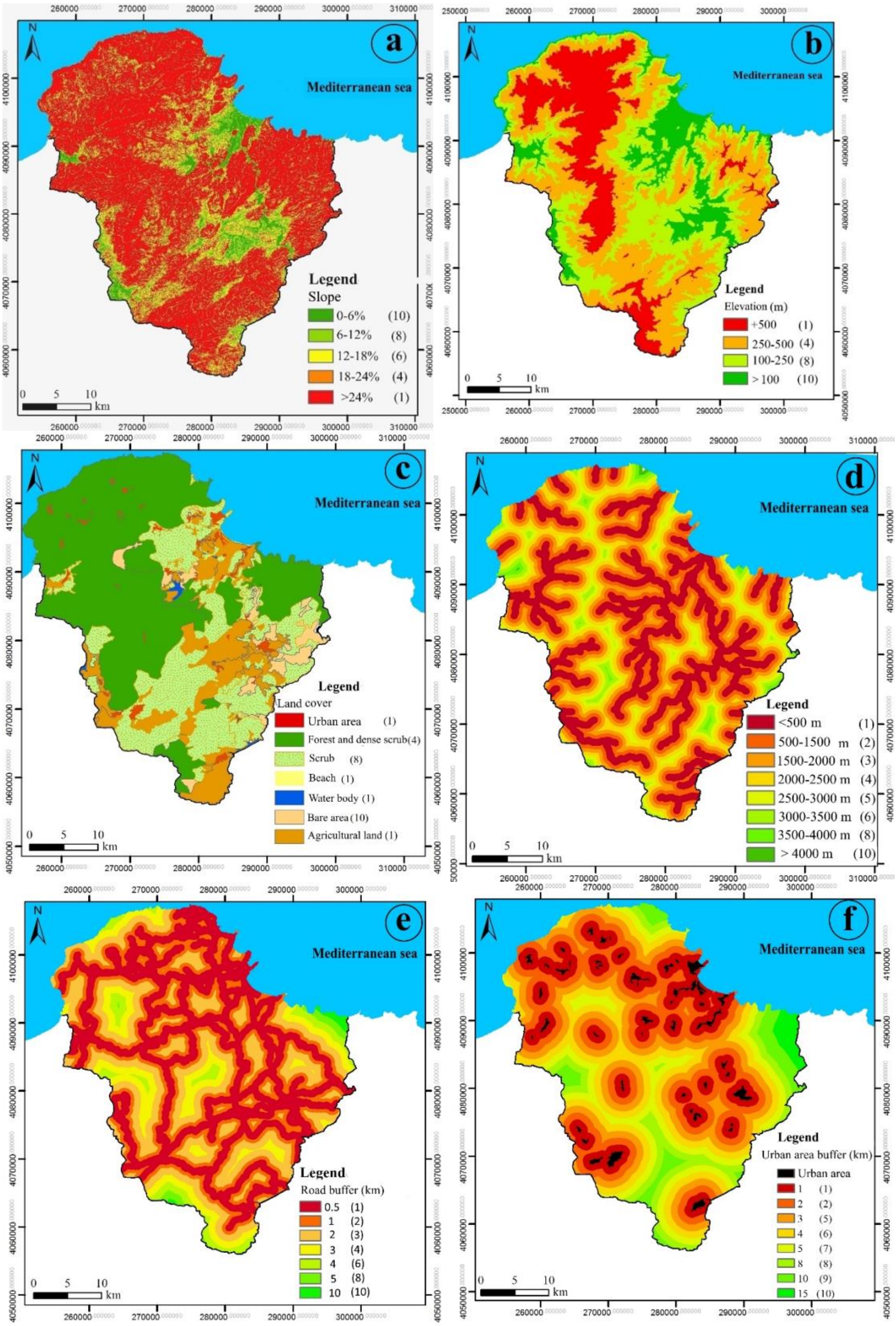
Factor maps and suitability level for evaluating the optimal location of the landfill (Fig. 4) based on the same utility scale with values ranging from 1 to 10 depending on the priorities of the criteria. Different regions become more or less convenient in the overall composite index map.

Slope: Slopes exceeding 24%, as shown in Figure 4a, predominately characterize the Collo Mount area. These steep gradients represent 75% of the entire area. It is worth noting that the low-slope lands located in the east and west. it represents Gentle gradients less than 6%. Accordingly, these areas have been identified as the most suitable for landfill sites. (Ersoy , H., and Bulut , F. 2009).

Elevation: In this study, elevations were classified into four classes, as illustrated in Figure 4b. Elevations ranging from 250 to 500 meters were considered moderately suitable, while elevations exceeding 500 meters were identified as suitable for a landfill site.

Land cover: Collo Mountain is characterized by dense vegetation and small, fertile coastal plains, as shown in Figure 4c. To reduce the risk of forest fires caused by burning waste, it is imperative to position landfills away from areas with plans and dense vegetation. A score of 10 was assigned to unused land, representing as suitability for landfill location, while a score of 1 was allocated to agricultural plains; dense forests and water bodies.

Distance from rivers: In order to attenuate the potential for contamination engendering from landfill sites, the land located within a 500-meter proximity to a river boundary were assigned a score of 1. Conversely, locations situated beyond a 4000-meter distance were assigned a maximum score of 10, as shown in Fig. 4d.


a
Mediterranean sea
Legend
Slope
0-6% (10)
6-12% (8)
12-18% (6)
18-24% (4)
>24% (1)
b
Mediterranean sea
Legend
Elevation (m)
+500 (1)
250-500 (4)
100-250 (8)
> 100 (10)
c
Mediterranean sea
Legend
Land cover
Urban area (1)
Forest and dense scrub(4)
Scrub (8)
Beach (1)
Water body (1)
Bare area (10)
Agricultural land (1)
d
Mediterranean sea
Legend
<500 m (1)
500-1500 m (2)
1500-2000 m (3)
2000-2500 m (4)
2500-3000 m (5)
3000-3500 m (6)
3500-4000 m (8)
> 4000 m (10)
e
Mediterranean sea
Legend
Road buffer (km)
0.5 (1)
1 (2)
2 (3)
3 (4)
4 (6)
5 (8)
10 (10)
f
Mediterranean sea
Legend
Urban area buffer (km)
Urban area
1 (1)
2 (2)
3 (5)
4 (6)
5 (7)
8 (8)
10 (9)
15 (10)

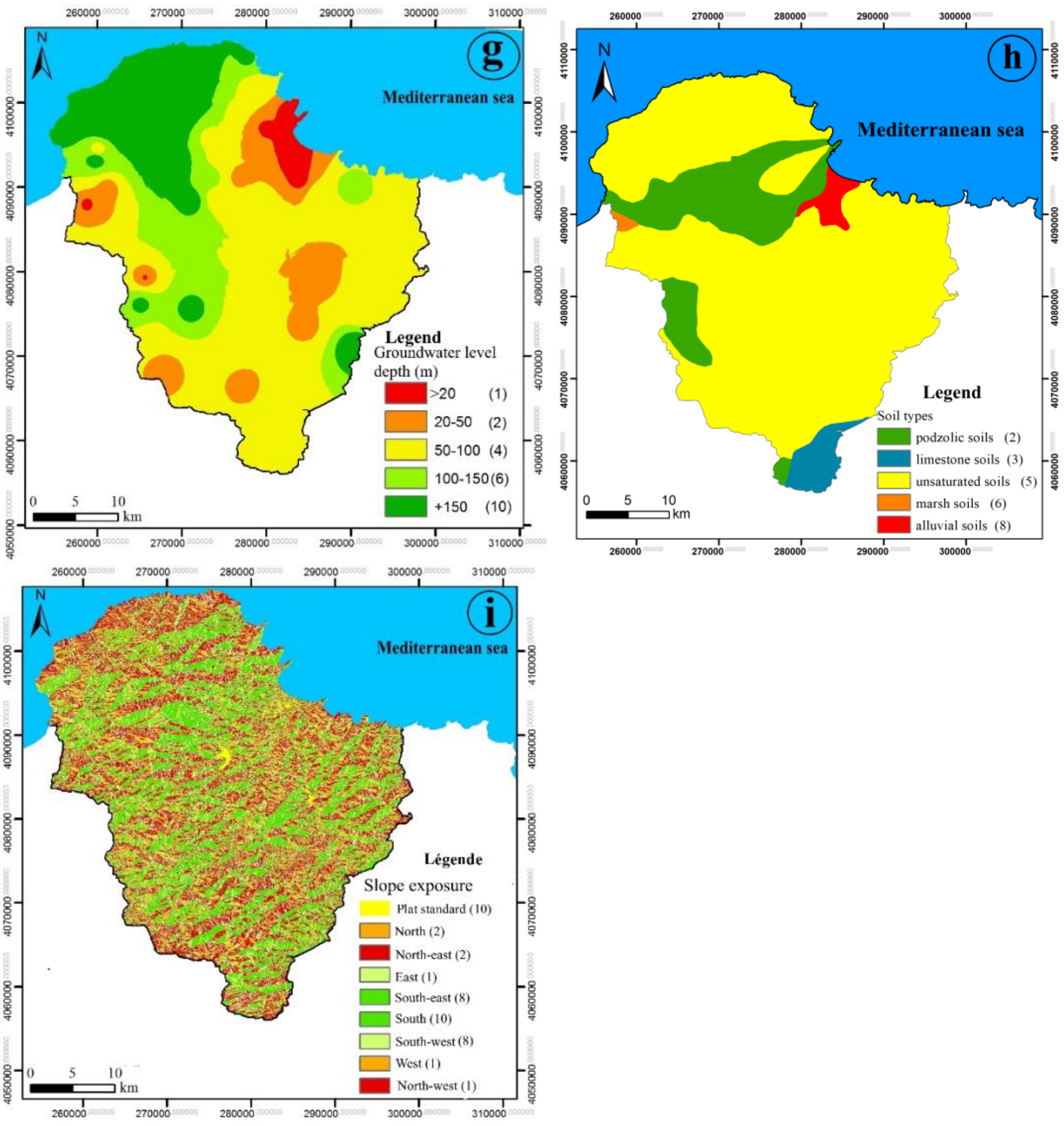


Fig. 4. (a) Slope, (b) Elevation, (c) Land cover, (d) Distance from river, (e) distance from road, (f) Residential area, (g) Groundwater depth, (h) Soil, (i) Slope exposure.

Distance from roads: Numerous researchers advocate for a buffer zone of 1000 meters between a landfill site and the road network, as supported by studies conducted by Al-Hanbali et al. (2017), Baban and Flannagan (1998), Chang et al. (2008), and Delgado et al. (2008). In this study, the classification of buffer zones between roads and landfill sites was established with seven categories, as depicted in Figure 4e. Distances less than 500 m were assigned a grading value of 1, while distances more than 5000 m received a grading value of 10.

Residential areas: The proximity of a landfill to residential areas raises substantial public concerns, encompassing potential issues related to air quality and sensory pollution, particularly olfactory and visual pollution, as identified by Mousavi et al (2022). Given these considerations and the absence of explicit national regulations, it is advisable to refrain from siting landfills within a distance of 5 km to 10 km from residential areas. Furthermore, the challenges associated with siting landfills in coastal mountain regions is exacerbated by the consistent presence of winds, as depicted in Figure 4f. As a result, it recommended maintaining a distance exceeding 10 km from residential areas.

Groundwater depth: Groundwater serves is the primary source of water for activities and drinking purposes in the Collo mount, which presents a high vulnerability to landfill contamination. To safeguard groundwater resources from the influence of waste dumps, it is imperative to located it at a depth of at least

150 meters. A value of 1 is assigned for depths ranging from 0 to 20 meters, with progressively larger values assigned for greater depths (Figure 4g).

Soil lithology: the soil permeability when choosing a location for a landfill to minimize the risk of contamination to the surrounding environment. High permeability soils allow liquids and gases to move more freely through the soil and potentially reach groundwater or surface water sources. The lithological map of the study area shows (Fig. 4h) that the soils are not very permeable except for the coastal plains. The Collo Mountain formed by eruptive rocks. The meticulous assessment of soil permeability holds utmost importance in the strategic selection of a landfill location to effectively mitigate the potential risk of environmental contamination. Soils characterized by high permeability exhibit enhanced fluid and gas mobility, heightening the possibility of reaching groundwater or surface water sources, there by precipitating pollution and other adverse environmental consequences. The lithological map of the study area, delineated in Figure 3h, reveals that the prevailing soils exhibit generally low permeability, with the exception of the coastal zone. Noteworthy is the comprehensive understanding that Collo mount, in its entirety, is predominantly constituted by eruptive rocks.

Slope exposure: The orientation of a slope plays a crucial role in determining the suitability of a landfill site. Slope direction influences factors such as wind patterns, runoff, and erosion, subsequently impacting the stability and long-term viability of the landfill. Generally, it is advisable to position a landfill on slopes that face away from prevailing wind patterns to mitigate the risk of wind-borne debris. Additionally, selecting slopes with effective drainage helps minimize the potential for runoff and erosion. In the study area, the prevailing wind direction is northwest. It is essential to highlight that this prevailing wind direction emphasizes the importance of choosing landfill locations on slopes that face away from the northwest to reduce the risk associated with wind-borne debris and enhance the overall environmental stability of the site.

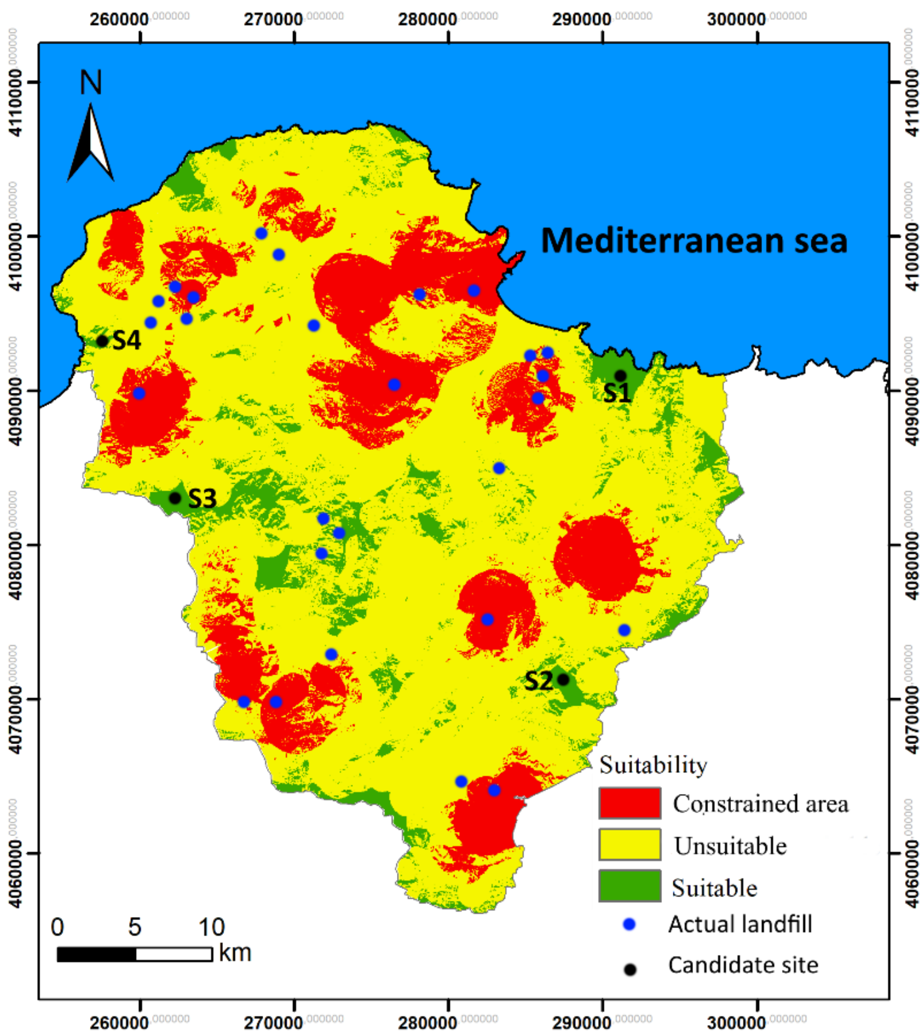


Fig. 5: Landfill suitability map

Finally, the landfill suitability map was developed from the aggregation of standardized criteria maps as depicted in Fig 5. The range of the landfill suitability index in the Collo coastal mountain is close between 1,21 and 7,76. Using the natural threshold method (Jenks). The MSW landfill suitability values of the study area were divided into three categories (Fig. 4): suitable (5,93-7,69), unsuitable (3,72–5,93), and constrained area (1,48–3,72) (table 5).

Table 5.
Classification of landfill potential

Landfill suitability	**Percent (%)**	**Area in (hectares)**	**Area in (km²)**
Constrained area	20,68	17174,29	289,65
Unsuitable	70,95	41049,28	939,13
Suitable	8,36	29524,11	112,22
Total	100	133929.51	1341

Constrained area: it covers 289,65 km^2, which is 20,68% of the study area, its suitability index ranges from 1,48 to 3,72. This area represents exclusion terrain, it includes urban centers, fertile coastal plains, lands with high permeability and potential land for commercial purposes.

Unsuitable area: This area covers 939,13 km^2, accounting for 70,95% of the total study area, with a suitability index ranging from 3,72 to 5,93. The topography is not severely restrictive, but the exploitation of this land is often limited by aesthetic and sensory considerations. This sector is located near urban centers and along major transportation roads and can be seen from these roads and settlements. It is imperative to note that these areas should be strictly avoided.

Suitable area: This area comprises 8.36% of the total mountainous region, covering 112,22 km^2, with indices ranging from 5,93 to 7,69. However, although theoretical and technical considerations show optimal conditions for accommodating landfills, visiting this land category revealed certain constraints that impede their utilization. It worth to noting, considerable distances from residential areas, isolating by natural barriers such as steep slopes. Accessing these lands requires considerable financial investment and long time. This challenge is worsened by the financial restrictions and limited human, material, and technical resources. In Algeria , the most of mountainous municipalities are categorized as underdeveloped. Furthermore, these areas serve as extensive grazing lands for rural neighbor communities, this can raise the potential social conflicts between local residents, stokeholds and waste management personnel. Additionally, the complex issue of land ownership in mountainous regions of Algeria, due to the lack of strategic planning and resource allocation, can further complicate the selection process for municipal landfill sites. This situation is largely attributed to the high costs involved, as well as the technical, material, and human resources required. To overcome these challenges, based on their accessibility from urban centers, absence of real conflicts associated with the land use, four alternative landfill sites (S1, S2, S3, and S4) are proposed.

The summary map of Optimal Landfill Site Selection highlights a significant finding: the majority of illegal landfills (16 out of 20) are situated in unsuitable areas, including urban and agricultural regions (Figure 5). Conversely, the map indicates the presence of underused lands that could potentially accommodate new landfill projects or receive the relocation of existing landfills from non-suitable locations. This discrepancy is predominantly attributable to a paucity of localized land data and the absence of advanced decision-support tools, which adversely affects the identification of optimal landfill sites in arrangement with environmental standards.

In these sensitive areas, to optimize efficiency and ensure precise outcomes, it is advisable to extend the assessment criteria to include an inclusive range of dimensions: social factors (such as public acceptance and land ownership), natural conditions, economic variables (including transportation costs, access time, and financial incentives), and environmental considerations. Furthermore, establishing a specialized organization dedicated to surveying and collecting statistical data related to Municipal Solid Waste (MSW) is estimated essential to address the substantial information gap. These results would signify a departure from primitive decision-making processes reliant on random negotiation or arbitration, towards adopting a scientific approach involving various methods and techniques as GPS, GIS, and Remote Sensing (RS), fostering a more resilient decision-making process, particularly in the challenging context of selecting landfill sites in mountainous coastal areas.

4. Conclusions.

This research aims to produce a cartographic model for suitable landfill placement in mountainous regions, serving as a decision-making tool. The study integrates various methods and techniques, including territorial diagnostics, the Analytical Hierarchy Process (AHP) with multiple-criteria evaluation (MCE), and Geographic Information System (GIS) technologies. This synergy allows for more effective and accurate results tailored to the specific characteristics of coastal mountainous areas. The approach was applied to the Collo Mountain in the northwest of Skikda state, Algeria.

The final mapping results reveal that approximately 70.90% of the study area is unsuitable for landfill placement. Additionally, a second category of land offers no potential opportunities for landfill sites, while only 8.36% of the total surface area is classified as suitable. However, effective decision-making in mountainous regions requires a comprehensive consideration of natural, environmental, economic, and social characteristics as key criteria in future studies. Appropriate decision-making also necessitates the development of legal frameworks for solid waste management, clarifying stakeholder responsibilities and establishing deterrent penalties for violations.

In conclusion, the results of this study, represents a pioneering effort can serve as a scientific approach support for future research interested the management solid waste in coastal mountainous areas in Algeria. This study has contributed to develop a fundamental database benchmarks and indicators considerate as paths not only within Algeria costal monotonous territories but also in similar geographical contexts.

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