

Evaluating AHP and WLC Methods in Site Selection of Waste Landfill (Case Study: Amol, North of Iran)

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ABSTRACT

Landfill siting should take into account a wide range of territorial and legal factors in order to reduce negative impacts on the environment. This research focused on determining suitable locations for construction of a suitable disposal centers. So in first stage, effective factors in site selection of waste landfill in Amol in Mazandaran county, Iran were considered; another stage consists of making numerical and weighting the 8 layers according to existent standards which include: slope, erosion, distance to fault, distance to surface waters, depth to ground waters, distance to agricultural lands and gardens, distance to road, distance to power transition lines, and entering mentioned layers into IDRISI and Arc GIS software and establishing specific databases for urban waste landfill and implementing different models of analytic multi criteria decision making such as analytic hierarchy process and weighted linear combination on current layers. Results of this research indicated that weighted linear combination in primitive stage have higher decision making power in locating burying place than analytic hierarchy process through choosing three site and at the end by selecting final site for waste landfill in south of Amol. At the end, through overlapping and also compounding similarities of these models in Arc GIS software, a site with 110 hectare area and accepting 170 ton waste per day for 20 years, was selected as recommended and final place of waste landfill in Amol. Results shows that this instrument has the potential to assist planners, decision makers and other agents involved in the process of selecting suitable sites for municipal landfills.

KEYWORD: Waste disposal; municipal solid waste; GIS, Amol.

INTRODUCTION

City is combination of complex phenomenon which all of its elements are completely connected to each other in an organized way so that disorder in each elements caused deficiency in whole system. Human have influence on environment and are affected by its results and consequences which indicates reciprocal relationship between human and environment [1].

The components of municipal solid waste (MSW) management include reducing the waste, reusing, recycling, energy recovery, incineration and landfilling [2]. Even if a combination of the mentioned or other management techniques is utilized and if policies of waste reduction and reuse are applied, the existence of a sanitary landfill is necessary to a MSW management system [3]. Decision and policy making based on detailed information as well as modeling for solving various environmental and ecological problems (e.g., siting MSW landfill) seem necessary [4]. Regarding the problems related to making decisions on (e.g., siting landfill with multi criteria), it can be said that decision making is not simple in this case, and the speed and precision are greatly reduced due to the lack of standards [5]. GIS can recognize, correlate and analyze the spatial relationship between mapped phenomena, thereby enabling policy-makers to link disparate sources of information, perform sophisticated analysis, visualize trends, project outcomes and strategize long-term planning goals [6].

In Iran, the waste demand has grown rapidly over the past years. A demand study for the country shows the need for new capacity to meet the growing wastes. Therefore, it's necessary to selection of new disposal centres. One of the most important factors, which should be considered in new disposal centre construction process, is the location of the disposal centre [7]. The suitability of selected site for disposal centre affects the amount of generated waste and the cost of transmission. In this paper, the required conditions for the establishment of disposal centres are comprehensively studied for Amol city in Mazandaran province in north of Iran. However, these effective planning tools GIS have not been effectively used in Mazandaran province in north of Iran, and certainly not in Amol city. Thus, the purpose of this paper is to demonstrate the use of GIS models to identify appropriate areas which are suitable for reasonable, convenient, and administratively transparent waste landfill siting in Amol.

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STUDY AREA

Amol is a city in and the capital of Amol County, Mazandaran Province, Iran. The Amol city located in 36°23'N latitude and 52°20'E longitude. At the 2006 census, its population was 197,470, in 55,183 families [8]. Amol and the old part of town is the first of the four towns that populate the world in which there is Nzamyh. Amol is a city of strategic accounts from beginning to end. Amol is located on the Haraz river bank. It is less than 20 kilometres (12 mi) south of the Caspian Sea and less than 10 kilometres (6.2 mi) north of the Alborz mountains (Fig. 1).

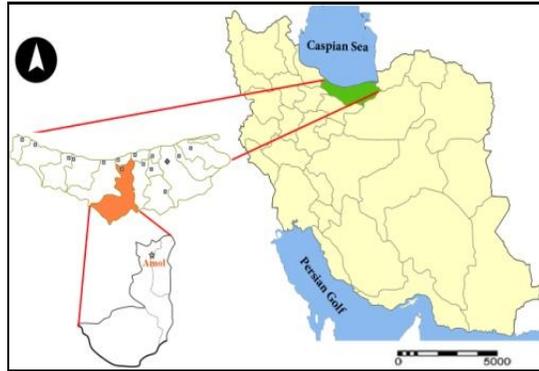


Fig 1: Geographical position of study area

MATERIALS AND METHODS

To locate in geographical information system, effective factors, criteria and limitations should be provide as map layers, then must be process and analyze. In this research, Additional data were derived from hard copy maps by scanning and digitizing topography maps of 1:50000 are used to supply slope map and slope aspect within the study area were obtained from a digital elevation model (DEM), map of communication lines, power lines extracted from Landsat ETM+ imagery of 11th July 2009 was obtained from the united states geological survey (USGS) were used as overlays to show topographic details in relation to digitized road network; ground water layer and surface water, fault map (extracted from geology maps), geology map in 1:100000 scale (provided from geological survey of Iran), erosion map (Using PSIAC model by nine layers) and vegetation.

Noticing that positioning process is a multi feature issue of decision making and can be performed by raster model; in choosing software it should take into consideration that selected software in addition to Vector model, will support raster model and also is capable to use multi feature decision making principles [9]. Therefore, according to performed investigations, software of Arc GIS 9.3 (ESRI; Redlands, CA, USA), IDRISI 15 are selected for multi feature analysis operation. During this research, Autodesk Map software was used in making numeral, modifying and providing layers. In this research, two models are used to select site of waste landfill in Amol city which consist of: Analytic Hierarchy Process and Weighted Linear Combination.

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP), which represented by "Saaty" in 1980, is based on three principles: refraction, comparative judgment and synthesis of priorities. In refraction principle it is needed to divide decision making problem into hierarchical form where elements have hierarchical structure in special levels through considering their origin in higher levels. "Synthesis principle" represented each site priorities with determined proportion scale in different levels of hierarchy and created compound set of priorities for elements in lower hierarchy (i.e. options). Through defining principle, AHP method consists of following stages [10]:

A. Producing binary comparative matrix:

This method applies basic scale with 1 to 9 values to determine the extent of relative priorities of two criterions (Table 1).

Table 1: Pair-wise comparison 9-point rating scale [11]

| Importance | Definition | Explanation |
|------------|------------------------|---------------------------------------------------------------------------------|
| 1 | Equal importance | Contribution to objective is equal |
| 3 | Moderate importance | Attribute is slightly favored over another |
| 5 | Strong importance | Attribute is strongly favored over another |
| 7 | Very strong importance | Attribute is very strongly favored over another |
| 9 | Extreme importance | Evidence favoring one attribute is of the highest possible order of affirmation |
| 2, 4, 6, 8 | Intermediate values | When compromise is needed |

B. Measuring Criterion Weight:

This stage includes following steps: 1. Sum of the values for each column of binary comparative matrix. 2. Dividing each matrix component on total of its column (Resulted matrix is called "Normalized binary comparative matrix"). 3. Measuring the mean of component in each row of normalized matrix.

C. Estimating agreement ratio: This stage includes following operations:

1. Determining Total weighted vector by multiplying the weight of first scale in first column of main binary comparative matrix, then multiplying second scale in second column, third scale in third column of main matrix and finally, summing these values in lines.
2. Determining agreement vector by dividing weight vector on scale weights which already were specified.

Weighted linear combination method (WLC)

Weighted linear combination method (WLC), is the most common technique in analyzing the multi scale evaluation. This method is based on the content of weight average. Analyzer or decision maker based on "relative importance" weighted directly to the scales. Then through multiplying relative weight in feature value, a final measure can be obtained for each option (Such as picture element in spatial analysis). After specifying the final value for each options, alternatives which have higher value, will be most proper options for desired purpose [12, 13]. Determining earth proportion for a specific operation or evaluating the potential of particular occurrence can be considered as desired purpose. In this method, decision making principle calculated the value of each A_i options by equation (1):

$$A_i = \sum_{j=1}^n W_j \times X_{ij} \quad (1)$$

Where, w_j is the j criterion weight; x_{ij} is a value which accepted i place in relation to j criterion. In other word, this value can indicate appropriate degree of i location in relation to j criterion; n is total number of criteria and A_i is a value which finally will attach to i location. In this method, total weight should be equal with 1; otherwise in last stage A_i should be divided on total of all weight thus A_i output will be between 0 and 1. Because higher or lower amount of output can be duo to an appropriate or inappropriate option, weight normalizing can be withdraw. At the end, ideal option will be one which has more amount of A_i [13].

Weighted linear combination method can be performed by geographical information system and overlapping capacities of this system. Use of this method is practical in both raster format and geographical information system.

RESULTS AND DISCUSSION

Integrating informational layers and determining suitable place for waste landfill in each model

Standardizing map layers

To locate and compound maps, efficient layers in locating should be standardize. It means that through decision making principles, layers should transform into scale which can combine them with each other [9]. For this case, two methods of Analytic Hierarchy process and weighted linear combination are used.

A) Standardizing maps of analytic hierarchy process

To perform this method, first, each studied criteria is compared, extent of relative importance will devote to each couple ratio and enter it in a matrix. Then weights and consistency ratio (CR) will be measured, if consistency ratio was lower than 0.1, then adjust it for an acceptable value through changing in binary comparative matrix. Duo to the weakness of Arc GIS software in this part, measuring of weights ratio and consistency ratio performed in WEIGHT majle of IDRISI software. If performed comparisons were acceptable, conclusion will be announced. Lower CR ratio than 0.1 is condition which results will be announces. It must be mentioned that this ratio obtained 0.07 for our data which indicates that obtained result is acceptable.

B) Standardizing maps of weighted linear combination

In weighted linear combination, each location is based on extent which observed desired criterion, gives a membership value which demonstrated the ideality of site. It means that each site with higher membership value will have higher ideality. Larger values will have more acceptability in these scales. Means that 1 value demonstrated higher acceptability and 0 indicated lack of acceptability and a spectrum of color take place between these two numbers [13].

In addition to scale selection process to supply WLC maps, type of WLC function should be investigated and more proper function must be selected for desired criterion. We used the Sigmoidal function in IDRISI software.

Integrating layers using decision making principles MADM:

After maps standardizing, integration stages of used layers will start to achieve proper waste landfill site (sites).

A) Integration by AHP method

In AHP method, locating operation was performed using MAP CALCULATOR menu. Obtained result is a map which classified into five classes, then area of each sites are measured by AREA menu (Fig. 2).

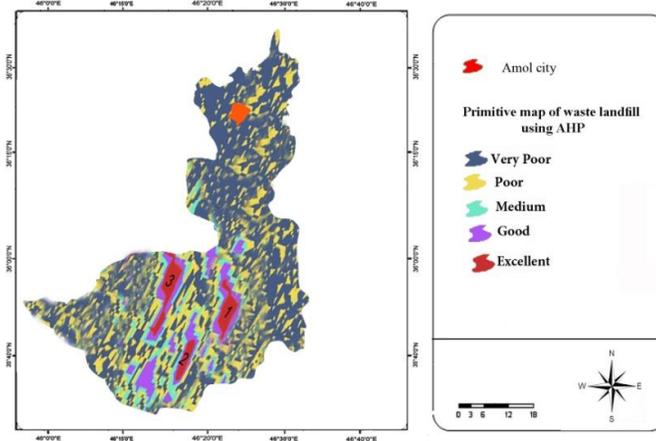


Fig 2: Primitive map of waste landfill using AHP in Amol

Finally, sites with area higher than 110 hectare will be separated as acceptable lands and final map will be provided (Fig. 3)

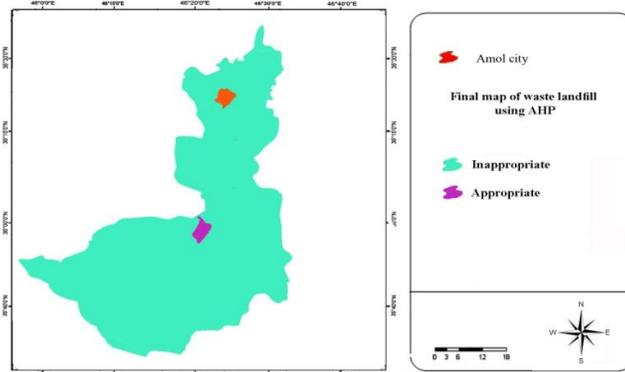


Fig 3: Final map of waste landfill using AHP in Amol

B) Integration by WLC method

Duo to widespread capacities of IDRISI software in multi criteria decision making analysis, this software was used to perform WLC integration and site selection of waste landfill. In this stage through use of MCE menu and WLC option, limitations maps and criterion maps will be integrated through apply corresponding weights as criterion weights. Results of this integration are demonstrated as primitive and final maps (Fig. 4).

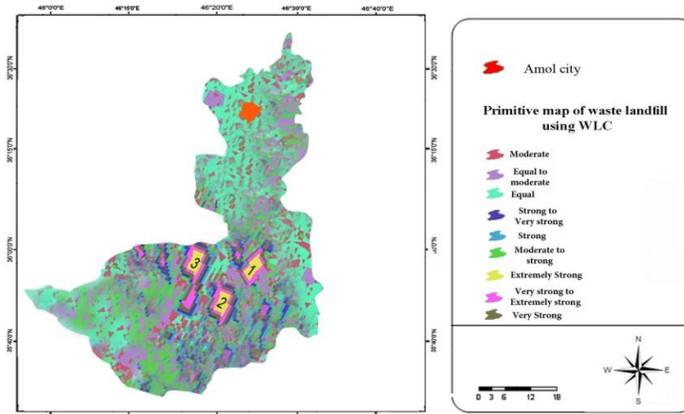


Fig 4: Primitive map of waste landfill using WLC in Amol

At the end, sites with area higher than 110 hectare from excellent classes will be selected (Fig. 5)

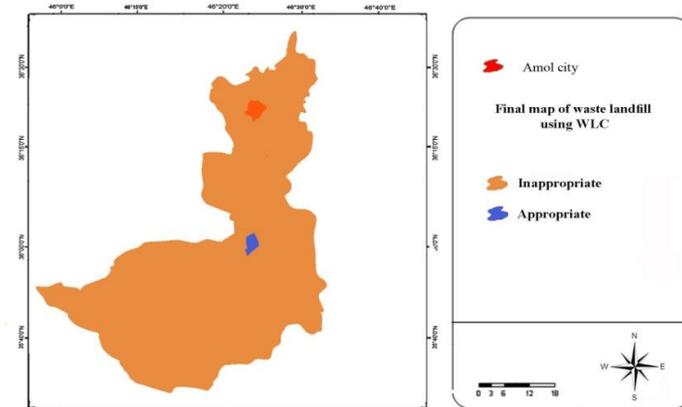


Fig 5: Final map of waste landfill using WLC in Amol

C) Final map preparation

Finally, regarding to different factors role in site selection of waste landfill of Amol, three sites were found for waste landfill of Amol according to different criteria from two methods. Characteristics of each three sites are mentioned in (Table 2) according to factors involved in locating process.

Table 2 : Features of three obtained sites for waste disposal of Amol

| Prior group | Evaluation components | Site number 1 | Site number 2 | Site number 3 |
|-----------------------------------|---------------------------------|----------------|-------------------------|----------------------------|
| Geomorphologic | Slope (percent) | 16 | 5 | 9 |
| | Erosion | High | Very low | medium |
| | Topography (natural phenomenon) | Valley | Field with gentle slope | Surface with average slope |
| Geology | Bedrock | Shale and Lime | Andesite | Andesite and clay |
| | Soil quality | Gravel | Clay | Gravel-Clay |
| | Fault (meter) | 200 | 600 | 400 |
| Hydrology and Geohydrology | Surface waters(meter) | 170 | 900 | 1000 |
| | Ground waters (meter) | 15 | 45 | 35 |
| Different factors | Land cover | Pasture | Dry farmland | Dry farmland |
| | Power lines (meter) | 1600 | 2100 | 3300 |

To select final site of waste landfill of Amol, results of analytic hierarchy process and weighted linear combination methods were compared to each other and through overlaying them on each other final site of waste landfill was selected. According to all main and secondary criteria which mentioned in Table 2 and with regard to performed field observation among three sites obtained from two applied models, site number 2 with area of 110 hectare is specified as recommended and final site of waste landfill for Amol city (Fig. 6).

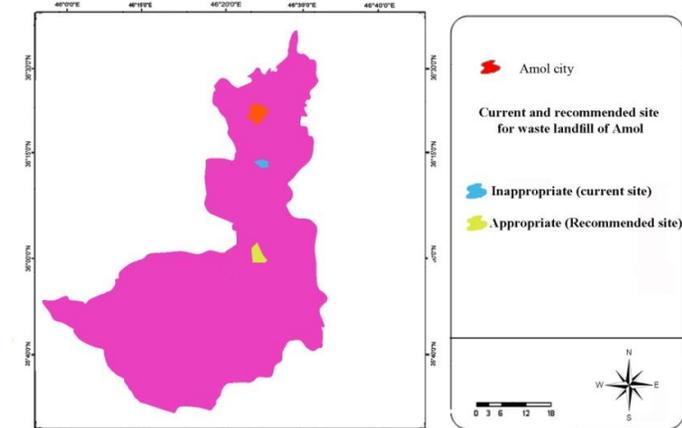


Fig 6: Current and recommended site for waste landfill of Amol

CONCLUSION

The final suitability index not only provides information about the optimality of the location, but also about potential problems that can affect one or more environmental components. This data is fundamental for any decision about whether or not to locate a landfill at a particular site. Based on the results obtained in our study as well as the sensitivity analysis carried out, we can conclude that Geographical Information Systems are a useful tool for the optimal siting of landfills. According to obtained results from two models of analytic hierarchy process and weighted linear combination and role of different factors in site of urban waste landfill, site number 2 is selected as the best alternative for waste landfill in south of Amol, because according to geomorphologic factors, this location have a slope lower than 10 percent; in the case of earth resistance against erosion take place in high resistance (Andesite) class; in the case of geology factors, have Andesite bedrock quality; in case soil science, the site number 2 is combination of clay; faults in this site is also far from major and minor faults; according to hydrologic and hydrogeology factors, site number 2 have more ideal and better conditions than other locations duo to its distance from surface water (900 meter) and ground water (45 meter). On land use site number 2 is placed in dry farmland class and is away from high quality agricultural lands and fruit gardens. According to 110 area of this site, it can be useful for next 15-20 years for waste landfill of Amol. In the case of distance from power transition lines, this site with 2100 (m) distance, have best possible condition for site selection of waste landfill. Models evaluating indicated that according to certain locations options, choices limitations and range of criteria values, WLC method has better segregation power among current spectra. Our study shows that this instrument has the potential to assist planners, decision makers and other agents involved in the process of selecting suitable sites for municipal landfills since it increases their knowledge of the physical terrain, thus facilitating the analysis and implementation of action plans.

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