

Sitting Management Solid Waste Landfill Combining Geographic Information System and Analytic Hierarchy Process: Ajdir, Morocco



Yassir Bouroumine, Lahcen Bahi, Latifa Oquadif, Ahmed Ait Errouhi

Abstract: *The Amount Of Household Waste Produced By The Mainly Urban Population In Morocco Continues To Increase Year After Year. Morocco Is Thus Confronted With The Problems Of Storage And Disposal Of This Waste, Which Are Composed Largely Of Organic Matter, Bio-Waste. In The Recent Past, These Wastes Have Been Buried In Wild Dumps Or In Old Quarries Located In Areas Close To Urban Centers Without Any Treatment Or Control. This Can Constitute Significant Risks Both For Public Health And The Environment And For The Future Of The Socio-Economic Activities Of The Country. Determination Of Proper Landfill Site Involves Multiple Disciplines. The Landfills Contain A Large Quantity Of Solid Waste. The Management Of Solid Waste (Msw) Necessitates The Involvement Of Different Stakeholders. In This Paper, We Aim To Determine The Appropriate Landfill Site At The Level Of The Municipality Of Ajdir In The Province Of Al Hoceima Morocco. We Take Into Consideration The Opinions Of The Stakeholders. Based On Environmental, Socio-Cultural And Economic Criteria. For This Purpose, We Used In This Paper Two Multi-Criteria Analysis Methods. The Geographic Information System (Gis) And The Analytic Hierarchy Process (Ahp). First, We Created The Database Gis Related To The Study Area. Next, This Data Was Processed To Determine The Landfill Sites That Respect The Stakeholder's Priorities And Exclusion Criteria. Then, A Multi-Criteria Analysis By Ahp Method Was Carried Out To Offer Different Visual Representations Of The Possible Solutions Of The Site's Choice, Especially The Multi-Scale, Multi-Theme Maps And The Construction Of The Free Zones Which Can Shelter A Landfill Which Will Contribute To The Evaluation Of These Criteria While Integrating The Stakeholders Who Assisted In The Rationalization Of The Sub-Criteria's Judgments Involved In The Study.*

Key words: Landfill, AHP, GIS, management solid waste, Al Hoceima

I. INTRODUCTION

Solid waste management represents a very serious subject that should not be ignored. It has a dreadful impact on the environment and poses risks to its components.

It also generates social, cultural, political and economic problems [1], [2]. MSW takes into account reuse, recycling, energy production, incineration and landfill [3].

Currently burying solid waste is the most widespread and appropriate solution. This method is more applied, due to the simplicity of the process and the low cost of treatment [4]. Other methods have complexities in the process and require qualifications of staff.

The determination of a proper landfill site in a region is complicated. It requires a detailed evaluation process that takes into account several criteria [5]. Those criteria's can change from a region to another. To solve this problem or minimize its side-effects, the multi-criteria decision analysis (MCDA) method is deployed. Each one follows particular rules and principles [6]. A sitting MSW landfill is a spatial multi-criteria decision analysis (SMCDA) for which both Geographical Information System (GIS) and MCDA methods should be used [7].

Among MCE techniques, the Analytic Hierarchy Process (AHP) is one of the most common analytical techniques. It is used for complex decision-making problems. Also, because of its agility and simplicity. It helps decision-makers discern which is best suited to their goal and problem design. It provides a comprehensive and rational framework for structuring a decision problem. It represents and quantifies its elements to link these elements to the overall objectives and to evaluate alternative solutions [8].

In Morocco, as the majority of developing countries, determination of the right landfill site is still considered a challenging matter. Given the nature of waste. The inconvenience of the landfill. Also, the definition and signification of a landfill to decision-makers and the population. The landfill site of Al Hoceima province spreads over an area of 43 hectares. This site currently receives around 100 tons of waste per day. This number does not stop increasing over the years. This landfill site has been made operational in 2008, and has been conceived for 15 years end-life. After 5 years from now, the decision-makers will be forced to find the appropriate area to allocate a new landfill site. The new site must meet several environmental, social and cultural criteria. Taking into consideration the standards and legislative distances implemented. The purpose of this paper is to determine the best suitable landfill site in the municipality of Ajdir, Al Hoceima, Morocco.

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* Correspondence Author

Yassir Bouroumine*, Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

Lahcen BAHI, Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

Latifa OUADIF, Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

Ahmed Ait Errouhi, Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

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This study proposed in this paper should respect the environmental, social and cultural criteria. It has to take into account the economic aspect. Also, it should take into consideration the opinions of the different stakeholders. Like: policymakers, politicians, experts, population and researchers. This work is based on the combination of the GIS and AHP multi-criteria analysis method. To determine a proper landfill site, that meets the criteria of choice, and takes into account the opinion of the stakeholders.

II. STUDY AREA

The province of Al Hoceima is located in the region of Tangier - Tetouan - Al Hoceima in northern Morocco. It covers an area of 3,550 km². This area represents 23.5% of the region. This province is limited to the North by the Mediterranean Sea. To the East by the province of Nador. The provinces of Taounate and Taza to the South and the province of Chefchaouen to the West.

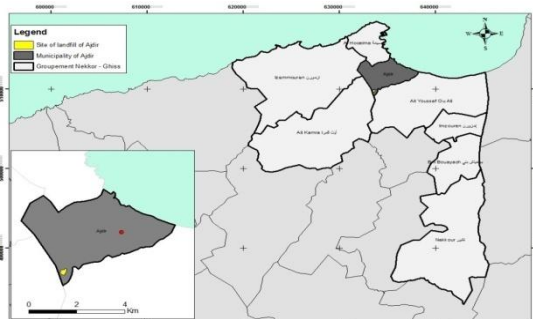


Figure 1 : Administrative situation of study area

At the current state, al hoceima's waste is placed in a controlled class i inter-municipal landfill. This landfill site has been in operation since 2008 and is located in the city of ajdir (16 Km south from Al Hoceima), with an area of 43 hectares. This landfill currently receives and assimilates the waste of the intercommunal group neckor - ghiss. It is composed of eight municipalities: al hoceima, ajdir, ait youssef ouali, ait kamra, beni bouayach, imzouren, izemmouren and neckor.

Annually, this landfill receives waste, up to 36,000 tons. That continues to increase over the years. The waste received is directly buried in bins and lockers, without any sorting at the entrance or at the source.

The peak of waste accumulated per day had been reached in summer due to the increase of population in this period. The waste accumulated reaches an average of 190 tons per day.

III. METHODS AND MATERIALS

3.1. Data used

To determine the landfill site, it is essential to use various data. This data includes geology, pedology, topography, land use, road network, hydrological network, tablecloths etc. In our case study, we used 1 / 50000 topographic and geological maps of Al Hoceima province to extract data on green spaces, rivers and thalwegs, geological data, faults and seismic hazard zones. Official population and housing censuses, used land, housing and road distribution by class, from the satellite images and the topographic map. The Digital Terrain Model of the study area to define the

topography of the study area, coordinates and data relating to the wells, boreholes and cemeteries.

In order to process and analyze these data, we developed a digitalized database of the GIS about the study area. That will allow treatment and combination according to need and desired outcome.

3.2. Exclusion criteria

Table.2 illustrates the processed data. That is related to various exclusion criteria. Also, to the minimum distances to be respected for a landfill implementation in the study area according to national and international standards, legislative requirements as well as questionnaires prepared and completed by waste specialists and parties concerned. The performed analysis allowed us to define 10 sub criteria. They belong to the two families of criteria: Environmental and Socio-cultural.

Table 2: Exclusion criteria

Criteria	Distance
Hydrology	500 m from rivers
	100 m from talwegs
Geology	1 km from a geological risk area
Lithology	Sites must not be on permeable lithologic layer
Forests	Sites must be at a distance of more than 300 m from forests
Slope	Slope lower than 10%
Littoral	2km of littoral
Roads	500 m of main roads
Agglomerati on	500 m of residential areas
Wind direction	downward of residential areas considering to prominent wind direction
Historical site	500 m of historical site

The exclusion criteria define the minimum distances to consider between the landfill site and other areas. According to the table established. The landfill site must be at a minimum distance of 500 m from habitable areas, minimum distance of 2 km from the coastline, and 500 m from rivers and 100 m from thalwegs.

3.3. Geographic Information System

GIS is often used for landfill sites selection and reduces the time and cost of site selection. Also, it provides a digital data bank for long-term monitoring of the site. GIS helps to maintain the data, to facilitate collection operations, customer service, analysis of optimal locations for transfer stations, planning of routes for waste transportation to transfer stations or to landfills, and the long-term monitoring of landfills [11]. To exploit the study area collected data. It was assembled and compiled in digital format using GIS.

GIS also simplifies in applying the exclusion criteria for each component, according to the previous table using a buffer tool. This characteristic helped defining the landfill site in the study area. While respecting the minimum distances that must be respected.

3.4. Rating of criteria

In order to take into consideration the opinions of stakeholders. They were invited to answer a questionnaire. Give their comparison between multiple criterions as shown in the table 3.

The experts are free to decide and mark the criterion they individually think is comparatively the most important. They have to mark their preference according to the 9 Likert type scale [12].

Participants can weigh each element against each other in each level. Each level is related to the levels above and below it. And the entire scheme is mathematically tied together.

Wi	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Wj
when: Wi to Wj = 1, they are of equal importance Wi to Wj = 3, Wi is moderately favored Wi to Wj = 5, Wi is strongly favored Wi to Wj = 7, Wi is clearly dominant Wi to Wj = 9, Wi is super dominant As such when Wi to Wj = 3, it implies that Wj to Wi = 1/3																		

3.5. Analytic Hierarchy Process (AHP)

In the work [6], the authors introduced the Analytic hierarchy process (AHP). This method is very effective in selecting alternatives [13] [14] [15].

AHP is an analytical method used to explicitly rank tangible and intangible criteria to select priorities. The process involves structuring the problem to multi levels of criteria and alternatives. Once the hierarchy is established. The pair-wise comparison matrix of each element in each level is constructed. The AHP method allows group decision-making. The group members can use their experience, values and knowledge. To break down the problem into a hierarchal AHP steps.

To facilitate AHP calculations for n criteria. We used the Android Application we developed. Considering all calculation steps described below. The application has been made available for download on play-store under the name (AHP & TOPSIS decision maker).

The matrix of the ratios of all weights

$$W=[W_i/W_j]=\begin{pmatrix} W_1/W_1 & \dots & W_1/W_n \\ \vdots & \ddots & \vdots \\ W_n/W_1 & \dots & W_n/W_n \end{pmatrix} \quad (1)$$

With n : the number of compared alternative
W1, Wn : their current weights

The matrix of pair-wise comparisons A=[aij] represents the intensities of the stakeholders. They are usually chosen from a given scale (1/9,1/7,...,7,9). Given n alternatives. The decision maker compares pairs of alternatives for all the possible pairs. A comparison matrix A is obtained. Where the element aij shows the preference weight of Ai obtained by comparison with Aj [16]

$$A=[a_{ij}]=\begin{pmatrix} 1 & a_{1j} & a_{1n} \\ 1/a_{1j} & 1 & a_{in} \\ 1/a_{1n} & 1/a_{in} & 1 \end{pmatrix} \quad (2)$$

The aij elements estimate the ratios wi/wj. Where w is the vector of current weights of the alternative.

$$Aw = \lambda_{max} w \quad (3)$$

With λmax: eigen value, [17].

The consistency index (CI) as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

Consistency Ratio (CR) measures the consistent judgment that is relative to large samples of purely random judgments.

If $CR \leq 0.1$ for matrix A. The assessments of the relative importance of the criteria are considered acceptable. If the CR is exceeds 0.1. They are considered unacceptable. We need to consider revising our subjective judgments (the exercise be repeated). The authors in [16] defined the consistency ratio (CR) as:

$$CR = \frac{CI}{RI} \quad (5)$$

With RI, the random index: consistency index for the n row matrices of randomly generated comparisons in pairs.

$$RI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

With λmax, [18]
 $\lambda_{max} = (2.7699 * n) - 4.3513 \quad (7)$

IV. RESULTS AND DISCUSSIONS

4.1. Extraction free areas

The input data of GIS database consists of environmental and social criteria. This data includes the hydrographic, road, buildings, green spaces and other components. We applied the exclusion criteria given in (Table.2). To define the free spaces (buffer zones) for each sub criterion. This allowed defining the exclusion zones and the free spaces for each criterion illustrated in Figure 2. After obtaining the exclusion zones for each criterion. We proceeded to the superposition of the various maps to be able to define the most suitable sites. By comparing the exclusion criteria proposed to shelter a landfill in the zone of our study. Fig.6 and Fig.7 show the results of this step.

This step based on GIS allowed us to select 3 favorable sites. That can shelter a landfill site in the municipality of Ajdir.

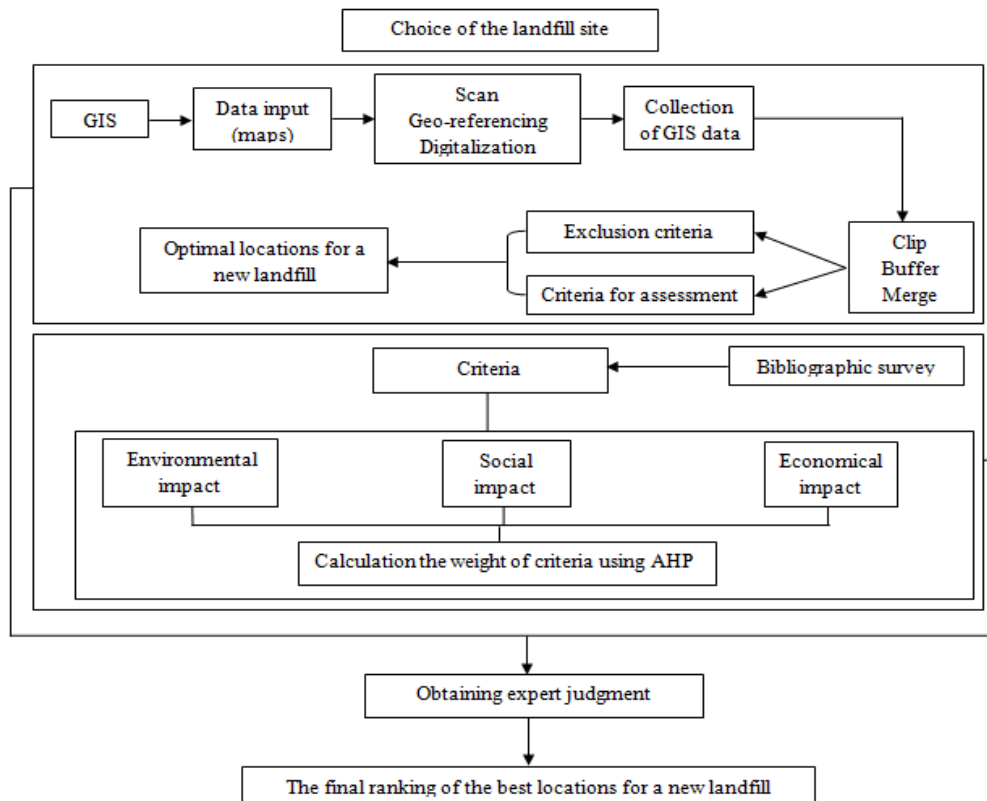


Figure 2 : The flow chart illustrating the methodology used for selection the best landfill's sites [7]

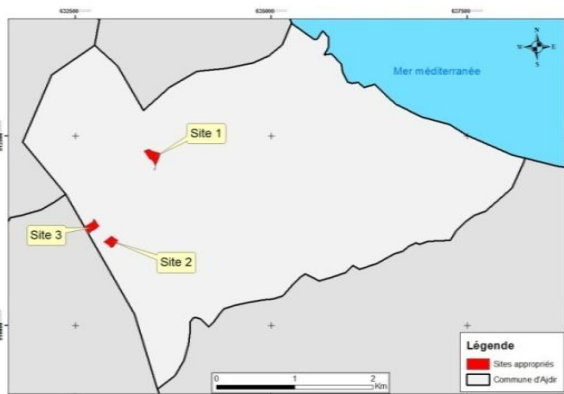


Figure 3 : Free areas and sites

4.2. Criteria Evaluation

The suitable sites obtained to shelter a landfill site have different characteristics, advantages and disadvantages in other areas. Meanwhile, to classify the sites obtained between favorable and least favorable, the sites were compared using the AHP multi-criteria analysis method.

Before using this comparison. It was essential to make a comparison between the environmental, economic and socio-cultural criteria. To have a comparison basis. And to select the criterion that must be favored in choosing our site.

To do this, we consulted the stakeholders: decision-makers, elected officials, experts, researchers and the local population. To weigh the criteria environment (envir), economy (eco) and socio-cultural (socio-cult) and compare them. The Table.4 presents the results of this comparison.

Table 4: Matrix for comparing and scoring criteria

Criteria	Envir	Eco	Socio-cult	Weight
Envir	1	3	7	0.649
Eco	1/3	1	5	0.279
Socio-cult	1/7	1/5	1	0.072

$$CR = 0.068 (6.8\%)$$

As shown in the Table.4. The environmental criterion is the most important criterion for stakeholders. This criterion weight 0.649. Followed by the economic criterion 0.279 and socio-cultural of 0.072.

4.3. Classification appropriate sites

Based on the obtained results. We compared the sites for each criterion. To score and rank them from most favorable to least unfavorable. By referring to the results of the previous table. Table.5 presents the results of this comparison.

Table 5: Matrix for comparing sites for each criterion

Criteria	Site	S1	S2	S3	Weight	C.R
Envir	S1	1	5	3	0.63	0.09
	S2	1/5	1	1/4	0.09	
	S3	1/3	4	1	0.28	
Eco	S1	1	4	7	0.69	0.129
	S2	1/4	1	5	0.24	
	S3	1/7	1/5	1	0.07	
Socio-cult	S1	1	1/5	1/9	0.06	0.03
	S2	5	1	1/3	0.27	
	S3	9	3	1	0.67	

From Table.5, for the environmental criterion, the site 1 is the most appropriate to shelter a landfill site. Its weight is 0.63, followed by site 3.

For the economic criterion, site 1 is the most suitable with a weight of 0.69 followed by site 2. For this criterion, we see that the CR exceeds 0.1. This can be accepted since the difference is small. Finally, site 3 is the most appropriate for the socio-cultural criterion and its weight is 0.67 followed by site 2

Table 6: Summary of the results

Sites	Envir	Eco	Socio-cult
S1	0.63	0.69	0.06
S2	0.09	0.24	0.27
S3	0.28	0.07	0.67
Weight	0.649	0.279	0.072

Table.6 summarizes the results of the comparison of the three criteria in our case study. The next phase consists of multiplying the weights of the sites for each criterion and the weight of the criteria that was obtained in Table 7. To define the most appropriate site. Taking into account the opinion of the stakeholders and the results of the GIS.

Table 7: Calculation of the weights of the sites selected in relation to the criteria

Sites	Envir	Eco	Socio-cult	Results
S1	0.409	0.193	0.004	0.606
S2	0.058	0.067	0.019	0.145
S3	0.182	0.020	0.048	0.249

The multiplication of weights allowed us to rank the three sites from most favorable to unfavorable. Site 1 was judged to be the most appropriate site for a landfill in Ajdir. Taking into account the exclusion criteria and stakeholder opinions. The overall result weight of site 1 is 0.606. Followed by site 3 with a weight of 0.249. Then site 2 as the least favorable with a weight of 0.145.

V. CONCLUSION

The present paper illustrated a methodology to select the best waste landfill site based on combining Analytic Hierarchy Process (AHP) with GIS. The methodology was based on environmental, economical and socio-cultural criteria. Also, the opinion of politicians, planners and decision makers. GIS was employed to create data base including different components. Geology, lithology, hydrology, roads, slope, littoral, forests, wind direction, agglomeration and historical site. Also, GIS was used to apply exclusion criteria and define free areas that respect the minimum distances. That helped narrowing the study area. A scoring system was employed to criteria. To define the more important criteria for different decision makers. Also, the sites defined by GIS were ranked for each criterion using a scale that ranges from 0 to 10. The methodology described in this paper is considered an approach to landfill selection. Based on opinions and different criteria considered by stakeholders.

The combination of methods used in our study allowed us to:

- Select 3 sites that meet the exclusion distances applied.
 - Rank the criteria by priority according to stakeholders.
- Where, the environmental criterion has been classified as

the most important. Followed by the economy and socio-cultural.

- Compare the selected sites for each criterion. To conclude the results, the site 1 could be considered the most favorable to house a landfill site in the study area.

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AUTHORS PROFILE

Yassir Bouroumine, Research engineer Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

Lahcen Bahi, Director Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

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Latifa Ouadif, Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco

Ahmed Ait Errouhi Laboratory of Applied Geophysics, Geotechnics, Geology of Engineers and Environment, Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco