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Research Article

USING GEOGRAPHICAL INFORMATION SYSTEM FOR WASTE LANDFILL SITE SELECTION MANAGEMENT BY AHP AND TOPSIS

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ABSTRACT
Waste landfill site can potentially cause negative and harmful effects on health, economic and environmental dimensions. Therefore, there is a need of a wide evaluation to establish landfill site. Using TOPSIS and AHP methods, the present study attempted to locate waste landfill in Qale Dare Si Village of Makoo City in Uremia Province. In this work, appropriate regions for urban solid waste landfill for a 10-year period were determined by applying landfill site localization criteria through TOPSIS and AHP methods. As the evaluation results revealed, out of 4 selected regions, alternative1 is the outmost alternative to establish landfill site.As found, the results obtained from AHP method have a higher accuracy and confidence since in each investigated problem, the weight and importance of each criterion is determined relative to other criteria. Therefore, in the present study, AHP process has been more applicable and it is suggested as a more efficient method.

Keywords: *Waste Landfill*

INTRODUCTION
Given to the excessive development of cities, the lack of proper consumption and increasing growth of wastes production as well as wastes management system inefficacy, healthy landfill is the most reasonable and affordable method for urban wastes landfill. Just like every engineering project, healthy landfill of urban wastes requires basic information and precise planning. In the process of waste landfill site selection, various parameters and their complex communications cause experts to use a system which can analyze different parameters, the effect size of each of them and their relations along with acceptable accuracy and adequate speed. As the most welcomed approaches, we can refer to decision making models in GIS (Malekzadez, 2008). With respect to the high volume of data and the need of information processing in the process of landfill site localization and the necessity of prioritizing proposed landfill alternatives, GIS, AHP (Analytic Hierarchy Process) and WLC (Weighted Linear Combination) methods can be used. Sener *et al.,* (2006) proposed to use GIS, AHP and fuzzy logic simultaneously. Gemitzi *et al.,* (2007) and Ount and Soner (2008) also investigated fuzzy TOPSISand AHP for optimal landfill site selection. In Iran, Panahande *et al.,* (2010), and Janaheri *et al.,* (2006) have employed GIS and AHP capabilities to process data, screen susceptible regions and prioritize proposed landfill sites. Also, TOPSIS technique has been used by Agahi and Abdi (1990) for geographical prioritization of establishing agricultural industries in rural regions, Malekzade (Naumann, 1998) to rank 6 industrial branches of Khorasan Province, Aghaii *et al.,* (1990) to study the capacity and site of the third Sugar factory of Kermanshah Province, and Iranzade and BabaeeHeravi (2010) to prioritize the factors influencing enabling Gas Company of Tabriz.

MATERIALS AND METHODS
AHP Method*:* for the first time, this method was proposed by Saati (2009). In AHP process, to weight criteria and alternatives, paired comparison method is used. Such that, a decision maker compare criteria and sub-criteria of each index in pair and there is no need to weight all indices simultaneously. In his method, relative weighting of elements is determined through paired comparison of each level relative to the respective element at higher level. Computing the weight of elements of each level relative to its higher level though paired comparison and relative weights integration, the final weight of each alternative is computed (Ghodsipour, 2005).

TOPSIS Method: Hwang and Yoon (1981) have proposed various models including TOPSIS. TOPSIS is a very strong decision making method to prioritize alternatives through simulating ideal response. In this method, the selected alternative should have the shortest distance from the ideal response and the longest distance from the most inefficient response. Onvert and Soner (2008) proposed a method combining AHP and TOPSIS for urban waste landfill site selection in Istanbul. In this research, they used AHP to compute the weight of indices and employed TOPSIS to rank the selected sites (Poor *et al.,* 2007; Al-Jarrah and Abu-Qdais, 2006; Khorasani and Nezhadkoraki, 1999; Leao *et al.*, 2001; Moeinadini, 2007; Saaty, 2008; Momeni, 2006; Iran Statistics Center, 2006).

The present paper attempts to analyze the efficacy of TOPSIS and AHP decision support technique in the frame of multi-criteria decision making to prioritize the proposed landfill alternatives in the investigated region. To this end, it has been used to select appropriate sites in the region which currently faces with the problem of waste landfill site.

Methodology

In the present research, the effective criteria in waste landfill site selection in the studied region were first determined. These criteria were formulated by investigating various standards such as standards related to Environment Conservation Organization, the Ministry of Iran and global standards as well as reviewing internal and international resources (Khorshiddoost and Adeli, 2009; Saeedi *et al.*, 2009) investigating the conditions of the studied region and its effective factors. Then, the layers related to each criterion were provided from respective organizations, processed and changed into vector form. In the following, integrating these layers in Arc GIS Software, the least area of the proposed landfill regions in the studied region was specified. Then, to investigate the efficacy of TOPSIS and AHP methods and compare their results in the proposed landfill alternatives prioritization, both methods were used.

In this study, the criteria employed in AHP process were classified and weighted based on the opinion of experts. There are several methods to determine the importance (weight) coefficient of the criteria and sub-criteria and paired comparison is the most common method. In this method, criteria are compared in pair and the importance degree of each criterion relative to others is specified. To do so, a standard method proposed by Satаty (1980) can be employed. In the proposed method, a number from 1 to 9 is attributed to each paired comparison. The meaning of each number has been explained in Table 1. After weighting, the weights should be normalized (8).

To normalize the weights, various methods are used. In this research, the weights are normalized through dividing each weight by the sum of the weights of the same column (8). After determining the importance coefficient of the criteria and sub-criteria, the importance coefficient of the alternatives should be determined. At this stage, the priority of each of the alternatives relative to each of the sub-criteria and in direct relation with the criterion (in case of lack of any sub-criterion) is judged. The process of obtaining the weight of the alternatives relative to each of the criteria is similar to determining the importance coefficient of the criteria relative to the target. In both cases, judgments are performed based on paired comparison of the criteria or alternatives based on the 9-quantity scale of Saati. Then, the obtained result is recorded in paired comparison matrix of the criteria or alternatives and the considered importance coefficients are computed through normalizing the rows of these matrices. Various alternatives are compared relative to criteria and sub-criteria (if any) while comparing the criteria with each other is performed relative to the target of the study. Finally, the weights of the criteria, sub-criteria and alternatives consistency ratio (CR) are computed using Excel and Expert Choice Softwares. Notably, if the computed CR ratio is less than 0.1, the comparisons are accepted and the weights of the criteria are extracted. However, if the computed ratio is more than 0.1, by applying some changes in paired matrix, the CR can be regulated at an acceptable level (Bertolini *et al.,* 2006; Bowen, 1990).

In TOPSIS method is thedecision making matrix of$m \times n$ in which m alternative and n criteria are evaluated. In this model, for mathematical computations, all the values attributed to the criteria should be quantitative and in case of qualitative attributed values, they should be changed into quantitative values. The criteria and indices have not identical priority and importance relative to each other and this problem is solved through the table of indices weights. For this purpose, the table of the investigated criteria and alternatives is formulated. At the nest stage, all the values belonged to decision making matrix entries should be changed into dimensionless values.

To make all the following criteria identical, the figures within the table are normalized in such a way that the range of all the criteria is put into the range of 0 to 1. The normalized matrix obtained from this process is shown with R. To make the value of the values of R matrix's entries the same, the sum of W_j parameters' weights is multiplied by the columns of this matrix in peer-to-peer form. A* and A- indicates alternative with the highest priority (the ideal response) and alternative with the least priority (the worst response), respectively. At the next step, to compute the distance of each alternative, Euclidean Distance Method (n dimension) is used. $S_{i\ Min}$ indicates the distance of alternative (i) with the best response and$S_{i\ Man}$ indicates the distance of alternative (i) with the worst response. At this stage, using C_i* parameter, the relative closeness of the alternatives to the ideal response is computed. To order and prioritize the alternatives, the obtained values of C_i* are ordered based on their greatness. Therefore, the importance and priority of the alternatives depends on the magnitude of their figures. The higher values have higher importance for election. To create identical conditions of paired comparison, the criteria are considered identical in both methods (3 and 4).

Table 1: Symbols used to compute the weight of the criteria

Symbol	Explanation
R	Matrix entry
W_j	Sum of weights
$R_{ij} = X_{ij}/\left(\sum_{i=j}^{m}(Xij)^2\right)^{1/2}$	Changing into dimensionless values
$V_i=W_i*R_i$	Sum of $W_j$parameters' weights multiplied in the columns of the matrix in peer-to-peer form
$A^{-} = \text{Min}\ V_{ij}; j_{\varepsilon J}$	The lowest priority
$A^{*} = \text{Max}\ V_{ij}; j_{\varepsilon J}$	The highest priority
$S_{i\ Min} = \left(\sum_{j=1}^{m}\left(V_{ij} - V_{j\ Max}\right)^2\right)^{1/2}$	The distance of alternative (i) with the best response
$S_{i\ Max} = \left(\sum_{j=1}^{m}\left(V_{ij} - V_{j\ Max}\right)^2\right)^{1/2}$	The distance of alternative (i) with the worst response
$C_i^{*} = S_{i\ Min}/(S_{i\ Max} + S_{i\ Min})$	The relative closeness level to the ideal response

RESULTS AND DISCUSSION

Results

In this research, the studied region is QaleDare Si Village of Makoo City in Uremia Province. This village has the geographical coordinates of $44°\,17'22''$to$44°\,37'\,44''$east longitudeand $39°\,9'\,37''$ تا $39°\,29'\,56''$north latitude (Figure 1). The village has an area about 480 km^2. It has been also located at an average height of 2000 m from sea level. Its southern points are mountainous but its central parts are flat plains. This village has common borders with Turkey and northern Chaybar village from the north, with southern Chaybar village from the south and with Chaldaran City from the west. Having a population of 12161 people, Qale Dare Si Village includes 36 villages with the centrality of Keshmesh Tape village.

The first stage result was to identify criteria and sub-criteria influencing site selection. The purpose of the research was to select solid waste landfill site in the considered region using AHP and TOPSIS approaches. In this regard, 45 alternatives were selected to determine landfill site with the area of at least 250 hectares. Accordingly, out of the entire the region, only 10% was found to be appropriate for landfill site. Using the two methods, the alternative 1 was identified as the most preferred alternative to establish landfill site. Figure 1 shows four points on the studied region. In Figures 2, 3, 4, and 5, the weight of the criteria, qualification percentage and the weight of the parameter, respectively, have been shown through AHP and TOPSIS methods. Figure 6 also presents the comparison between the two methods. Given to the weight of the parameters, the final maphas been shown in Figure 7.

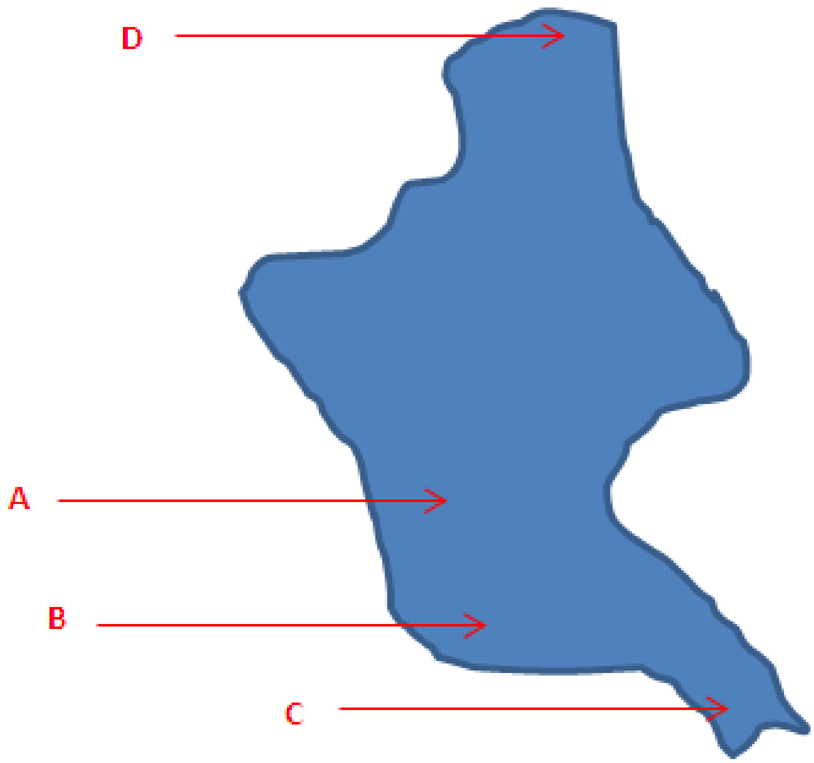

Figure 1: The appropriate alternatives to establish landfill site

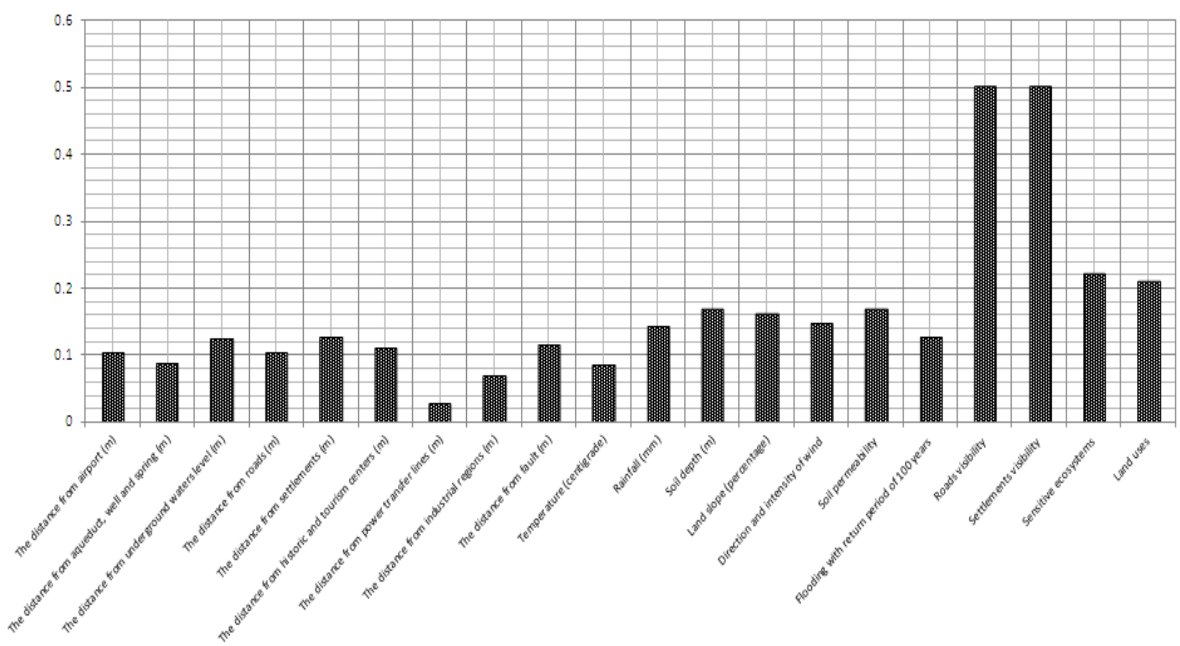

Figure 2: The relative weight of the criteria

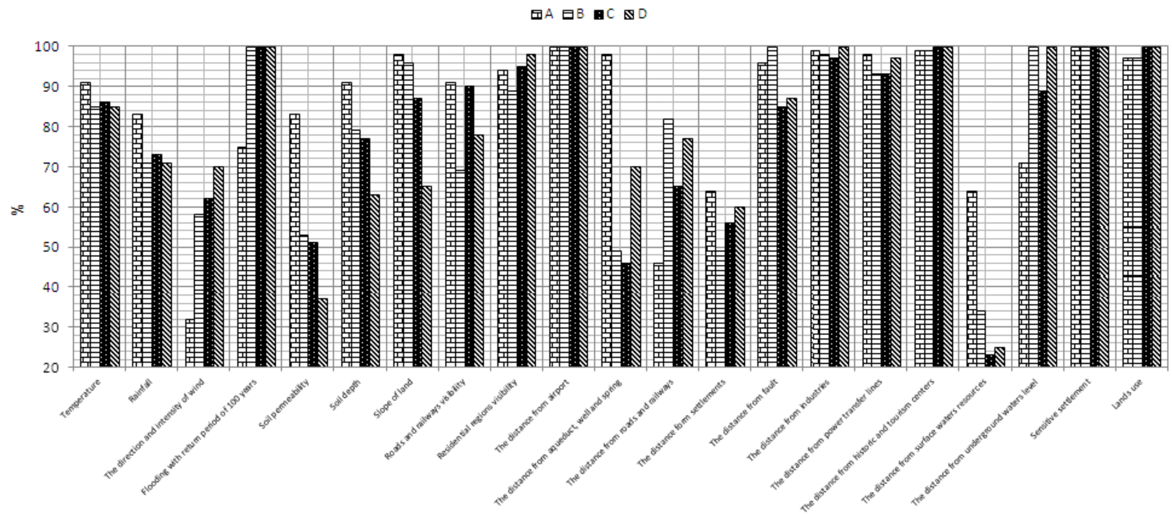

Figure 3: The qualification percentage of the criteria in the 4 points

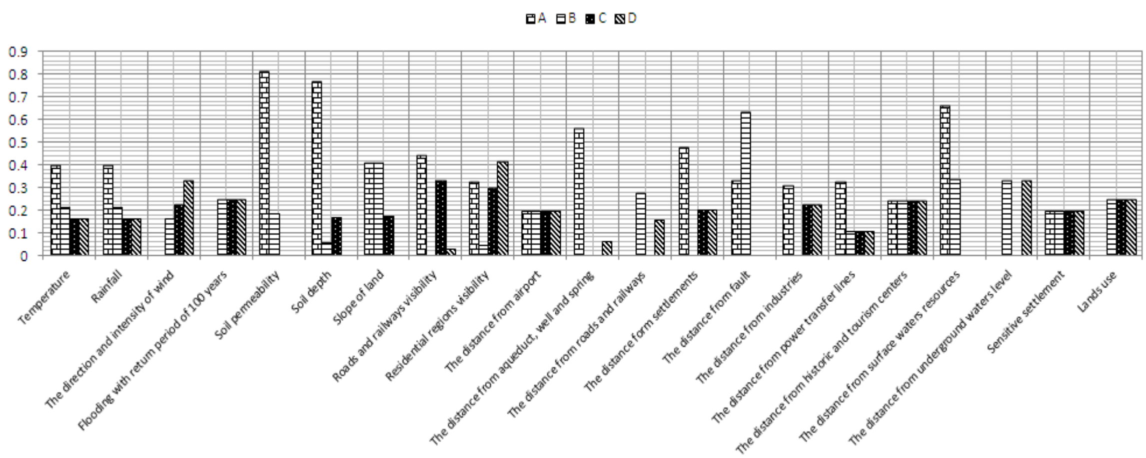

Figure 4: The computed relative weights of the alternatives using AHP

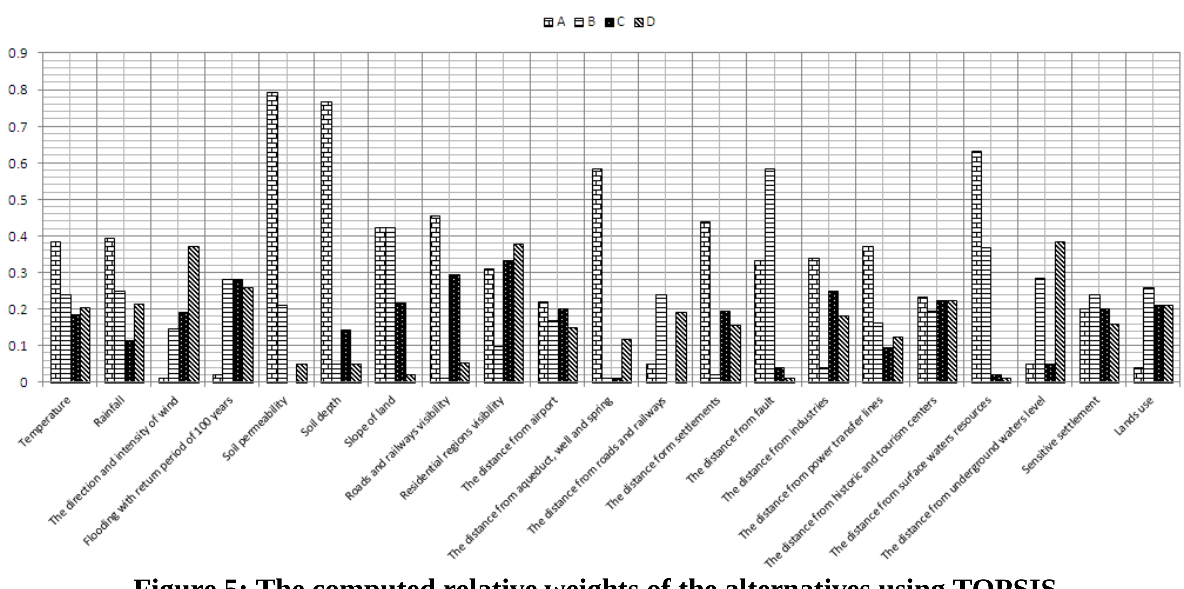

Figure 5: The computed relative weights of the alternatives using TOPSIS

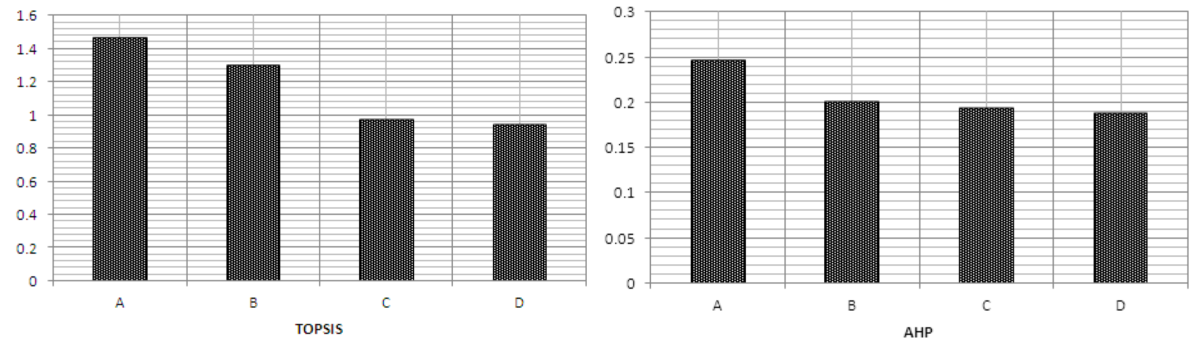

Figure 6: The comparison of AHP and TOPSIS results

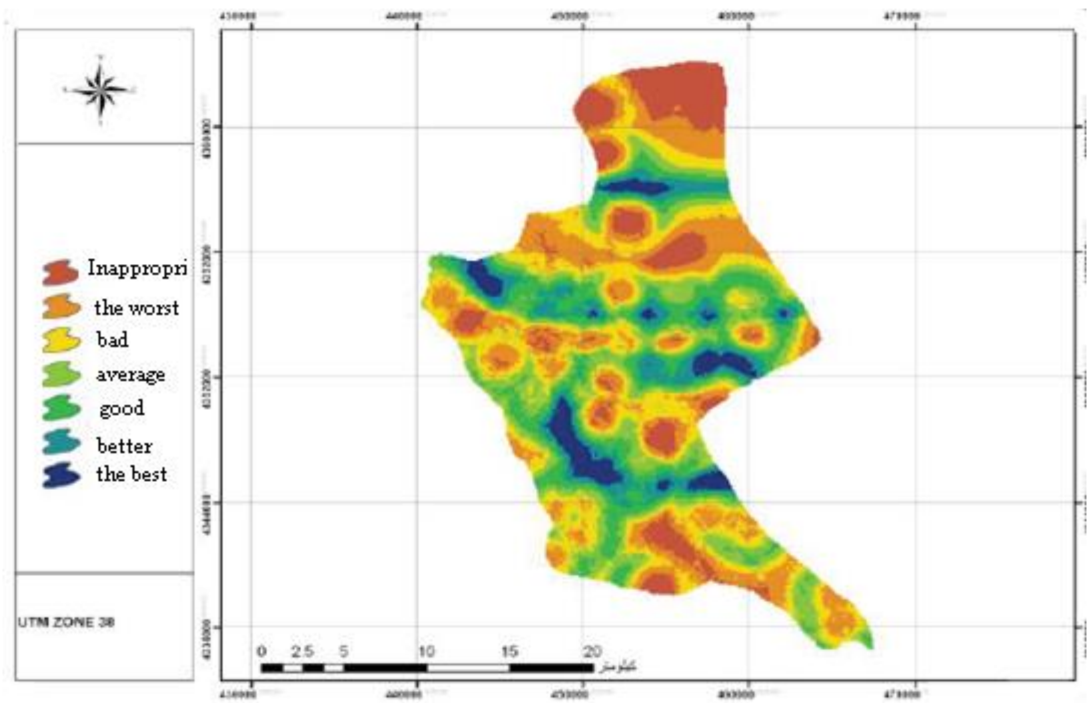

Figure 7: The desirability of waste landfill site

According to the results of both methods, the criterion of hydrology has the highest weight and the criterion of climate has the lowest weight. Therefore, the proximity of the proposed landfill alternatives has caused that in AHP method, the weight of the four landfill points are close to each other and climate and economic-social criteriaallocateless weight to themselves. In other words, they have less proportion in landfill alternatives prioritization. To determine the most effective criterion in zoning landfill site construction is a function of the studied region's features. Also, to select waste landfill site in Bonanb-Tabriz, Khorshiddoost and Adeli (2009) introduced the criterion of geomorphology and Panahande *et al.*, (2010) introduced the criteria of the distance from fault and the distance from residential places as the most effective and restricting parameters.

In investigating the results of these two methods, it should be declared that AHP method is based on three principles of analysis, paired comparison and alternatives summarization and prioritization. In this method, criteria with higher importance are placed in higher rows of this branch structure. Since the base of all computations in AHP process is experts' opinion, unlike TOPSIS method which is based on mathematical computations, AHP results are flexible. It is regarded as one of the strengths of AHP method. Moreover, using AHP allows investigating more important factors which are considered more effective in site selection issue by experts. It should be noted that both methods are applied techniques in multi-criteria decision making process. Also, in both methods, qualitative and quantitative criteria are simultaneously involved. In TOPSIS method, system performance is desirable and acceptable. In this method, input information can be changed and the way of system responding can be investigated based on these changes. The relations used to normalize information and compute distances are optional and adjustable with information type existing in problem. Output can quantitatively state priorities; in fact, these quantities are the final weight of alternatives in prioritization. Therefore, these weights can be used to solve linear programming problem or integer as target function coefficients. If thereare some limitations for the problem, solving the problem of linear programming in this way can perform selection among alternatives (Asgharpour, 2004). However, TOPSIS method is suggested to be used when the number of indices and accessible information is limited. This method is not suggested when the number of investigated parameters is high. In his research, Pahlevani (2009) made use of hierarchical TOPSIS in fuzzy environment to prioritize investment. In this model, the weights or decision matrix is defined as fuzzy figures. The technique used in investment prioritization is capable to solve the problem with hierarchical structure (the main advantage of AHP method). Regarding the problems with hierarchical structure (such as landfill site selection), this method is superior over classic TOPSIS. Accordingly, compared to classic TOPSIS, using this model in the present research is more efficient.

Conclusion

Comparing the results obtained from TOPSIS and AHP methods, we can conclude that in AHP process, prioritizing alternatives is based on their criteria and weights and alternatives in each criterion (such as soil depth and permeability and etc.) relative to each other are compared in pair and it is not limited to the score of alternatives in each parameter (without applying paired comparison with other alternatives). Finally, integrating the weights of respective low levels' elements with high levels' elements in hierarchy, the weight of index and alternatives are obtained. Then, the alternative with the highest weight will have the highest priority. While, in TOPSIS method, there is no comparison between alternatives and the weight of alternatives is computed without comparing with other alternatives. On the one hand, the weight of criteria is computed distinctively without paired comparison. Therefore, it seems that AHP method results have higher accuracy and confidence since the weight and importance of each criterion in the investigated problem is determined relative to other criteria. Accordingly, the present study suggests AHP process as a more applicable and effective method.

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