IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 18, Issue 4 Ser. 1 (April 2024), PP 49-60
www.iosrjournals.org

Use Of A Multi-Criteria Approach For The Selection Of Controlled Landfill Site In Morocco: Case Of The Errachidia

Mohammed Saddik[1], Nabil Dahhou[2] , Soufiyan Bahetta[2]
1-Faculty Of Sciences, Earth Sciences Department, El Jadida, Morocco
2-Faculty Of Economics And Management, Lemo, Kénitra, Morocco

Abstract:
In the present work, we propose a multi-criteria approach for the selection of landfill sites, considering the criteria of exclusion and assessment. These criteria are based on data related to several disciplines such as geology, hydrology and hydrogeology, biodiversity, urban planning, topography, finance, etc. The approach adopted is based on the succession of three steps: (1) systematic inventory of the environment and associated activities, (2) identification of open areas and (3) selection of sites. This work allowed us to select five (5) potential landfill sites for the Errachidia region. The standardization of this approach with the objective of its application on various other areas constitutes a tool for sustainable development and preservation of the Environment.
Keywords: *multi-criteria approach, solid waste, controlled landfill, rating system, waste management.*

Date of Submission: 04-04-2024 Date of Acceptance: 14-04-2024

I. Introduction

Waste management is closely linked to the development factors of the "Consumer Society", the main factors involved being the rapid growth of urban and rural populations; the evolution of consumption, production and eating habits. These factors have led to an explosion in the amount of waste produced, making waste management a major global issue that raises numerous challenges in terms of natural resource protection, public health, and political and economic issues[1].

This global concern was raised at the Rio Conference in 1992, whose resolutions adopted in "Agenda 21", were complemented by those adopted in the action plan of the Johannesburg Summit (2002), particularly with regard to the implementation of waste management systems, giving priority to the prevention of waste and the minimization of the volume of waste, and to environmentally friendly disposal facilities.

In Morocco, the increasing production of waste has caused the multiplication of large unauthorized dumps everywhere (more than 300 unauthorized dumps), the negative repercussions of this situation on natural resources, public health and on the budget of local communities, have been highlighted[2].

Among the problems of household waste management in Morocco, is to find the best landfill site for which favorable conditions are met regarding the constraints posed by environmental aspects (water, soil, air) and economic aspects (operating cost, development cost and cost of land) and social (the distance of sites from urban areas, living environment, aesthetics).

In this context, the present work presents a multidisciplinary approach as a decision support tool in the selection of suitable sites for household waste storage. The methodology adopted is based on a multi-criteria analysis. The criteria are of two types: exclusion criteria and assessment criteria. These criteria are based on data from several disciplines such as geology, hydrology and hydrogeology, biodiversity, urban planning, topography, finance, etc. After integration of all the data on the study area and the exclusion criteria (not favourable for the implementation of a landfill) in the Geographic Information System, suitable sites were pre-selected.

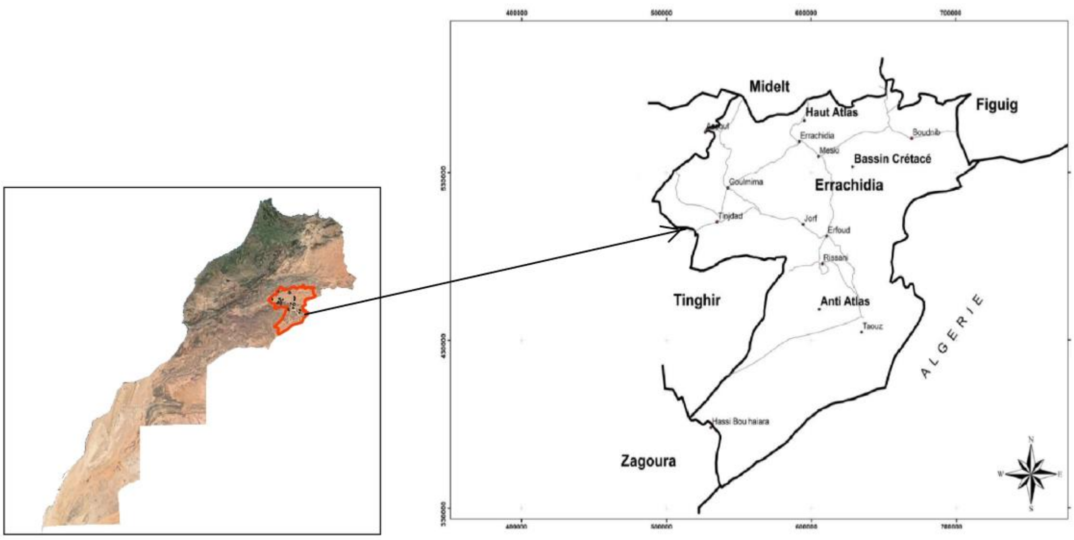
Then, a multi-criteria analysis (assessment criteria) was applied to each of the pre-selected sites retained. This is based on the identification of selection criteria allowing the realisation of a ranking based on a score (the site with the highest score is the best ranked).

Presentation Of The Study Area

The province of Errachidia is an integral part of the Region of Draa-Tafilalet, it covers an area of 42 852 km ² and currently has 29 municipalities

.

Geographically, the province of Errachidia is a geographical area of Tafilalet located in the center / southeast of Morocco in a semi-desert area. It is limited to the north by the High Atlas; to the east and south by Algeria; and to the west by the foothills of the Anti-Atlas.



Système de projection cartographique : Projection Conique Conforme de Lambert (Maroc Zone 1) ;

Figure 1: Study Area

Geologically, the geological outcrops of the territory of the province are located in the South-Atlasic corridor formed essentially by Plio-Quaternary, Cretaceous, Jurassic, Cambro-Ordovician terrains.

On the hydrological level, the two watersheds of Ziz and Ghéris are part of the Errachidia basin which extends from the southern slopes of the Eastern High Atlas in the North to the Taouz region in the South.

The hydrographic network is composed of several wadis of which the most important are : the Ziz, the Ghris and the Guir. These wadis originate in the southern flank of the High Atlas and flow towards the south and east sometimes transversally to the general orientation of the relief.

The hydrogeological basin is composed of the following main aquifers:
- The shallow water tables located along the valleys of Guir, Ghéris and Ziz;
- The shallow and deep aquifers of the Cretaceous basin of Errachidia - Boudnib;
- The deep aquifers of the High Atlas.

The province of Errachidia includes three main sensitive environments in terms of biodiversity[3]. These are:
- The SBEI of El Kheng also called "Aferdou gazelle reserve" is located 15 km west of the city of Errachidia;
- The SBEI of Merzouga also has the status of a BirdLife International classified site;
- The Oases of Tafilalet classified RAMSAR.

To date, the province of Errachidia has no operational controlled landfill, the amount of household waste produced annually amounts to 78 400 tons in 2019[4].

II. Materials And Methods

Principles of the approach

The choice of landfill sites is an operation that must be carried out with care, in order to minimize the impact on the environment and optimize the investment and operating costs of the landfill.

The methodology adopted for the choice of landfill sites in Errachidia province consists in finding the best site for which favorable conditions are met with respect to the constraints posed by environmental aspects (water, soil, air) and economic aspects (operating cost, development cost and land cost) and social aspects (distance of the sites from urban areas, living environment, aesthetics)

To do this, it is first necessary to delimit the study area and identify a "free surface" that does not contain exclusionary elements: physical, biological or human vulnerable to the negative impacts of the establishment of a landfill. Thus, it is necessary to define these exclusion elements in the study area, to each element will be assigned a safety perimeter that constitutes an area considered inappropriate and within which the establishment of a landfill will produce significant negative impacts on the environmental, economic and social aspect.

In a second step, a more detailed study of the "free surface", which is the result of the first step, was carried out and the different sites selected were evaluated according to the preference criteria. More specifically, this approach is based on the principle of the Analytic Hierarchy Process (AHP) method developed by Saaty[5]. This is a multi-criteria analysis that combines environmental, financial and technical selection factors and ranks their respective scores to protect the environment and reduce financial costs.

Description of the adopted Approach

Step 1: Multidisciplinary diagnosis of the study area.

In a first step, the study area was delimited, then a systematic inventory was made of the physical, biological and human characteristics of the study area, likely to be impacted by the implantation of the household waste dump[6].

Step 2: Delimitation of exclusion zones.

The information collected on the characteristics of the study area, are plotted on thematic maps in which a safety or exclusion radius (Table 1) [7]–[12] is given to each parameter that may create conflicts: environmental, social and economic due to the installation of a household waste landfill.

The exclusion of areas is based on the respect of a corresponding safety radius (SR). The themes and the safety radii applied are presented in Table 1 below and are modulated according to the importance of each element: environmental, economic, and social to be protected[13].

Table 1: the exclusion criteria and their corresponding safety radius

Exclusion Criteria	Safety Radius
1. Geology	
• **Fault zone**	300 m
• **Karst zone**	300 m
2. Water	
• **Catchment for drinking water supply**	2000 m
• **Private wells**	500 m
• **Flooding areas or marshes**	300 m
• **Main wadis and their 1st order Tributaries**	300 m
3. Agriculture	
• **Traditional irrigation perimeters**	300 m
• **Irrigated perimeters with important infrastructures**	500 m
• **Irrigated perimeters with planned infrastructures**	500 m
• **Traditional irrigation perimeters**	300 m
4. *Forest and natural reserves*	
• **Forest reserves (cork oak, cedar and pine)**	300 m
• **Natural parks**	1000 m
5. Socio-economic and cultural	
• **Site of worship**	500 m
• **Agglomeration**	500 m
• **Isolated settlements**	300 m
• **Paves roads**	300 m
• **Gas\Pipeline**	300 m
• **Sites of historical interest**	500 m

NB: The safety radii given to each parameter are defined in accordance with the landfill site screening guide established by the Environmental Management and Protection Program-GIZ (EMPP-GIZ) , these criteria are at this stage of equal importance.

Step 3: Delineation of open areas.

The previously developed thematic maps are overlaid and the intersection of the exclusion zones will result in free areas that are provisionally considered suitable for a waste disposal site after excluding the conflicting parameters. All the identified free areas were pre-selected within a radius of 40 km from the waste tonnage center of gravity of each municipality, in order to reduce the cost of waste transportation.

Step 4: Analysis of free surfaces and determination of provisionally suitable sites

After the exclusion of unsuitable areas for a landfill and the development of the open space map, the identified land was further analyzed to identify the most suitable sites for a landfill. This determination is based on the following criteria:

- The proximity of the dwellings (new situation in relation to the topographic funds used);
- The proximity of the main roads ;
- Hilly terrain, making the development and access to the site impossible.

This first screening allowed us to eliminate several sites, the shortlisted sites will be subject to a multi-criteria analysis.

Step 5: Selection of favorable sites.

A multi-criteria analysis was applied to each of the shortlisted sites selected. This is based on the identification of selection criteria allowing for a ranking based on a score, with the site with the highest score being the best ranked.

All of the site selection criteria and their corresponding weightings are shown in Table 2 below. These weightings are sufficiently objective as they give importance to water resources, soil, population, etc. Only landscape aesthetics is under-ranked in relation to the remaining factors. The weights assigned to water, habitat, soil, etc. are of the same order of magnitude.

Table 2: the site selection criteria and their corresponding weightings

Source of conflict	***Primary assessment***	***Secondary assessment***	***Max.sum of possible point***
1.water	***24***		***120***
1.1 Surface water		***12***	
1.2 wells and springs		***12***	
2.Agriculture	***20***		***100***
2.1 Exploitation of the soil		***10***	
2.2Agricultural Development		***10***	
3. Accessibility	***18***		***90***
3.1Connection to the main road networks		***6***	
3.2Condition of the tracks		***5***	
3.3Transit through urban areas		***7***	
4.Housing and infrastructure	***16***		***80***
4.1 Noise and odor nuisance		***6***	
4.2 Distance to housing		***10***	
5.Landscape	***8***		***40***
5.1Panorama		***8***	
6.Geology and morphology	***14***		***70***
6.1 Geology		***6***	
6.2 Morphology		***8***	
Total	***100***	***100%***	

III. Results

Multidisciplinary diagnosis of the study area and delineation of exclusion zones

The first cartographic operation consists in the production of thematic maps of the elements (of exclusion) of the physical, biological and human environment, likely to be negatively impacted by the establishment of a landfill of household waste (map 1: Agriculture, map 2: Groundwater, map 3: Agglomerations, map 4: surface water, map 5: protected Area). This operation allowed the elaboration of the exclusion zones.

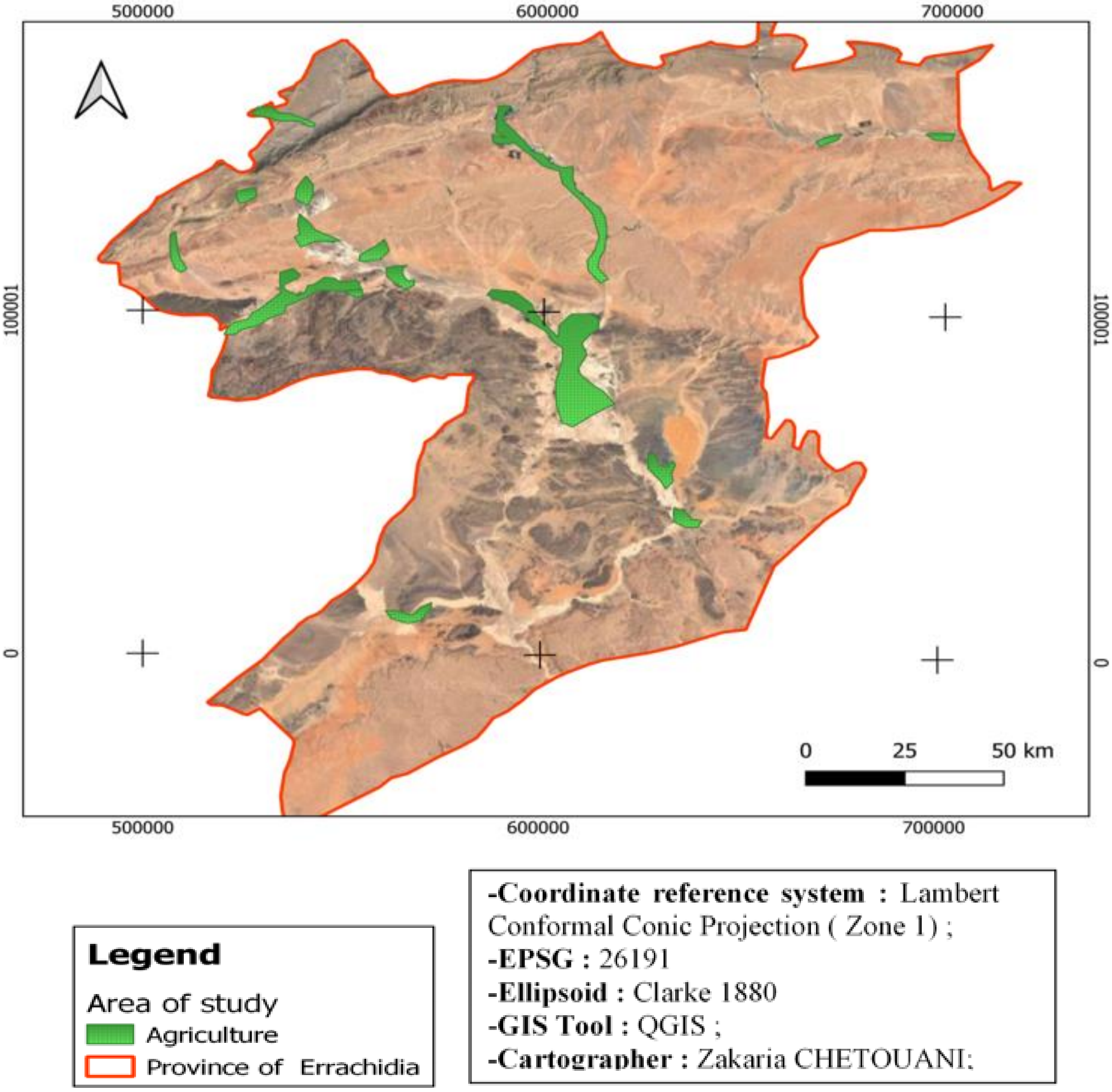


Figure 2: Agriculture map at Errachidia province

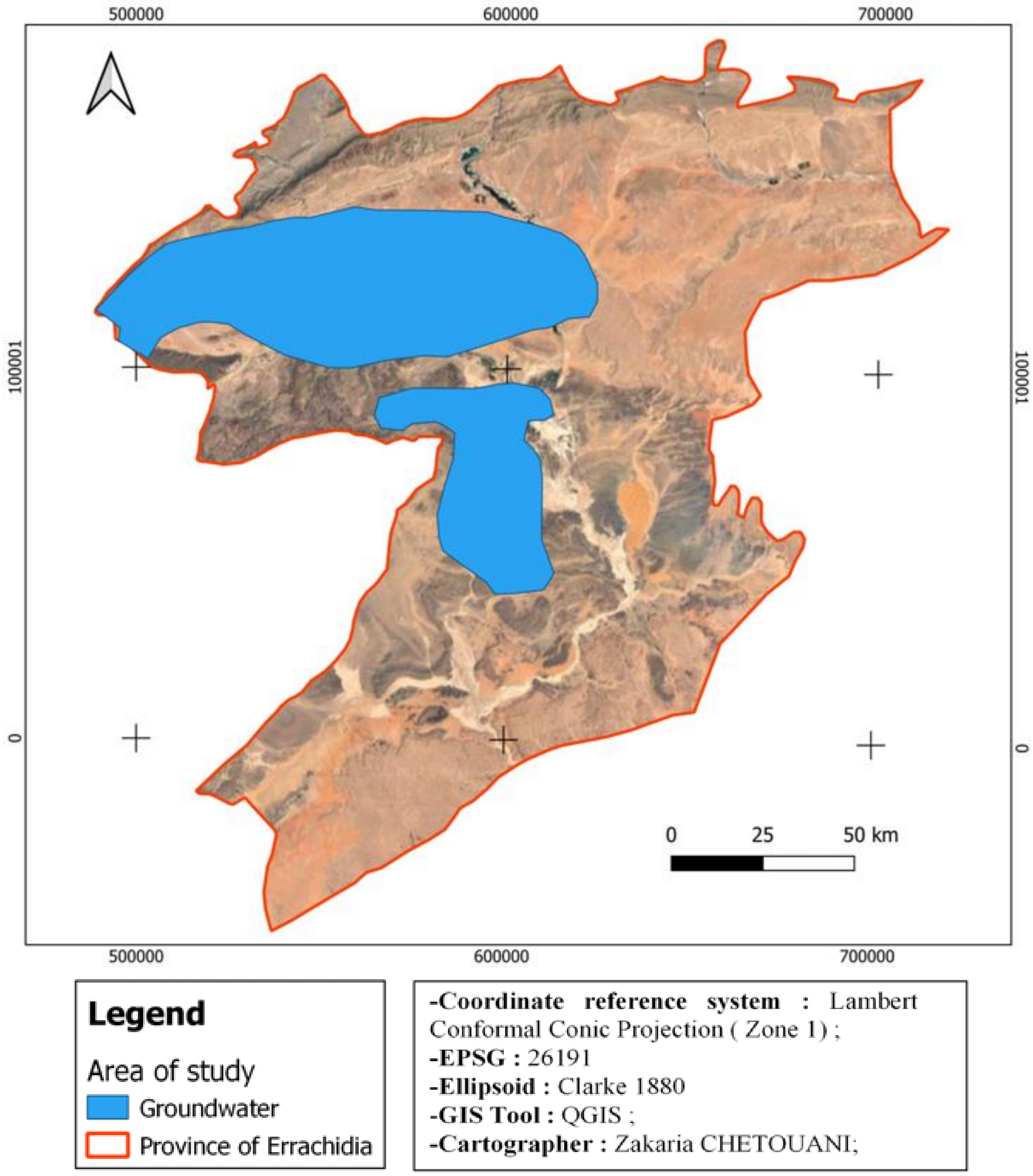


Figure 3: Groundwater maps at Errachidia province

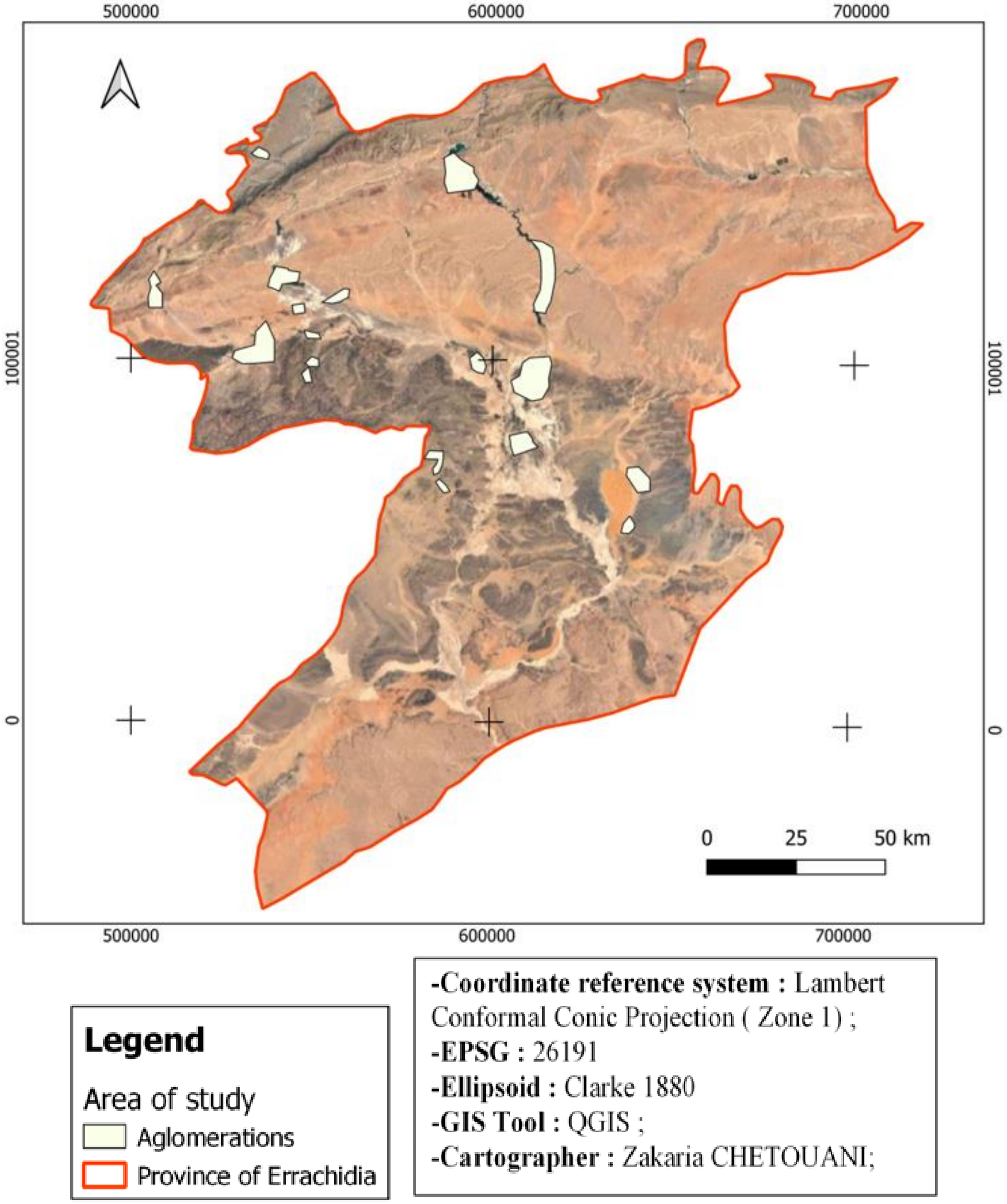


Figure 4: Map of agglomerations at the province of Errachidia

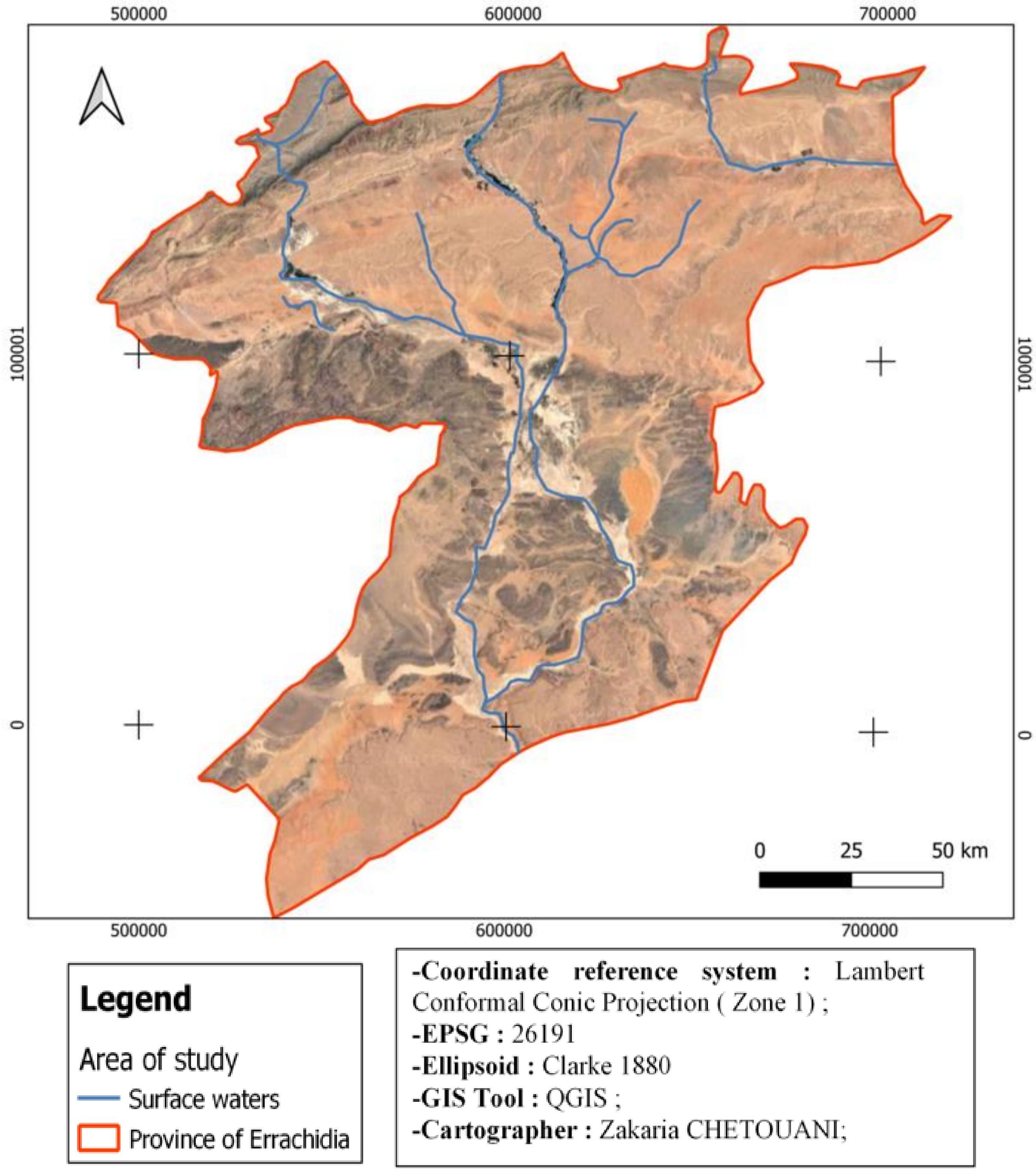


Figure 5: Surface water map at Errachidia province

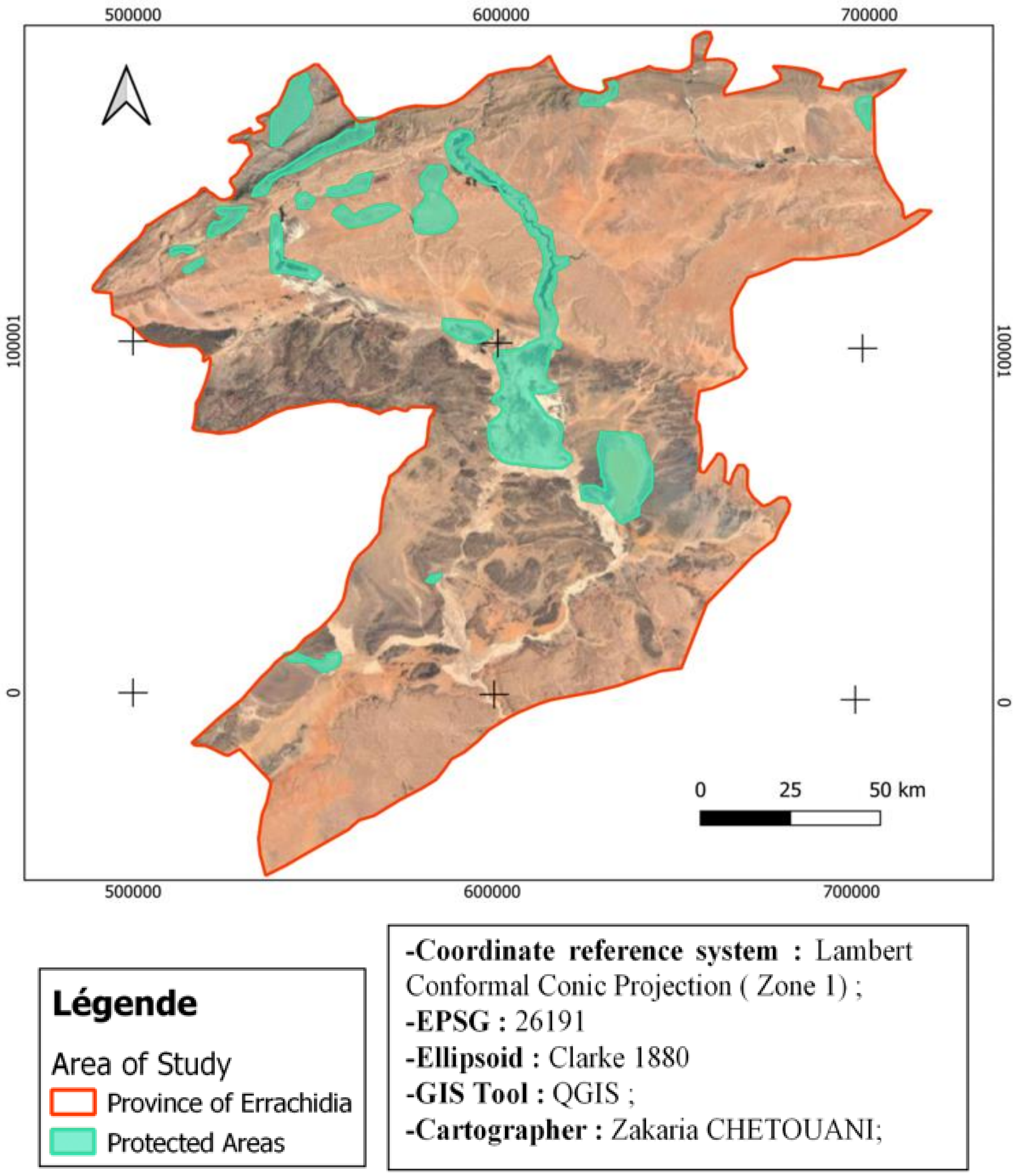


Figure 6: Map of protected areas at Errachidia province

Determination of free area

Thus, the elaborated thematic maps (map 1: Geology, map 2: Water, map 3: Agriculture, map 4: Forest and natural reserves, map 5: Socio-economic and cultural) are superimposed and the intersection of the exclusion zones gave free surfaces. This is a new map that gives the surfaces considered provisionally suitable for a waste disposal site after excluding the parameters of conflict. All of the identified open areas were pre-selected within a 40 km radius of the waste tonnage center of gravity of each sub-area (grouping of communes) in order to reduce the cost of waste transportation (Figure 6).

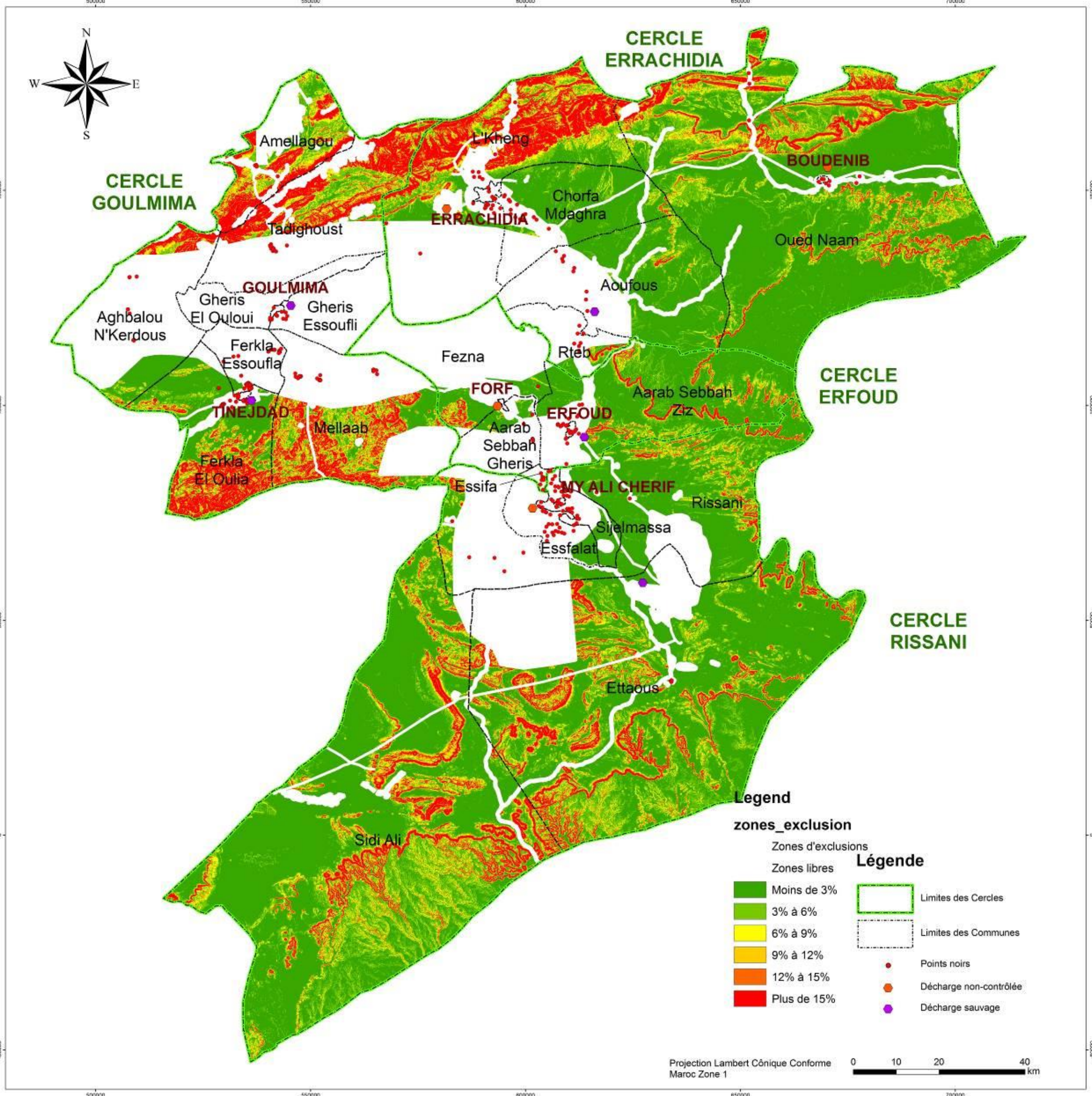


Figure 7: surfaces considered provisionally suitable for a waste disposal

Determination of free area

Thus, of the sites initially shortlisted, 94 were selected for further analysis, the main reasons for elimination being related to:

- Proximity to homes (new location relative to the topographic backgrounds used);
- Proximity to main roads;
- Hilly terrain, making development and access to the site impossible.

The following table lists these sites.

Table 3: List of free sites identified for each sub-area

Sub-Area	Identified sites
Sub-Area 1	A1, A2, A3, A4, A5, A6, A7, A8
Sub-Aera 2	B1, B2,B3, B4, B5, B6, B7, B8, B9, B10, B11
Sub-Area 3	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13
Sub-Area 4	D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32
Sub-Area 5	V13, V12, V14, V15, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20, T21, T22, T23, T24, T25, T26

Adopting a radius of 30 km around the waste production barycenters to optimize transportation costs, and eliminating sites that are located in areas with hilly or inaccessible terrain, the sites that will be studied are the following:

- The first screening has already eliminated 64 sites; the remaining sites will be subject to a multi-criteria analysis for each of the identified sub-areas to determine favorable sites.

Determination of free area

After establishing the weights and scoring systems, a comparative summary matrix of the different sites was developed. From this matrix, a final score is calculated for each site, using the following relationship:

NF = Σ . Pi.Ni

Where NF is the final score, Pi is the weighting coefficient and Ni is the score assigned to the factor.

The scores were assigned according to the criteria defined in the previous paragraph, based on the data collection and field visits.

Table 4: List of free sites selected for in-depth analysis, with their score and ranking

Sub-Area	Selected sites	Score	Ranking
1	A1	490	6
	A3	490	6
	A4	494	4
	A5	534	2
	A6	530	3
	A7	492	5
	A8	550	1
2	B5	498	1
	B6	478	3
	B7	482	2
	B8	476	4
3	C1	478	4
	C2	478	4
	C4	452	5
	C5	514	2
	C6	530	1
	C9	412	6
	C15	480	3
4	D16	484	2
	D17	446	6
	D18	458	5
	D19	510	1
	D20	466	3
	D28	460	4
	D29	466	3
5	V13	490	4
	V12	458	5
	V15	512	2
	T9	492	3
	T12	524	1

Of the 30 sites considered favorable for landfill, the top five ranked sites are:

- A8 in sub-area 1;
- B5 in sub-area 2;
- C6 in sub-area 3;
- D19 in sub-area 4;
- T12 in sub-area 5.

At the end of the study, these sites could be selected as future waste disposal sites in the province of Errachidia.

IV. Conclusion

The choice of waste disposal site and waste management in developing countries still pose major problems. In Morocco, the quantity of waste produced has increased from 600,000 tons per year in 1960 to more than 7.82 Mt per year, i.e. a multiplication of 13 while the population has barely multiplied by 3 during the same period. Waste has become a problem that requires a considerable effort from the government and local authorities, especially since it includes a significant proportion of hazardous products, mainly from various industrial and medical activities. The selection of solid waste disposal sites should be carried out for each city in

Morocco, but it is very difficult and costly. Therefore, GIS and remote sensing techniques are becoming powerful tools for this type of preliminary studies because of their ability to handle a large volume of spatial data from various sources. In addition, AHP is being used to address the challenges that decision makers face in handling large amounts of complex data. The integration of GIS and the AHP method is a powerful tool for solving the landfill selection problem[14]. This type of integration of GIS and AHP allows the decision maker to perform decision analysis functions such as ranking alternatives to select the best option, especially the best landfill site[15].

In the present study, a site suitability assessment methodology for municipal solid waste landfills was developed using GIS and remote sensing techniques with AHP methods. Based on the results of this study, the most suitable locations for solid waste landfills in the Errachidia region were determined. For this purpose, several criteria such as geology, water, agriculture, forestry and nature reserves and socio-economic factors were determined according to the properties of the region. The evaluation criteria were determined according to Moroccan waste management regulations. The criteria were then weighted using the AHP method, which provides an objective allocation process, and mapped using GIS and remote sensing techniques. GIS was used to prepare spatial statistics and clustering processes to reveal the most appropriate areas for landfill siting. The GIS techniques used were buffer zoning, interpolation and overlay analysis. The criteria map was prepared using a 1:10,000 scale map. In addition, the lineaments and land use map of the basin were prepared using raster satellite images and remote sensing techniques.

This work fulfilled the original goal of finding ecologically, socioeconomically and technically suitable potential landfill sites for the Er-Rachidia region. It should be emphasized that these sites were discovered after a thorough study of the area. Standardizing this approach for use across the rest of the kingdom will save valuable time. Our perspective in this regard is to apply this approach to other regions to verify the relevance of the selected parameters and the robustness of the applied scoring system.

References

[1] J. Reno, "Waste And Waste Management," Annu. Rev. Anthropol., Vol. 44, No. 1, Pp. 557–572, 2015, Doi: 10.1146/Annurev-Anthro-102214-014146.

[2] United Nations Economic Comission For Europe, Environmental Performance Reviews : Morocco Second Review. 2022.

[3] S. Bensalem, "Évaluation De La Biodiversité Et Des Services Ecosystémiques Au Maroc," 2020.

[4] B. Rachid, "Essais De Caractérisation Des Déchets Ménagers Et Assimilés Réalisés Au Maroc Résultats," 2017.

[5] T. L. Saaty, "How To Make A Decision: The Analytic Hierarchy Process," Eur. J. Oper. Res., Vol. 48, No. 1, Pp. 9–26, 1990, Doi: 10.1016/0377-2217(90)90057-I.

[6] S. E. Taelman, D. Tonini, And A. Wandl, "A Holistic Sustainability Framework For Waste Management In European Cities : Concept Development," Sustain., P. 33, 2018, Doi: 10.3390/Su10072184.

[7] L. André And H. Alain, "La Sélection Des Sites De Décharge En Région Wallonne(Belgique)," Biotechnol, Agrono.Soc.Environmental, Vol. 3, No. 1, Pp. 49–56, 1999.

[8] W. Paul T, Waste Treatment And Disposal, Wiley. 2005.

[9] Z. E. A. El Morjani, "Conception D'un Système D'information A Référence Spatiale Pour La Gestion Environnementale : Application A La Sélection De Sites Potentiels De Stockage De Déchets Ménagers Et Industriels En Région Semi-Aride (Souss, Maroc)," Université De Génève, 2002.

[10] A. Fekri, "Impact De La Décharge De Médiouna Sur Les Ressources En Eaux Souterraines," 2007.

[11] A. Fekri, J.-L. Pineau, M. Wahbi, A. Benbouziane, And C. Marrakchi, "Les Lixiviats De La Décharge De Déchets Urbains De La Ville De Casablanca (Maroc), Une Pollution Annoncée," Environnement, Ingénierie & Développement, Vol. N°42-Avr, Pp. 4–7, 2006, Doi: 10.4267/Dechets-Sciences-Techniques.1776.

[12] M. Zamorano, E. Molero, Á. Hurtado, A. Grindlay, And Á. Ramos, "Evaluation Of A Municipal Landfill Site In Southern Spain With Gis-Aided Methodology," J. Hazard. Mater., Vol. 160, No. 2–3, Pp. 473–481, 2008, Doi: 10.1016/J.Jhazmat.2008.03.023.

[13] S. Sehnaz, S. Erhan, And K. Remzi, "Solid Waste Disposal Site Selection With Gis And Ahp Methodology : A Case Study In Senirkent – Uluborlu (Isparta) Basin , Turkey," Pp. 533–554, 2010, Doi: 10.1007/S10661-010-1403-X.

[14] B. Sener, M. L. Süzen, And V. Doyuran, "Landfill Site Selection By Using Geographic Information Systems," Environ. Geol., Vol. 49, No. 3, Pp. 376–388, 2006, Doi: 10.1007/S00254-005-0075-2.

[15] M. Banar, B. M. Kose, A. Ozkan, And I. P. Acar, "Choosing A Municipal Landfill Site By Analytic Network Process," Environ. Geol., Vol. 52, No. 4, Pp. 747–751, 2007, Doi: 10.1007/S00254-006-0512-X.