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Geomatics tools and AHP method use for a suitable communal landfill site: Case study of Khenifra region – Morocco.

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- ✓ Khenifra region;
- ✓ Suitable sites;

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Abstract

The management of household waste is a major environmental problem in all Moroccan communities. This is linked to several factors including the significant quantity of waste produced and inadequate infrastructure. These factors create a significant pressure on the environment and led to negative impacts on natural resources and the health and hygiene of the population. The Khenifra region is characterized by diverse and fragile natural environment resources. Therefore, it is necessary to preserve and protect this heritage against pollution. This paper describes an approach for sites selection to store solid waste by combination of spatial analysis and multi-criteria decision analysis methods. Based in an integration and treatment of exclusion criteria in a geographic Information System (GIS), we determinate the free surfaces screened, afterward we evaluate them on the basis of the assessment criteria using the AHP (Analytical Hierarchy Process) method. In order to appreciate the socio-economic and hydrological aspect which are favored from geological and land use factors, field controls have been carried out to determine the accuracy and relevance of the suitable places. Finally, we chose 3 adequate sites which are considered the most favorable places for controlled discharge installation in Khenifra region.

1. Introduction

The quantity of waste in Morocco had an extremelyincrease in the last decade.And had anestimation of annual production of nearly 7.5 million tons of solid waste, including 6.5 million tons of household waste [12]. The recycling and transformations of waste are became the methods widely used to manage solid waste. However, in all these methods there is always a residual matter which cannot be valorized and conveyto disposalprocess in discharge. The necessity of getting rid of these waste yields in an economic approach which is called landfilling [2]. In this study, we are interested in the selection of a good waste storage site inKhenifraregion that is characterized by set agglomerations and diversified ecosystems namely: rivers, forests, lakes, water sources, etc. In the scientific literature, the Geographic Information Systems (GIS) combined to Methods of Analysis Multi-criteria (CMA) [16] have been widely used by many researchers and in different countries for the selection of sites and waste management systems [19-20]. The multi-criteria analysis is a method commonly used to help decision-makers [1], or even regarded as the most important method in this area [4]. However, the analytical Hierarchy procedure (AHP) is much more used in the weighting of the criteria for the assessment of the sites [1-3-5],and it is asystematic decision approach first developed by Saaty[6]. This technique provides a means ofdecomposing the problem into a hierarchy of sub-problems thatcan be more easily comprehended and subjectively evaluated.
The main aims of this work are to contribute to the design of a multi-criteria decision model. In order to help decision makers in choosing a suitable site for the household wastestorage,taking of the geo-environmental and socio-economic criteria into account.

2. Materials and methods

2.1. Study area

The region of Khenifra is located in the North of Beni Mellal-Khenifraregion(Figure 1). Administratively, the province is divided into 3 circles (Khenifra, El Kbab and Aguelmous) and 10 Caïdats.It contains two urban and twentyrural communities. Otherwise the geology of the study area is subdivided into two major different units; the Meseta Central in West and the Middle Atlas in East. The KhenifraProvince is characterized by mountainous terrain. The altitude varies from 306 m in the North West and the South of the province, to 2210 m in the South East and the North, with an altitude diminution from East to West.

The climate in the study area is Mediterraneanand continental. It is characterized by a rainy and cold winter with periods of snow in the high mountains, and a dry and warmsummer during the periods of storm.

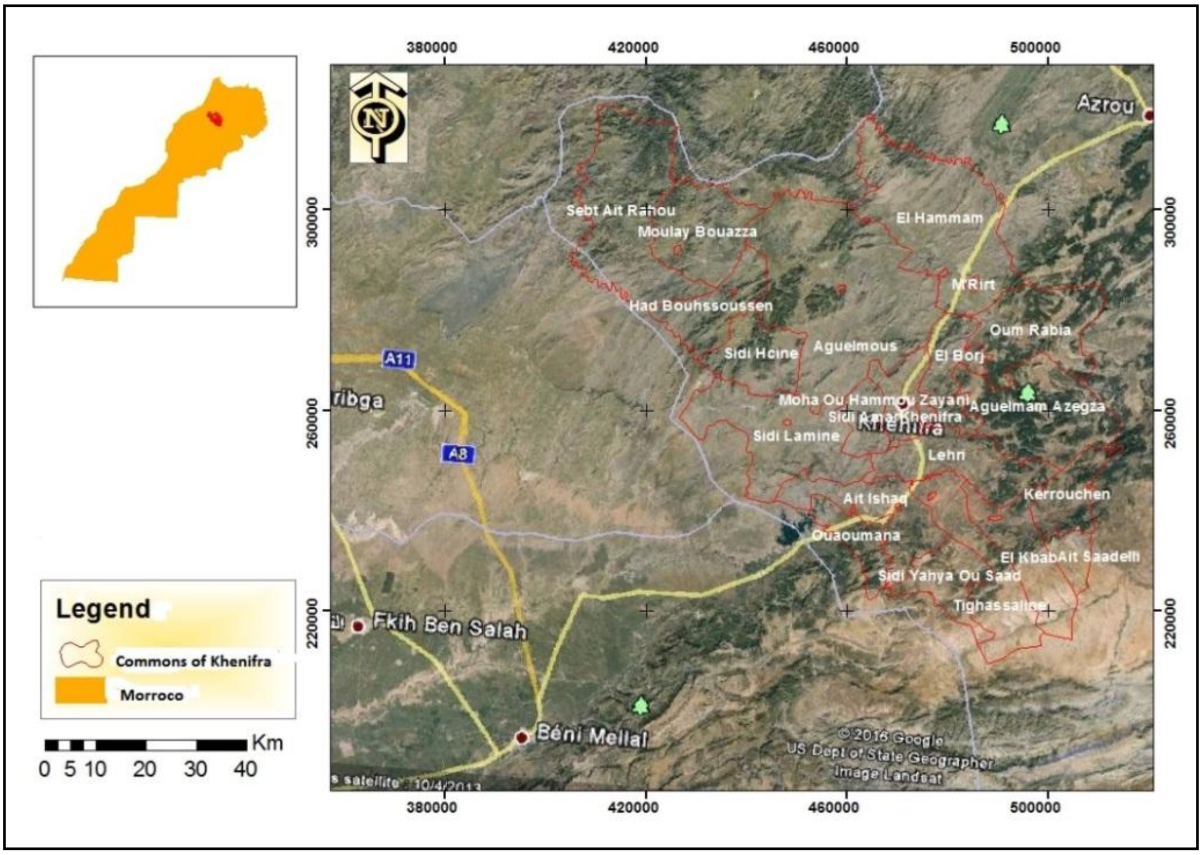

Figure 1: Location map of the study area.

2.2. Methodology

2.2.1. Exploration area

To arrive in an identification of the prospectingarea thiswill receive the future implantation site of the landfill in Khenifraregion,we determinate the barycenter that is mandatory in order to have a site closer the maximum possible to thewastegravity center. For this purpose we create a buffer zone of 20 km around the gravitycenter [7] to minimize the costs of transport, and be a part of the commons that will have the collect of their waste. The coordinates of the barycenter (Figure 2) are obtained from the following equation[8]:

$$\mathbf{X}_{B} = \frac{\sum \mathbf{X}_{i}\, x\, \mathbf{P}_{i}}{\mathbf{P}_{t}} \quad \textbf{and} \quad \mathbf{Y}_{B} = \frac{\sum \mathbf{Y}_{i} x\, \mathbf{P}_{i}}{\mathbf{P}_{t}}$$

Where

$Y_B$and X_B=coordinates of barycenter; X_i and Y_i = are the centroid of the commoni; P_i =Number of commonpopulation i; and P_t =total number in all provincecommons.

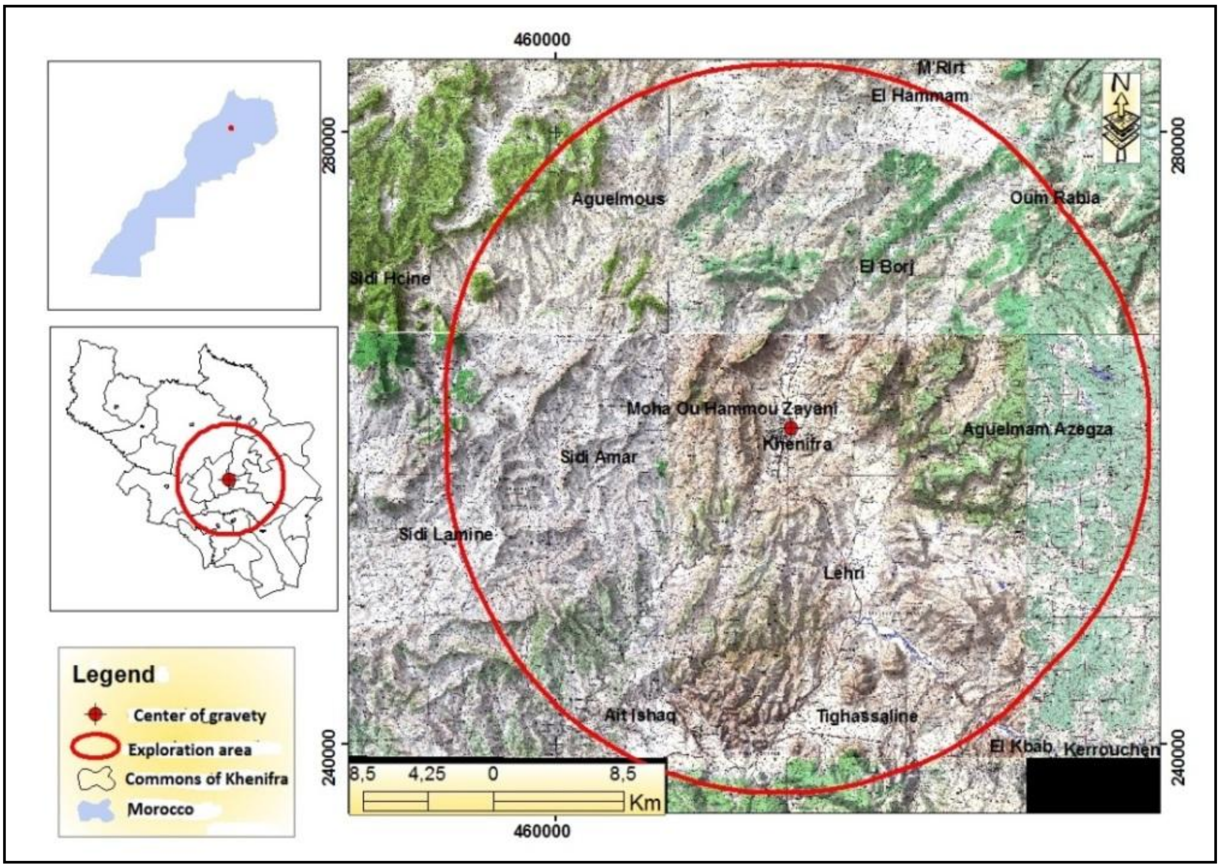

Figure 2: Exploration area.

2.2.2. Population and the quantities of waste producedprojection

The calculation of the projectedpopulationin Khenifraprovince during the period of 2016-2044 has been carried out by the following formula [11]:

$$P_n = P_0 (1 + T_a)^n$$

Where: P_n = projected population; P_0 = reference population; T_a = population growth rate and n= number of years.

The quantity of waste produced at different horizons is estimated using the following equation:

$$Q_{Ai} = Q_0 (1 + T_c)^{(A_i - A_0)}$$

Where

Q_{Ai} = quantity of waste in t/year in A_i (year projection); Q_0 = Quantity of waste in t/year corresponding to the reference year A_0; A_i = year projection; T_c= average annual growth rate of withheld (ratio) and A_0 =reference year.

The results of different simulations are given in the following table:

Table 1: The quantities of household waste production during the next 28 yearsprojection

Year	2016	2024	2036	2040	2044
Population	235 184	247 767	266 825	275 952	283 912
Quantity of waste estimated t/year	54363	57944	62554	64171	65828

This quantity of waste is closely linked to the population. For this reason, the period 2016-2044 has a correlation of (R^2 =0.95) with the amount of waste generated during this period (Table 1). The obtained equation is given bellow (Figure 3):

$$y = 2915.7\,x + 52225$$

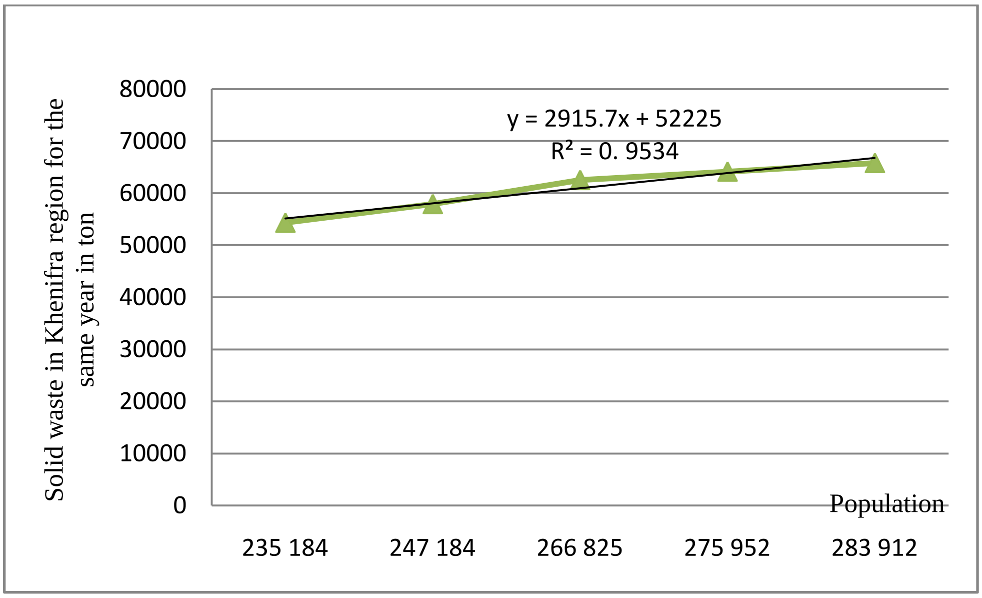

Figure 3: Projection of solid waste in Khenifraregion by population.

2.2.3. Estimated Area of Landfill

The determination of the surface area of the future landfill depends on several parameters, such as thepopulation growth, waste quantity; waste height and density, compaction rate at landfill. This formula used to estimate the landfill area is given bellow [9]:

$$\boldsymbol{SUE = 10^{-7} * Tc * d^{-1} * P * R * 365 * h^{-1}}$$

With**SUE**: Land area for burial in (ha); $\mathbf{T_c}$: Compaction rate (0.7); **P**: Population served by waste collection; **d**: density of waste (0.5); **h**: Effective height of waste (h = 20m), this height does not include the earth cover layer (1.75m).

2.2.4. Data collection

The available data on the geology, hydrogeology, hydrology, soil and the eco-sociology have been collected and produced in digital form and papers. Several thematic maps are served in the preparation of the reference space database. These maps were at various scales and contained several types of information (table 2).

Table 2: Data used for the choice of the site

Data type	Date	Resolution / scale	Source
Topographical map of Khenifra	1975	1/50000	National Agency of Land Conservation, Land Registry and Mapping
Topographical map of KafN'sour	1975		
Topographical map of M'rirt	1974		
Topographical map of Aguelmous	1974		
Topographical map of Krouchen	1974		
Topographical map of ElKbab	1977		
Topographical map of El Hammam	1977		
Geological map of Rabat		1/500000	Ministry of Energy and Mines Morocco
Road Map of Khenifraregion	2012	1/25000	Equipment of Khenifra-Direction roads and road traffic
Shuttle Radar Topography Mission (SRTM)	2010	30*30 m	National Geospatial– Intelligence Agency (NGA) [15]
Satellite image of the LANDSAT	2015	30*30	National Aeronautics and Space Administration

2.2.5. The approach

The recommended methodology is based on the Guide for the landfills selection recently developed by the Department of the Environment [10] andrelevant international literature,[3], [17-12] and [18-19]. In this article, Geomatics and the multi-criteria analysis (AHP) have a crucial role in the determination of the suitable site for a controlled discharge inKhenifraregion (figure 4).

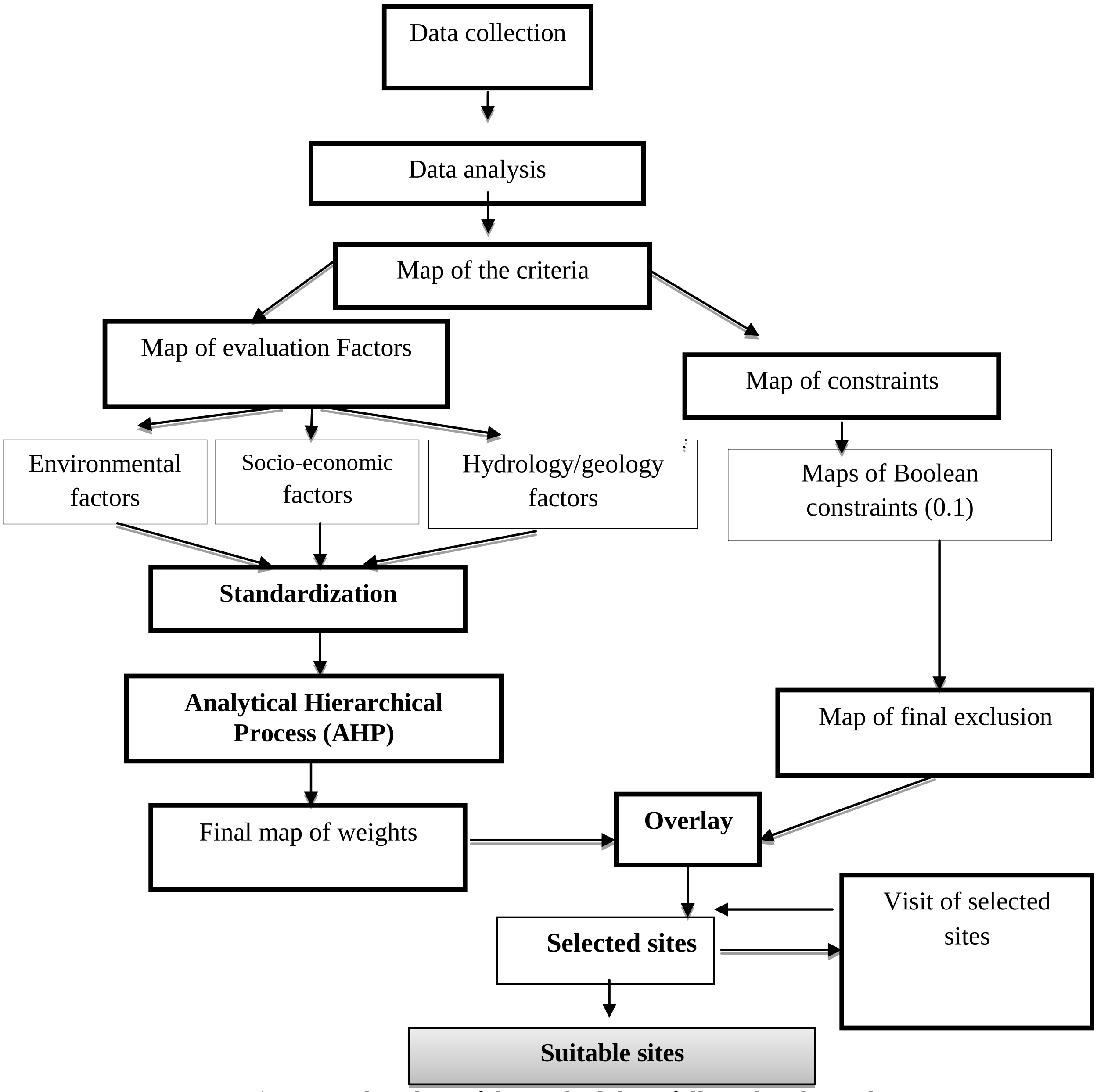

Figure 4: Flowchart of the methodology followed in the study.

2.2.6. Exclusion Criteria

The procedure of exclusion is to assign a radius of security in which the location of a discharge is prohibited during the establishment thematic maps. The choice of the securityradius is a function of the importance of the criteria of specific constraints to the theme (table 3).The final exclusionmap has been obtained by the superposition of all the thematic maps of binary fifteen criteria which have been developed for the Constraints. They were combined using the Boolean logicmodel.

2.2.7. Criteria for evaluations (factors)

The assessment of the factors of assessment has been carried out by the process of necessary decision with the use of the AHP method whose prior notice of the problem or the purpose of the analysis must be well identified. The decision tree developed for the problem of the selection of a suitable site provincially for the controlled discharge of Khenifra. Twelve criteria have been developed as layers of digital data of entry, including urban areas, the occupation of the soils, hydrographic network, roads, slopes, surface water and geology.The step of standardization has been applied by the result according to a common interval of the value 1 to 4. This step is to unite and to standardize the units of the criteria considered by the Euclidean distance (discontinuous function).

Table 3: Selection criteria and their rays of security

Criteria	Buffer zone (m)
City	2000
Village	1000
Roads	500
Douar	500
Sacred areas	500
Electrical lines	200
Mine and career	500
Land cover	200
Land use	300
Flaw	500
Slope	≤ 5%
Hydrographic network	500
Water sources and wells	500
Lakes	500
National Office Equipment of Drinking Water	2000

- ✓ **Weight criteria**

A weight may be defined as a value assigned to an evaluation criterion that indicates it's important in relation to other criteria to the study. The allocation of significant weight to the assessment criteria takes into account: 1) changes in the range of variation for each evaluation criterion and 2) The different degrees of importance attached to these ranges of variation [13]. There are several techniques to assign the weight: classification, assessment and comparison by pair [13]. In this study we will focus on the comparison in pairs, the weights of the criteria have been calculated using the comparison matrix shown by using scale values of 1 to 9 [6]. The comparison matrixes indicate the relative important of criterion in the columns by report to the criterion in the lines. For each comparison, it will be decided which of the two criteria is the most important, and then a score is assigned to show how it is more important. The verification of the matrix consistency has been carried out by calculating the ratio of consistency (RC) [6]. The value RC must be less than 0.1 [14]. The resulting weights are given in table 4.

Table 4: Resulting weights.

Criteria	Sub-criterion	Weights	RC
Occupation of the soil	Natural Park	0.75	0.08
	Forest Environment	0.17	
	Agricultural surface	0.08	
Socio-economic	City	0.52	0.03
	Village	0.21	
	Sacred area	0.21	
	Roads	0.06	
Hydrology (water)	Hydrographic Network	0.21	0.01
	Sources and wells	0.24	
	Lakes	0.55	
Geology/Topography	Slop	0.25	0.006
	Flaw	0.75	

3. Results and Discussion

The aptitude map for the storage site of household waste in the Khenifra regionis a result of the complete aggregation using both theconstraints map and the weighted factors map.

3.1. Exclusion of unsuitable landfill areas

The criteria for exclusion were subdivided into two major families: geo-environmental and socio-economic.We apply a radius of security and then reclassifyit following the Boolean logic 0 or 1: 0 for the unfavorable area and 1 for the favorable area. The waste management and disposal law does not oblige any criteria for the optimum location choice. All these parameters have been identified based on literature review of landfill site selection [12-20]. In this step the data are in vector format such as buffer, overlay, merge and erase, and are used to create the exclusion areas.

3.1.1. Socio-economic constraints

To protect residential and sacred areas (mosque, schools, cemetery and Marabous) and roads against excessive nuisance resulting from the operation of the landfill (odor, machines noise in the spill and derivatives of lorries carrying Waste, dispersion of waste by wind) it must respect a radius of security [9] and [12] (figure 5). However, another consideration was given to electrical lines (high voltage), mines and quarries in the study area.

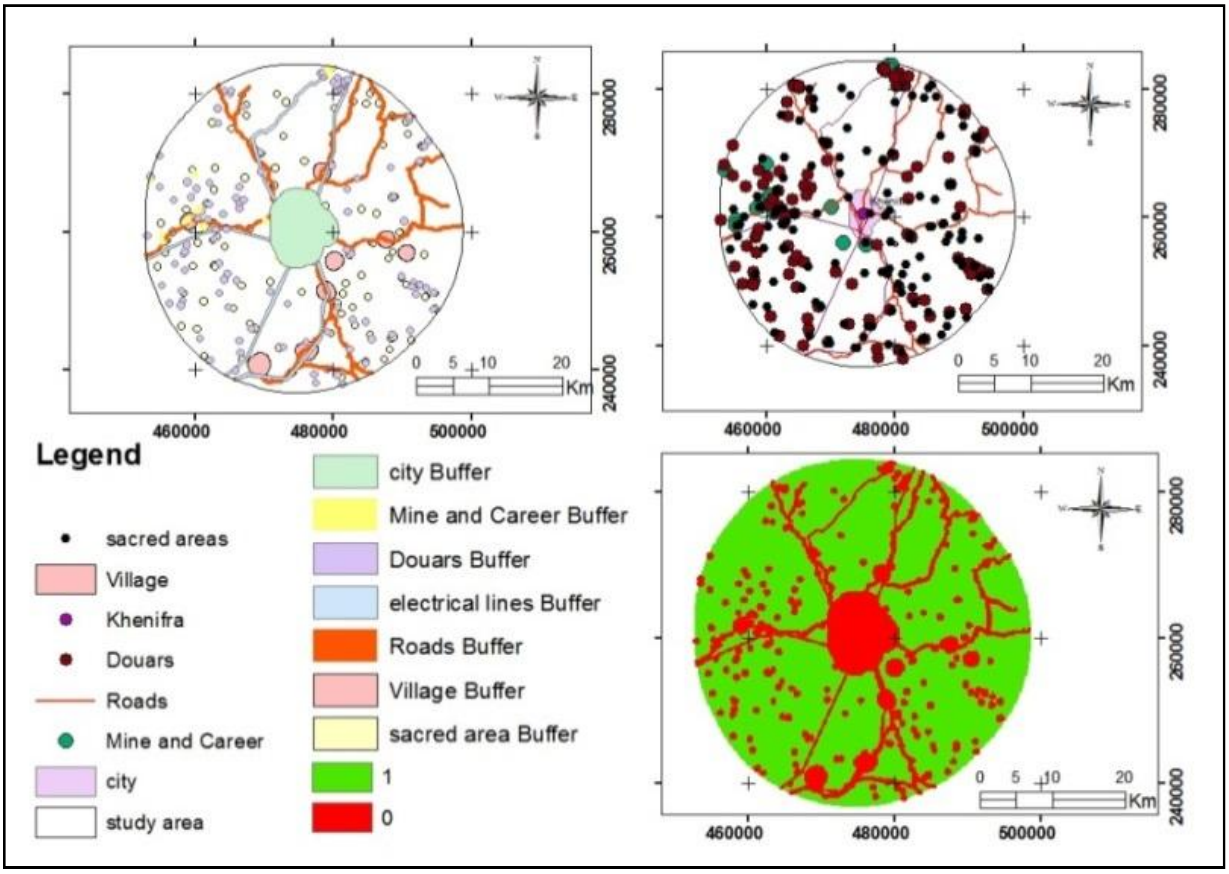

Figure 5:Determination step forfavorable areas taking in account the exclusion zones by the socio-economic criterion**.**

3.1.2. Soil occupation

The soil aspect use is an important step for agood site selection of controlled discharge in theKhenifraregion, in order to mitigate and manage the pollution generated by the deposited waste in the future in order to avoidsoil contamination, these components (agricultural surfaces and forest areas). The buffer zones should be created around these components(Figure 6).

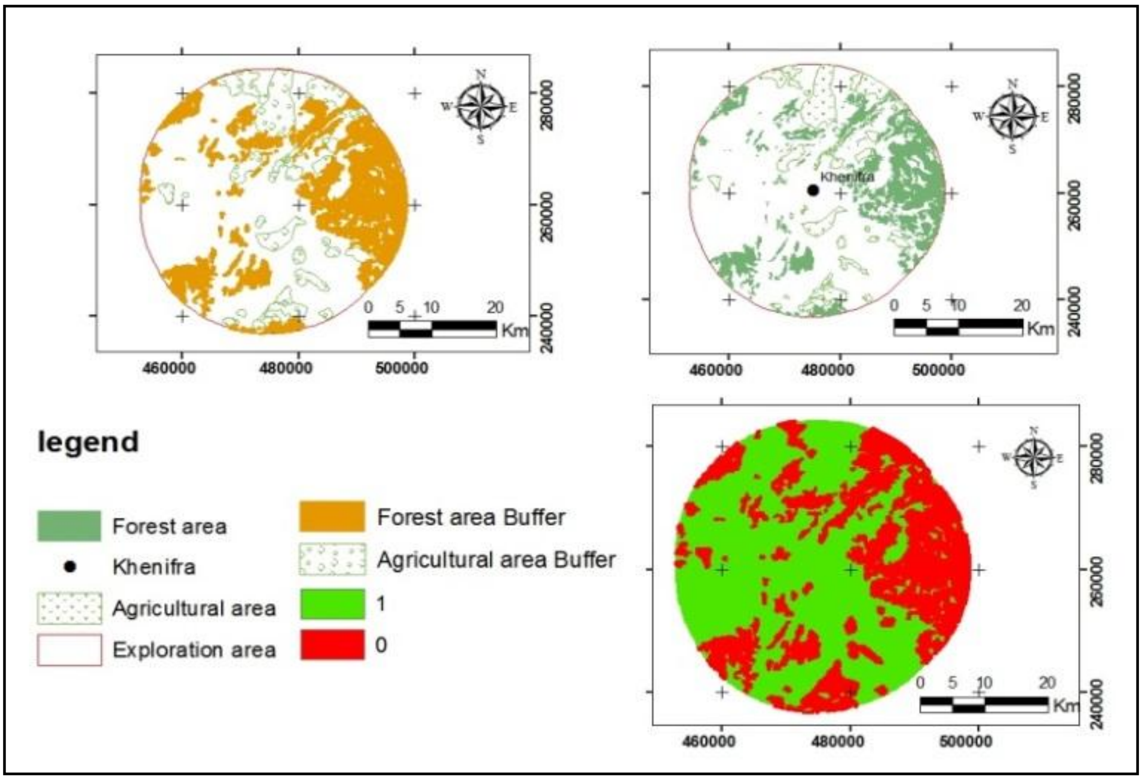

Figure 6: Determination step for favorable areas taking in account the exclusion zones by agricultural and forest area criterion**.**

3.1.3. Geo-environmental constraints

✓ *Geological criteria*

The landfill site must be designed in such a way that its location does not exposed to the risk of land sliding, erosion or flood risk, therefore the areas that containgreater slope of 5% are excluded (Figure 7).

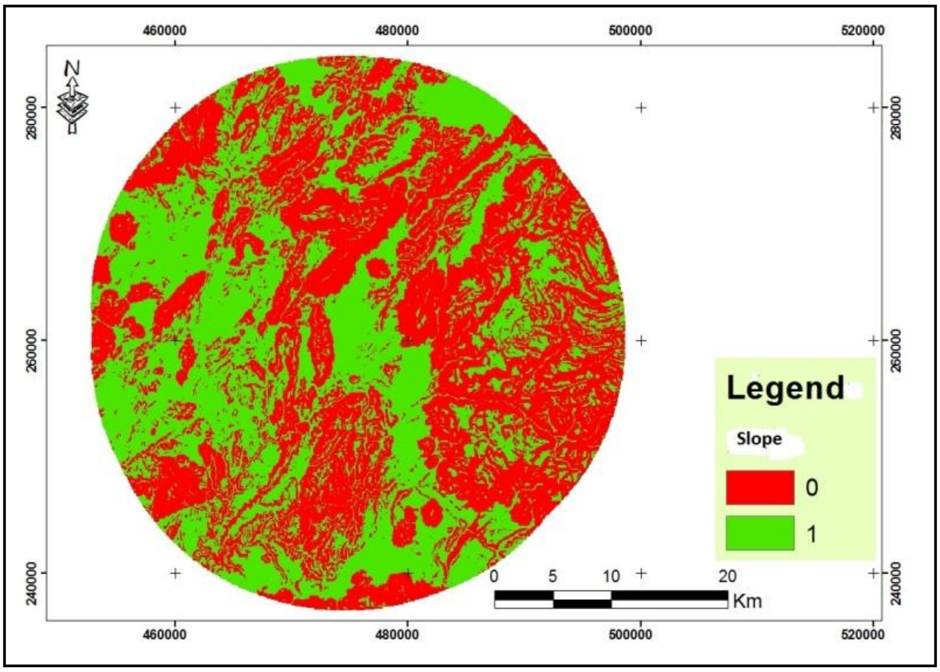

Figure 7: Slopes exclusion Map

The site must also be installed on a ground which is not fractured to prevent the infiltration of leachate toward the water. This criteriahas thus created a buffer zone (500 m) [10-12] around the existing vulnerabilities based on the Geological Map of the region (Figure 8).

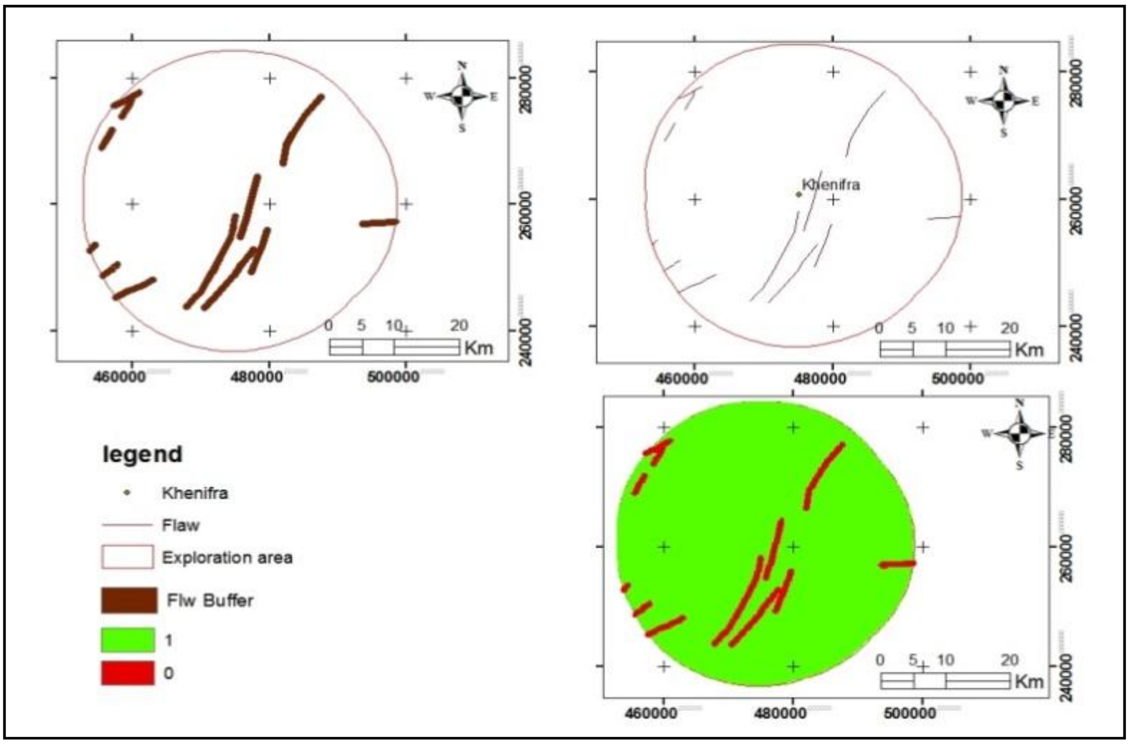

Figure 8: Flawsmapexclusion.

- ✓ *Water criteria*

To protect the aquatic surfaces in the region such as rivers, sources and the constitution of the hydrographic network against the leachate generated by waste, we should take in consideration buffer zones around the aquatic surfaces (figure 9) according to the protection of the Environmentagencies [12].The main objective is to help decision-makers choose and implement, as soon as possible, the necessary measures to remedy any anomalies detected. The design of the monitoring program will depend, among other things, on the nature of the pipeline, water levels and flow, and on the soil permeability.

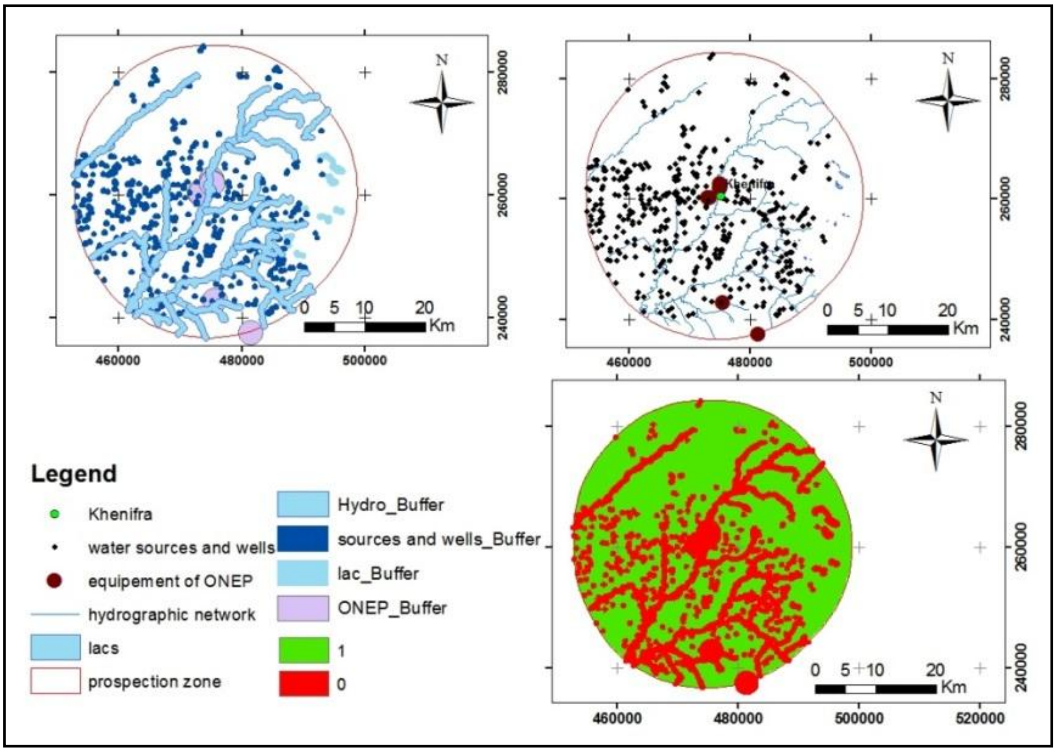

Figure 9: Determination step fora favorable areas taking in account the water zones exclusion.

After the application of the exclusions criteria, 12 % of the exploration areas arefavorable for the controlled dischargeestablishment (Figure 10), the values 1 represent the spaces suitable for the implantation of the unloaded while the 0 values are unfit.The mathematical formula for the site choice by the use of exclusion criteria is:

$$SI = \sum kj = 1 = BJ$$

Where, SI: value of the criterion index in the overlay (0 or 1), BJ: value of the ability index for each criterion (0 or 1) and K: number of criterion.

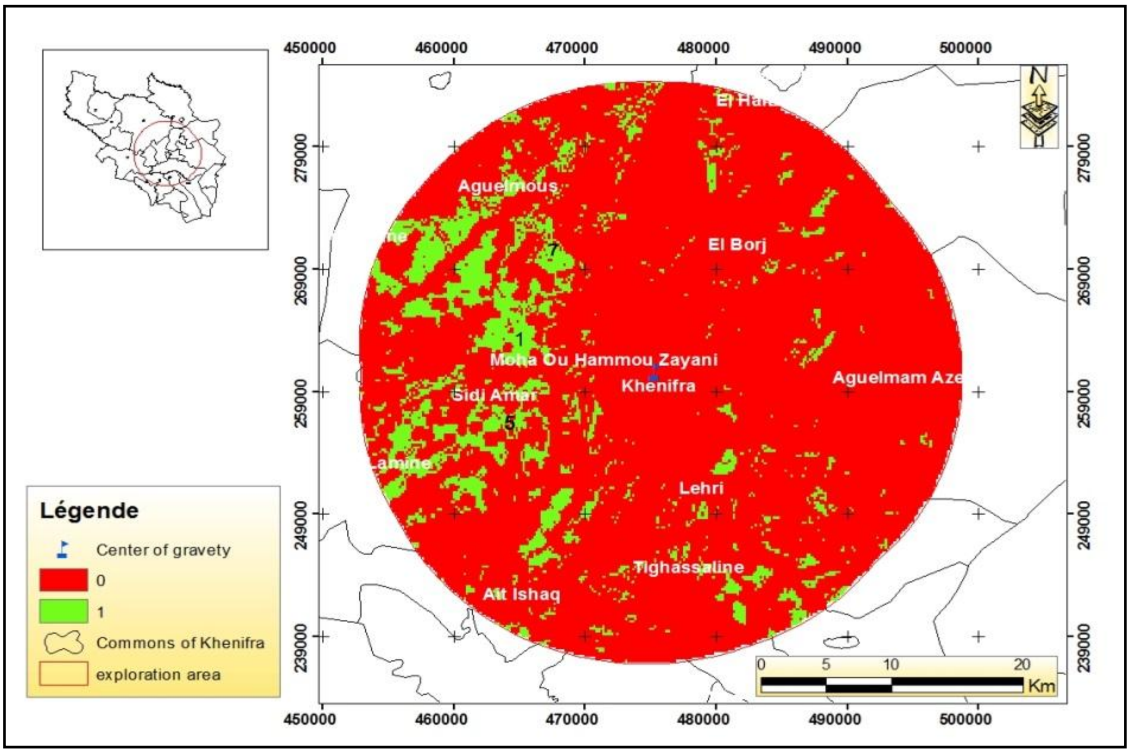

Figure 10: Total Constraints map.

3.2. Assessment Criteria

The assessment criteria had the objective to improve or reduce the relevance of the free surfaces resulting from the previous step.The aptitude map for the storage site of household waste is the result of the complete aggregation using the constraints and weighted factors map. Which is created on the basis of two scenarios (Table 5 and Table 6),that are designed on the variation of the relative importance of two appreciation factors (socio-economic and water factors).

Table 5: Firstscenario.

Assessment Criteria	Water	Socio-economic	Soil Occupation	Geology	Weight
Water	1	1	1	1	0.25
Socio-economic	1	1	1	1	0.25
Soil Occupation	1	1	1	1	0.25
Geology	1	1	1	1	0.25

Table 6: Second scenario.

Assessment Criteria	Water	Socio-economic	Soil Occupation	Geology	Weight
Water	1	1	1	1	0.33
Socio-economic	1	1	1	1	0.33
Soil Occupation	½	1/2	1	1	0.17
Geology	½	1/2	1	1	0.17

The quantitative comparison between the two scenarios shows a remarkable difference in the pixels number of unsuitable and suitable area. The number of suitablepixels decreases in the 2nd scenario contrariwise to the first scenario (Figure 11).Based on the socio-economic and hydrological aspects chosen in the present study, these two factors have been favored in relation to geological and soil occupationfactors. The meshes similar contiguous have been grouped in the space to not retain at the end those sites having a minimum area of 12 ha and a geometry adequate for the implementation of the landfill. Three candidates sites have been selected (Figure 12), they are considered to be the most favorable for the installation of the controlled discharge inKhenifraregion.

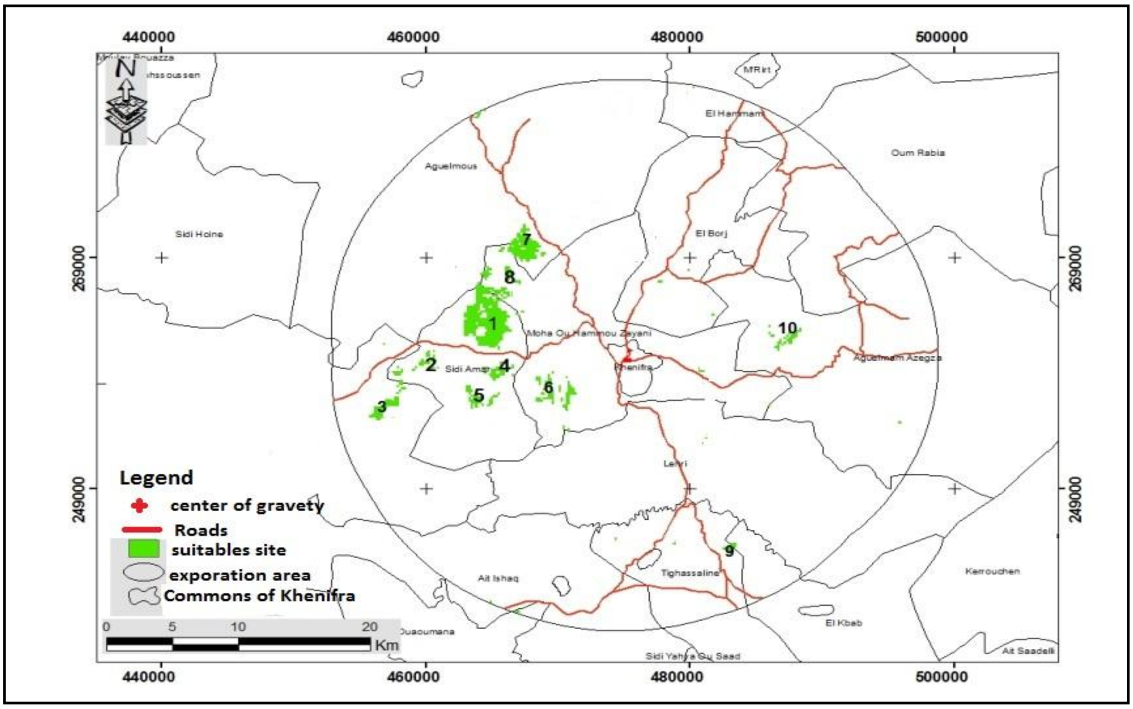

Figure 11: Suitable sites situation according to the first scenario.

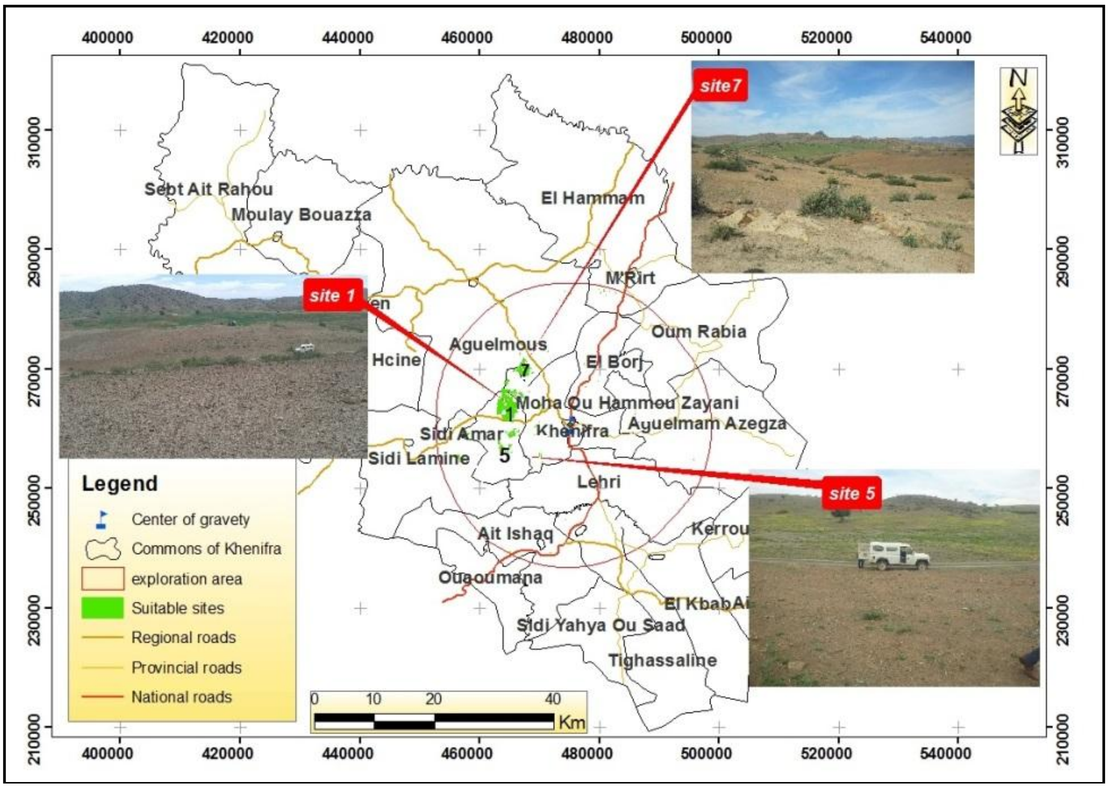

Figure 12: Suitable sites situation according to the second scenario.

Table 7: Selected sites location and area.

Site	X (m)	Y (m)	Area (ha)	Commons	Distance from barycenter (Km)
1	465039	262160	55	SidiAmer	12
5	465316	256920	35	SidiAmer	13
7	468153	270278	30	Aguelmous	10

Concerning the geology,it is considerate that the site selection for landfill should particularly give attention to underlying bedrock and foundation soil in order to prevent the groundwater pollution [12-20].For this reason, the geology of the new landfill should be characterized by impermeability and sufficiently thick. Sites 1,3 and 7 selected due to their location in geological formations represented by schist with quartzite and sandstone beds. Those formations are covering the Central Moroccan Massif and dating from the Paleozoic era (Figure 13).

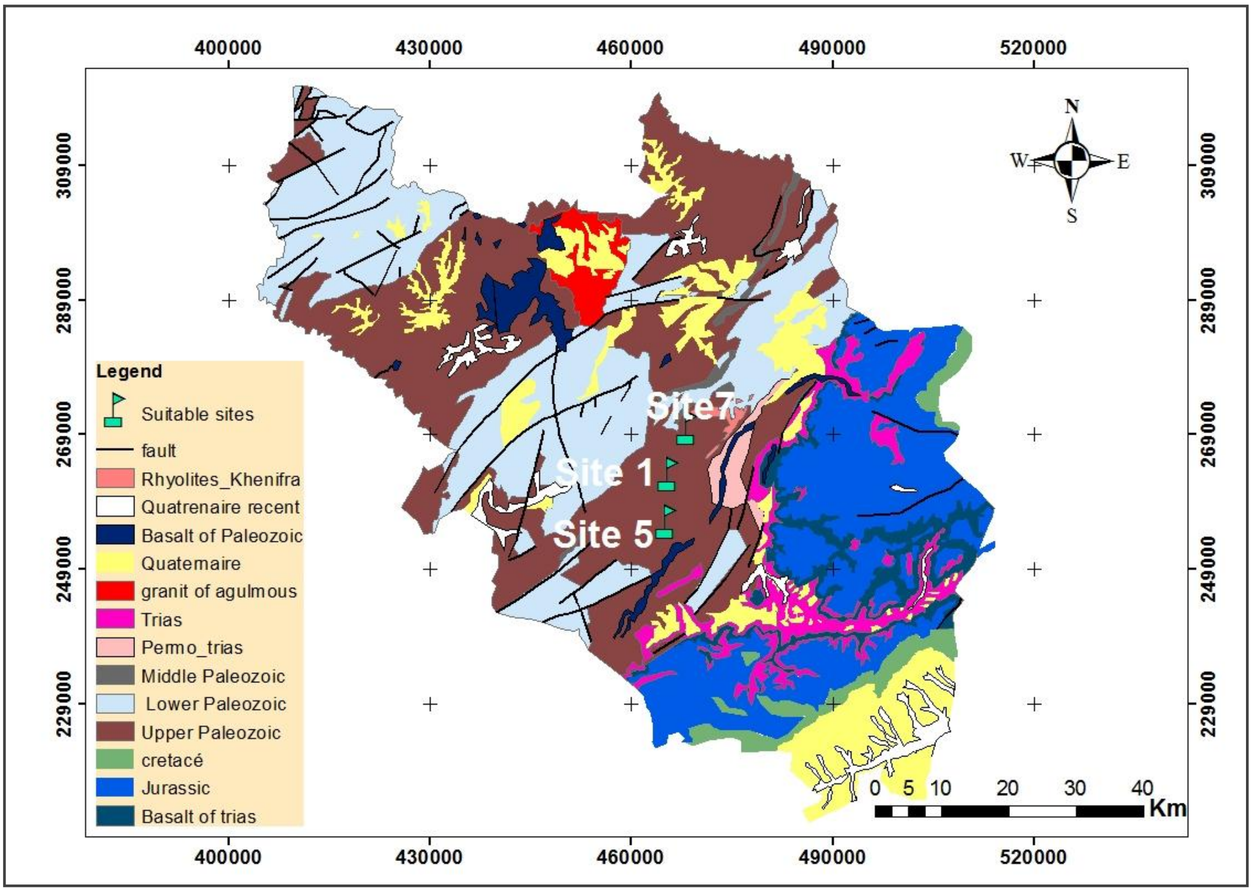

Figure 13: suitable sites situation on the geological map of the study area

Conclusion

The selection of an optimum site for the controlled discharge in Khenifra region is a complex procedure. It has been performed by the coupling of Analysis Multi-criteria AHP method and standardization of discontinuous functions. This multi-criteria analysis is based on mapping treatments using geomatics tools especially GIS. Fifteen criteria of exclusion were applied to obtain a map of constraints that allows excluding areas unfit for site choice. This treatment has allowed us to obtain the free surfaces that represent more than 12% of the total exploration area. The evaluation factors were applied to evaluate the free areas resulting from the first step, by the use of the Euclidean distance to standardize the factors. The analysis AHP was used for weighting and the linear combination weighted and aggregated. The field visits were conducted to verify the selected sites. In addition, the volume of solid waste has been calculated to ensure that the selected site can occupy this volume. As a Result, three sites were chosen after obtained the best indices of aptitude according to the two scenarios.

In conclusion, the present study the used methodology gives accurate results for site selection. Therefore, an integration of GIS and AHP methods showed a satisfactory mechanism to thoroughly explore complicated problems and provide immediate feedback for decision makers.

References

1. Chuang P. T., *Intern. J. Adv. Manufac. Tech.*18(2001)842-849.
2. Tchobanoglous G., Theisen H., Vigil S.A., *Integra. Sol. Was. Manag.*(1993).
3. Şener S., Şener E., Nas B., *J. Eng. Sci. and Design.*1 (2011)134 – 144.
4. Jiang H., Eastman J. R.,*Intern. J.Geog. Info. Sci*. 14(2000) 173-184.
5. Allen B.G., Caetano P., Costa C., Cummins, V., Donnelly J., Koukoulas S., O'Donnell V., Robalo C., Vendas, D., *Intern. Was.Manag.andLandf. Symp.* (2003).
6. Saaty T.L., *J.Oper.Res. and Eco.*2 (1993)119‐137.
7. Gemitzi A., Tsihrintzis V. A., Voudrias E., Petalas C., Stravodimos G. *J. of Environ. Geo.* 51 (2007) 797-811.
8. Kemal K. M., Erdagi B., *J. of Was. Manag.* 32 (2012)2315–2323.
9. Khajuria A., Yamamoto Y., Morioka T., *J. of Environ Bio.* 31(2010) 649-654.
10. Kiker G. A., BridgesT. S., Varghese A., Seager T. P., Linkov, I., *Integr. Environ. Assess. And Manag.* 1 (2005) 95-108.
11. Nadhir A., Alanbari M. A., Hadeel K. J., Sven K.,*J. Nat. Sci.*6(2014)828-851.
12. Mansour D., El Hmaidi A., Essahlaoui A., Morad El Abassi, *Intern. J. Eng. Res. and Dev.* 10 (2014) 01-10.
13. Rakotoarivelo J. B.,J. *Res.*07 (2015) 62.
14. Kontos T.D., KomillisD.P.,Halvadakis C.P., *J. Waste Manag.and Res.* 21 (2003)262-277.
15. Danielson, Jeffrey J., Dean B. G.,*US Geo Survey*, (2011)-1073
16. Al-Taie L., Al-Ansari N.A., Knutsson S. and Pusch R., *J. Earth Sci. and Geote. Eng.*3 (2013) 81-91.
17. Vatalis, K., Manoliadis, O., *J. Geog. Info. and Dec. Anal.*6 (2002) 49–56.
18. Akbari, V., Rajabi, M.A., Chavoshi, S.H., Shams, R., *Wor. App. Sci. J.* 3 (2008) 39–47.
19. Chang N.B., Parvathinathan G., Breeden J.B., *J. Environ. Manag.* 87 (2008)139–153.
20. Şener S., Şener E.,Bilgehan N., Remzi K., *J. Was. Manag.* 30 (2010) 2037–2046.

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