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An Environmental Investigation into Khorramabad's Landfill and Optimal Site Selection of Landfill using Weighted Linear Combination (WLC)

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Abstract

The determination ofmunicipal waste landfillis a major issue in the process of urban planning due tothehuge impact it has on the economy, ecology and environment of any region.In the process of determining municipal waste landfill, attempt is madeto consider sites with minimum risks for the environment and human health as well.This study aimedto have an environmentalevaluation and determination of municipal waste landfillin KhorramabadusingGeographic Information System (GIS) andWeighted Linear Combination (WLC). For this purpose,the current landfill was first assessed in terms of the environment.The results of the evaluation show that the biochemical and chemical activitiesare very high in the desired site. Therefore, paying special attention to the environmental impacts ofthe current landfill is of greatsignificance.Then, themap for the site selectionof Khorramabad's landfill was prepared based on investigating and assessing 13 parameters including the distance from city, village, river, groundwater, fault, major and minor roads, airport, historical places, lithology, land use, slope and elevation,.According to the results obtained from themap for the site selectionof landfill, 10.03%, 21.85%, 28.38%, 25.30% and 14.42% of the site area are located in the very unsuitable, unsuitable, moderate, suitable and the bestsuitable area, respectively.

Keywords: Municipal Waste Disposal, Site Selection, Weighted Linear Combination, Geographic Information System, Khorramabad.

1. Introduction

Solid municipal wastes are those wastes produced by the population in everyday life. These wastes indicate great mixed changes in different zones and times.Population growth will increase the rate of waste production in urban areas and as a result, it will affect the region's natural resources and ecosystem. Khorramabad is a city with about 360 thousand inhabitants and due to its growing trend andimmigration to the city, special attentionto the dry waste collection and organization of landfills are required in order to reduce destructiveenvironmentaleffectsin the city.

Lack of attention to proper selectionof landfill andprincipleddisposalof the wastes in any site will result in environmental problems such as the contamination of groundwater, arable lands and soil. Selecting a correct and principled site which requires different factors is one of the most important objectives to manage the waste. In addition to structural conditions, the status of groundwater and surface water and environmental and topographic conditions, a series of social, political, economic and ecological factors should be consideredin this regard (Guiqin et al. 2009).

In this study, the assessment of environmental conditions and determination of the optimal site for Khorramabad's municipal waste landfillhave been emphasized using weighted linear combination in GIS software. Today, the use of GIS as a support system has been increasedin local decisions (Uyan 2014). The advantage of using GIS in determining suitable locations for disposal and waste disposal causes to prepare digital data bank for the long-term monitoring of such sites in addition to reducing time and cost (Moeinaddini et al. 2010; Donevska et al. 2012; Eskandari et al. 2012). Several studies have so far been conducted on the site selection of landfills including: Donevska et al. (2012) and Gorsevski et al. (2012) added fuzzy approach to the combined use of AHP and GIS and tested its application in determining the proper position. Researchers such as Guiqin et al. (2009), Moeinaddini (2010), Sener et al. (2010) and Eskandari et al. (2012) took advantage ofa combination of AHP and GIS for similar objectives.

2. The study area

Khorramabad, the capital of Lorestan Province, Iran, is one of the most importantcities in the western Iran. This city is in 21 minutes and 48 degrees longitude and 43 minutes and 30 degrees latitude.It is a mountainous terrain at an altitude of 1300 meters above the sea level and is surrounded by Komreci, Shynshah, Taf, Makhmalkoh, Yafte and Aspikoh mountains (Fig. 1).

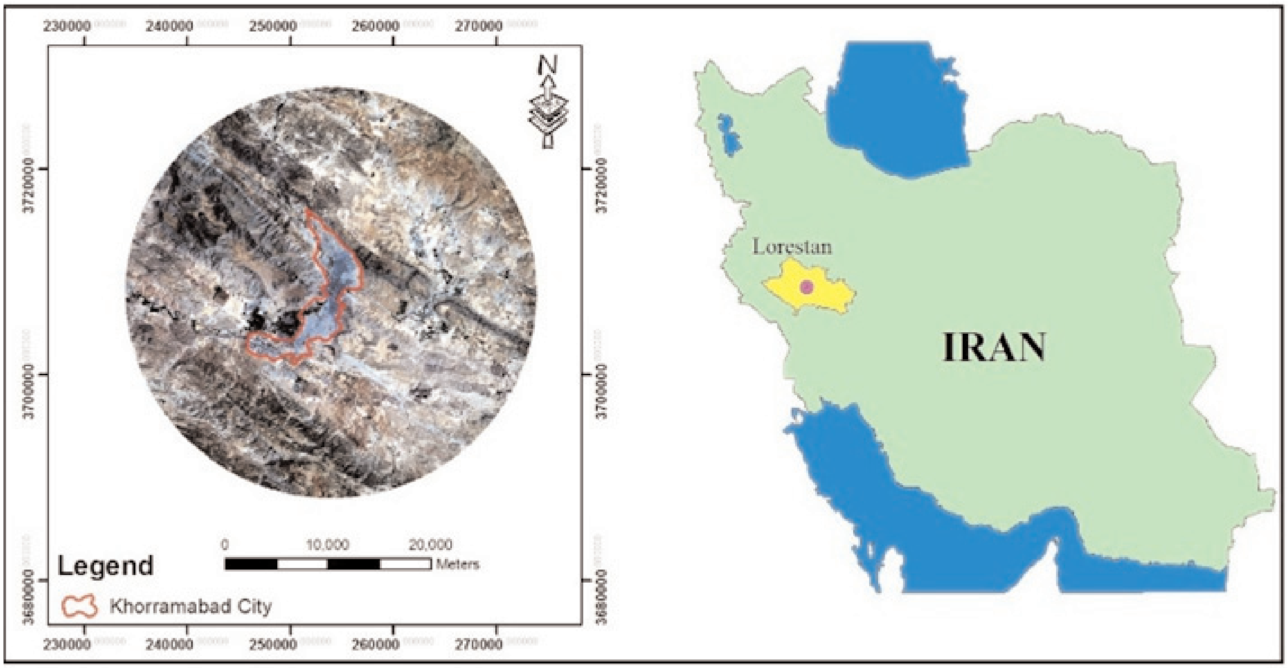


Figure 1. Geographical location of Khorramabad

Khorramabad is located in the folded Zagros zone on the basis of geological divisions.This zone includes Zagros Mountains in southwest Iran with simple and slow structure and low tectonic activities.This is also a set of compressed and very close sequence of anticlines to each otherwith an upright and northwest-southeast axis. Khorramabad is located on one of these anticlines.

3. Materials and Methods

By examining conducted studies andresources, 13 criteria including distance from city,distance from village, distance from rivers,distance fromairport, distance from historical places, groundwater,land use, lithology, distance from major and minor roads,slope and elevation difference above sea level were selectedas factors affecting site selection of municipal waste landfill in Khorramabad.The overall process consisted of gathering information, evaluating current environmental waste and landfill waste disposal site, and selection mapping using weighted linear combination.

3.1 Data collection

In this study,the criteriawere divided into five groups of environmental, socioeconomic, access, hydrological and tectonic factors.The criteriaand sub-criteria were selected, evaluated and identifiedalong with standards according to Iranian Department of Environment, Interior Ministry of Iran andinternational experiences (Table 1).

3.2 Weighted linear combination (WLC)

In this study, weighted linear combination (WLC) was used for the site selection of Khorramabads' municipal waste landfill.In this method, each informationlayer wasfirst standardizedusing fuzzy method. Then, using analytic hierarchy process and doublecomparison, the weight of each layer is determined and the final map of areas suitable for site selection of landfill we=as prepared by the integration of all layersstandardized in their weight.

3.2.1 Standardization

By determining a set of criteria for evaluating deci-

Table 1. Criteria, sub-criteria and their acceptable range

Criterion	Sub-criterion	Type of data	Range	Extraction method	Standardization method
Environmental factors	Slope	Qualitative	0-5 degree	Topographic map of the area	Linear
	Elevation	Quantitative	Less than 1300m	Topographic map of the area	Linear
Socio-economic factors	Urban areas	Qualitative	5000-10000m	Satellite images	Gaussian
	Rural areas	Quantitative	More than 1000m	Satellite images	Linear
	Land use	Qualitative	Use with a low value	Satellite images and field study	User defined
	Distance from airport	Quantitative	More than 4000m	Satellite images	Linear
	Distance from historic places	Qualitative	More than 3000m	Field study	Linear
Accessfactors	Major roads	Quantitative	1000-3000m	Google Earth images	Gaussian
	Minor roads	Qualitative	1000-8000m	Google Earth images	Gaussian
Hydrological factors	Distance from river	Quantitative	More than 500m	Dem map of the area	Linear
	Groundwater	Qualitative	More than 20m	Water level in the piezometer of the area	Linear
Tectonic factors	Lithology	Quantitative	Hard and impermeable formations	Satellite images (using the band combination 531 images +ETM) and field studies	Userdefined
	Fault	Quantitative	More than 2000m	Satellite images (using directional filters) and field studies	Linear

sion-making items, storing each criteria as a map layer in ArcGISdatabaseis required. A variety of scales is used to measure the traits. Accordingly, the conversionof values indifferent map layers to the comparable units and in proportion toeach otheris necessary in order to have comparable and standard maps. One of the standardization methods is fuzzy method.Fuzzy operation takes inputs and allocates a suitable gradeto each by the related membership functions (Mahjori 2012). One of the most basic discussionsin fuzzy theoryis membership function and the way they are defined.The difference basis among fuzzy methods with other methods is in the definition of the membership function which can be defined as the dependency of reference sets' elementsto its subsets displayed in the form ofцc(X). There is no specific algorithm to obtain the membership function; however, experience, innovation, and evenpersonal opinions are effective in the formation and definition of membership function.In this study, the maps ofeach factor affecting the site selection of Khorramabad landfill have turned to fuzzymaps using Linear, Gaussian and user definedmembership functions (Table 1).

3.2.2 Prioritization of factors and weighting them using hierarchical approach

In this study, Analytic Hierarchy Process (AHP) which is a multi-criteria decision-making model wasused for the site selection of landfill in Khorramabad. AHP is a semi-quantitative methodincluding a weight matrixon the basis ofpaired comparisons among factors and determining the contribution of each factor in the site selection of landfills.This method provided by Saaty in 1980 is based on three principles of analysis, comparative judgment and synthesis of priorities (Saaty 1980).

In AHP, the method is in a way thatto determine the preference of various factors and change them intoquantitativeamounts, oral judgments (expert opinion) are first usedon the basis of paired comparisons so that decision makerconsiders the preference of a factor to the other as Table (2) and converts these judgments into the quantitativeamountsbetween 1 to 9. Then, the results of these comparisons are imported in Expert Choice softwareto measure inconsistency index.If the calculated index is less than 0.1, the results are acceptable; otherwise, weightingshould be reviewed again.

4. Discussion and conclusion

4.1 Environmental evaluation of current landfill

As it was stated, the composition of waste variesin different areas and times and cultural and economic issues in each community are the most important factor in determining it.According to the conducted surveys, the most proportion of productive waste allocates to the perishable materials (on average more than 86%) in Khorramabad as many parts of the country whereare the lack of a proper system for recycling and composting. Therefore, the environmental impacts from acidic leachate production caused by perishable ingredients in the current landfill are very important.Plastic, paper, and cardboard are alsowith the distance of perishable materials in the next places of waste produced in the city (Table 3).

Studies show that the leachate of Khorramabads' landfills hasweak alkalinity which reflects their average age (Alloway et al. 1997). By increasing the waste disposal time, pH increases.The organic active is measured using BOD and COD of its leachate in landfill. In landfill, the activity of microorganisms is increased over time i.e. the amount of Biochemical Oxygen Demand (BOD) activitiesis increased in the leachate. Chemical Oxygen Demand (COD) is raised

Table 2. Classifyingthe preference ofamounts of weights based on expert judgment (Saaty and Vargas, 2001)

Linguistic description of classes' preference	Numerical value of weights
Very important or more favorable	9
Very strong importance	7
Strong importance or desirability	5
A little more favorable or a little more important	3
Importance or the same desirability	1
Priority among intervals	8, 6, 4, 2

as a reversedprocess compared to BOD in a way that the amount of COD is dropped over time and the amount of BOD of leachate. The results indicate that-biochemical and chemical activitiesare extremely highin the desired site and the high levels of BOD and CODin leachateconfirm it (Table 4). The main reason for the high rate of BOD, COD and nitrate may pertain to the high rateof perishable material in the waste transferred to the region.Compounds containing nitrogen and phosphorus are the most important inorganic contaminants in the leachate of landfill. According to the obtained results, these compounds have very high and risk levelsin the studied area.

In this area, given the high rate of chemical parameters of leachate, there will be the probability of soil contamination and as a result, the pollution of plants and animalsin a chain system. The results of conducted analyses (Table 5) show thatthe soil contamination withsome heavy metalsis widely known in the studied area and these metalscan also be observed in plantsin the studied area.Based on the results of analyses, paying special attention to the environmental impacts of the current landfill seems quintessential.

Table 3. Composition of waste produced (%) in Khorramabad and their seasonal changes

Parameters	Spring	Summer	Fall	Winter	Annual average
Perishable materials	86.63	881.41	89.30	89.87	86.80
Plastic	5.09	6.07	3.25	3.71	4.53
Paper	4.22	5.06	2.88	2.80	3.74
Cardboard	0.91	2.47	0.68	0.42	1.12
Ferrous metals	0.90	0.89	1.09	0.71	0.90
Glass	0.31	1.00	1.21	1.04	0.89
Textiles	0.37	0.75	0.82	0.67	0.65
Other products	0.72	0.85	0.26	0.22	0.51
Trash	0.38	0.60	0.31	0.34	0.41
Wood	0.12	0.34	0.12	0.18	0.19
	0.11	0.26	0.11	0.01	0.12
PET	0.14	0.13	0.08	0.09	0.11

Table 4. Results of the analysis of physicochemical parameters forthe leachate of landfill in Khorramabad

Parameter	Amount	Parameter	Amount
PH	7.94	Iron (mg/l)	12.5
Electrical conductivity (µS/cm)	6500	Hg(mg/l)	12.5
TDS (mg/l)	19040	Pb (mg/l)	1
Total hardness (mg/l)	12133	Barium (mg/l)	7.5
Chloride (mg/l)	1205	Silver (mg/l)	1
Nitrate (mg/l)	637.59	Zinc (mg/l)	16
Nitrite (mg/l)	1.988	Orthophosphate (mg/l)	98.99
Sulfate (mg/l)	278.85	Polyphosphate (mg/l)	1.8
Calcium (mg/l)	3450	Total phosphate (mg/l)	100.79
Sodium (mg/l)	3150	BOD (mg/l)	7400
Potassium (mg/l)	4000	COD (mg/l)	8785

4.2 Site selection of optimal urban landfill

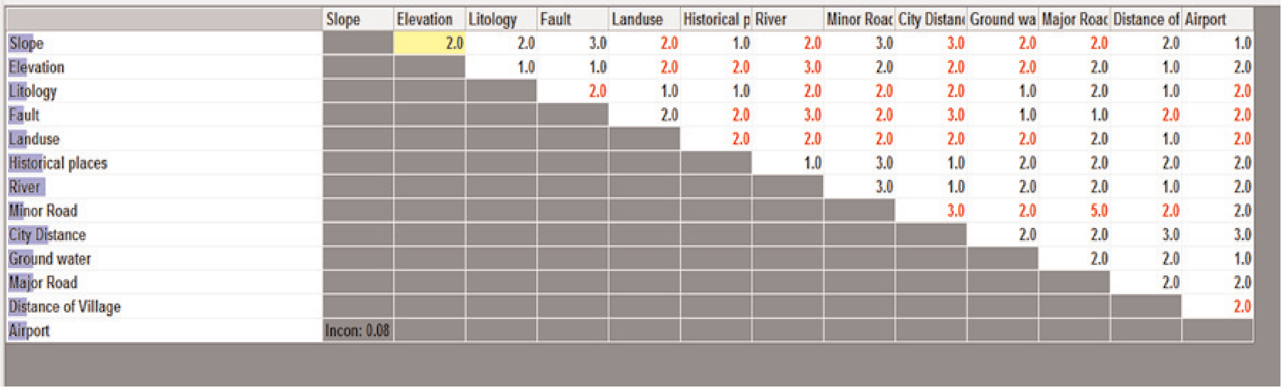
In this study, after preparing the desired layers, the layers were standardized. Fuzzy method was used to standardize the data.The point which should be considered for standardization in the selection of fuzzy function is the increasing or decreasing desired sub-criteria. For example, the more the distance from river, the more suitable the distance is for the purpose of site selection of landfill. Accordingly, incremental linear function is used here. Some sub-criteria such

Table 5.Measured heavy metals in soil and plants in thestudy area

Measured parameters in soil (%)		Measured parameters in plants (%)	
Lead	0.0017	Lead	0.004
Chromium	0.0035	Chromium	0.0006
Copper	0.0020	Copper	0.0004
Barium	0.1025	Barium	0.0258
Manganese	0.0253	Manganese	0.0045
Zinc	0.0068	Zinc	0.0025
Nickel	0.0067	Nickel	0.0004
Mercury	0.0200	Mercury	0.0095

as distance from city, distance from rural areas and distance from road have an increasing - decreasing distance because of economic and environmental justifications, as a result, Gaussian membership function can be used to standardize them. For the qualitative data such as land use and lithology, using the expert opinion, each of the units in the range of zero to one was weighted and standardized using the User defined membership functions. After standardizing the data, given that each sub-criterionhas adifferent effect on determining the appropriate landfill, weighting the layers will be necessary. So, this hierarchical analysis method was used.In so doing, by paired comparison (according to Table 2), the layers were first double compared (Fig. 2).The obtained results were transferred to Expert Choice software to calculate the weights of each obtained factor. The results obtained from the measurement of inconsistency coefficient indicated that the comparisonshave been correctlydone (Fig. 3).

In the following, to prepare a final map of site selection of Khorramabad's waste in the Arc GIS Desktop software, Raster calculator was used.Accordingly, thestandardized mapswere multiplied byweights obtained for each criterion and by collecting maps of all factors, the final map was prepared for the site selection of landfill (Fig. 4).



	Slope	Elevation	Litology	Fault	Landuse	Historical p	River	Minor Roac	City Distan	Ground wa	Major Roac	Distance of	Airport
Slope		2.0	2.0	3.0	2.0	1.0	2.0	3.0	3.0	2.0	2.0	2.0	1.0
Elevation			1.0	1.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	1.0	2.0
Litology				2.0	1.0	1.0	2.0	2.0	2.0	1.0	2.0	1.0	2.0
Fault					2.0	2.0	3.0	2.0	3.0	1.0	1.0	2.0	2.0
Landuse						2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0
Historical places							1.0	3.0	1.0	2.0	2.0	2.0	2.0
River								3.0	1.0	2.0	2.0	1.0	2.0
Minor Road									3.0	2.0	5.0	2.0	2.0
City Distance										2.0	2.0	3.0	3.0
Ground water											2.0	2.0	1.0
Major Road												2.0	2.0
Distance of Village													2.0
Airport	Incon: 0.08												

Figure 2. Comparative matrix of factors influencing the site selection of landfill

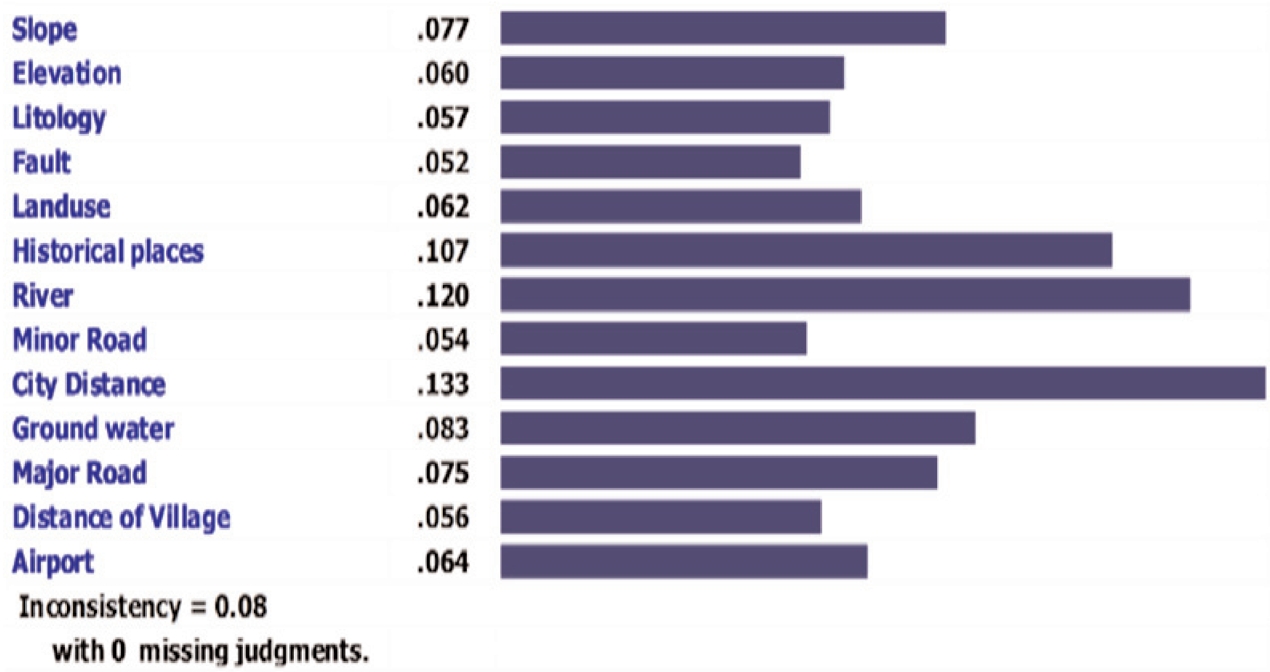


Figure 3. Diagram of the final weight applied to the main criterion for the site selection of landfill by Expert Choice software

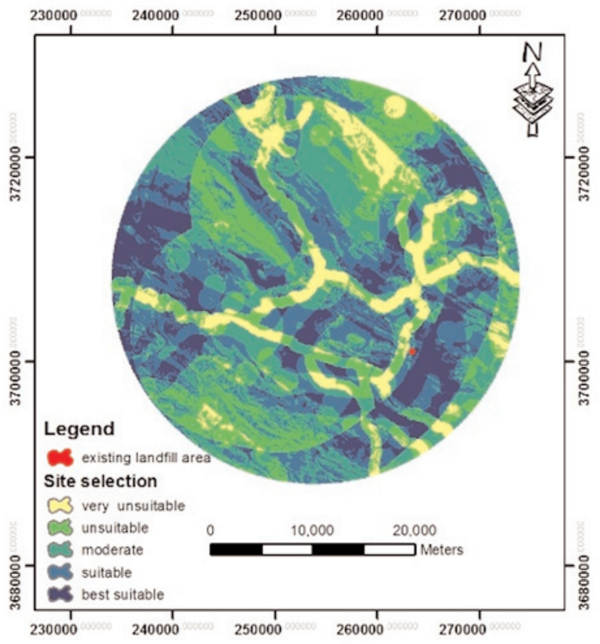


Table 4. Map of site selection of Khorramaba's landfill

5. Conclusion

In this study, bythe environmental assessment and site selection of Khorramaba's landfill,the following results were obtained:

1. After selecting appropriate criteria for the site selection of landfills, the studied area was zoned in terms of the ability of landfill using weighted linear combination. According to the obtained results, 10.03%, 21.85%, 28.38%, 25.30% and 14.42% of area of the area are in the very unsuitable, unsuitable, moderate, suitable and the bestsuitable zones, respectively.

2. Current landfill of Khorramabad is not acceptable due to its location in the poorand moderatezones, so choosing a new site is essential.

3. Given the daily production of 300 tons of waste in Khorramabad and the city's current population (360 thousand), the amount of daily waste produced by citizens is 0.841kg. Therefore, it can be said that Khorramabad ispotential to create a composting plant. Recyclingorganic materials and composting not only reduces the volume of waste but alsowill be very usefulfor agricultural lands.

4. After perishable materials, paper, plastics and rubber have the highest percentage of waste in Khorramabad and the most principled method to deal with is the separation, collection and recycling of these materials. So suitable places and ways should be considered to collect the materials.

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