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CASE STUDY

A GIS- Based suitability analysis for siting a solid waste in an urban area

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ABSTRACT: Locating an appropriate solid waste disposal site has been a major problem in the municipal environment. The use of landfills is the most economical and environmentally acceptable method for the disposal of solid waste all over the world. The analysis of spatial data and consideration of the regulation and accepted criteria are part of the important elements in the site selection. The aim of this paper is to show how application of geographic information system helps in locating solid waste disposal in Abadan city. In this paper, the types of suitable soil for solid waste disposals, land use/ land cover, transportation routes and proximity to surface water are thoroughly studied. Relative importance weight of each criteria in the geographic information system and Analytic hierarchy process was determined and finally the suitability map was prepared. Based on the final suitability map, appropriate solid waste landfill site was located in the northeast part of the study area. Select the best landfill site among the candidate ones, and the output results can enable decision makers to make appropriate decisions to reduce the costs both in economic and environmental criteria.

KEYWORDS: *Abadan; Analytic hierarchy process (AHP); Geographic Information System (GIS); Positioning; Solid Waste (SW)*

INTRODUCTION

Environmental problems associated with the generation of waste are part of societal change, where households play an important role (Monavari *et al.*, 2012). The increase rate of the population has led to the production of the extensive amount of municipal solid waste (Demesouka and Vavatsiko, 2013).

Different methods of primary waste disposal, leading to water pollution, soil and air, which inevitably leads to risks to public health (Gbanie *et al.*, 2013). Increasing population growth and increasing urbanization next to the reduction of nonrenewable resources and exposure to this toxic and dangerous waste are the biggest environmental problems, which must be eliminated or minimized for the survival of human life. (Boroushaki and Malczewski, 2010).

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Depending on the type of industrial activities, huge amount of industrial disposal is produced. Due to lack of properly equipped plants and sanitary dumping sites operating within the required standards, the industrial wastes are released in an ad hoc manner to the environment (Bidhendi *et al.*, 2010). Because of the complexity of waste and also due to the high growth rate of its production, choosing a proper location with all the required criteria is of particular importance (Wang *et al.*, 2009; Basak *et al.*, 2006). Landfills are strategic places, which are located for the collection of solid waste for either condensation or burning (Nwambuonwo and Mughele, 2012). Locating suitable and correct disposal site location is the most effective and most important step to create and develop a satisfactory landfill for urban waste when the urban master plan of construction and development are

prepared (Rezaee *et al*., 2007). The process of locating multiple criteria landfill is very complicated and difficult ([a]ener *et al*., 2006). Locating the landfill in urban areas due to the impact on the economy, ecology and health and the environment, is one of the most important issues in urban planning ([a]ener *et al*., 2006). Therefore, proper management and proper disposal of waste are the main concerns of the world, in both developed and developing countries (Kontos *et al*., 2005).

Due to natural and harmful environmental features of waste, municipal solid waste sanitary landfill location is very complex and highly susceptible. Hence, the location is the most important step in the process of site selection as the appropriate location can eliminate many foreseeable problems. (Madadi *et al*., 2013). In this procedure, multiple indicators and standards are used and each of them creates limitations in this regard (Shahabi *et al*., 2010). The process of waste management includes collection, transporting, processing, recycling or in other words, disposal of waste materials and waste monitoring. The important stage in the waste management is the landfill location choice (Vasiljevic *et al*., 2012). City planners around the world are facined with the concept of solid waste management, especially the developing countries where urbanization, poor planning and lack of adequate resources, causing many complex issues in the waste management process (Grsevski *et al*., 2012). Site selection and designing the disposal site are the first steps and the most important steps in solid waste management. Modern waste management approaches focus on reduction, reuse, recycling, and recovery of the waste (Kontos *et al*., 2005). The location of the disposal of sanitary operations must be in an area with no danger of the health hazards and effects neither on man nor on the environment and all the risks must be eliminated nor minimized with minimum cost (Khan and Faisal, 2008). Rapid deterioration of environmental conditions due to the conventional system of collection and dumping of solid wastes results in contamination of soil, water and air, which inevitably lead to risks to human health and other organisms (Gbanie *et al*., 2013). Geographic Information System (GIS) with high ability in combination and integration of different information layers required locating a suitable landfill, good tools that could be used for this purpose, the ability of geographic information system in the management and analysis of layers makes this system suitable for optimal management of urban waste utilization (Salari *et al*., 2011). However, even with the aid of GIS, it can be difficult to include both expert and public opinions (Boroushaki and Malczewski, 2010).

Disposal include unloading the waste, spreading on the ground, compressing and fast covering with covering materials such as soil in order to prevent the spread of waste and also prevention of environmental pollution and health hazards. Choice of location for landfill operations should be in such a way to minimize or, if possible, eliminate any risk to the public and the environment and could be operated with affordable cost (Afzali *et al*., 2013). Many researches have extensive research work in this field using different methods. Al-Nabi and his colleagues worked on determining the effective parameters in site selection for nuclear waste disposal using the expert choice software in Kerman (Al-Nabi *et al*., 2013). Ebadi and his colleagues, research were about locating an urban waste landfill using GIS (Ebadi *et al*., 2014). Nasery and her colleagues in a research titled locating the appropriate place for urban waste disposal site using Analytical Network Process in Khoramabad-Iran (Nasarei *et al*., 2014). Moreover, many other scholars using different tools and methods attempt to locate the solid waste disposal site in the urban areas (Gbanie *et al*., 2013; Demesouka and Vavatsiko, 2013; Vasiljeviæ *et al*., 2012; Hadyani *et al*., 2012; Aragonés-Beltrán *et al*., 2010).

The partial objectives of present research are included:

1- To determine the optimal location of the case study waste landfill.

2- To determine the optimal selection criteria effective in the case study waste landfill.

In this study, for locating the appropriate place for the landfill in the city of Abadan, nine criteria were used, including: slope, distance from land use, the distance from the communication lines, the distance from urban centers, the distance from the rural centers, soil maps, hydrographic and geological network maps, the map of precipitation in the geographic information system.

MATERIALS AND METHODS

Abadan is located in the central west of Iran (68 km or 42 miles long, 3–19 km or 2–12 miles wide). The city is bounded in the west by the Arvand waterway and to the east by the Bahmanshir outlet of the Karun River (the Shatt al-Arab), 53 Kilometres (33 miles) from the

Persian Gulf near the Iraqi-Iran border (Eghbali *et al.*, 2013) The climate in Abadan is arid. Geographical location of Abadan is shown in Fig.1.

In this study, the following steps were taken respectively: first, the criteria, the subset criteria, and the standards of site selection for waste disposal have been identified, selected (Tasban *et al.*, 2015) and evaluated (Table 1).

Then the required information layers including, soil science, geology, land use, slope, area, the topography, the position of the villages, the metropolitan area, surface water, groundwater, rainfall maps were prepared. These layers were digitized and entered into the GIS format and were evaluated. Then by means of Expert Choice, version 11 software, slope, surface water, groundwater, rural areas, urban areas, land use, soil, rainfall pattern, road access, grasslands were weighted. In this research, Analytic Hierarchy Process method (AHP) is used for comparison of the criteria and

Table 1: Urban Waste Disposal Standards (Tasban *et al.*, 2015)

Criteria for the position	Distance of landfill criteria of the position
Slope	0-10%
Main road	300-1000(M)
Minor roads	150-300(M)
Soil tissue	Small
Pastures coverage	Poor
Rural areas	500-1000(M)
Urban areas	1000-1200(M)
Subsidiary waterway	150-300(M)
Geology	Hard formation
Landform Height	Low
Protected areas	500-1000(M)
Stream Main	500-600(M)
Land use	Low
Fault	30-150(M)

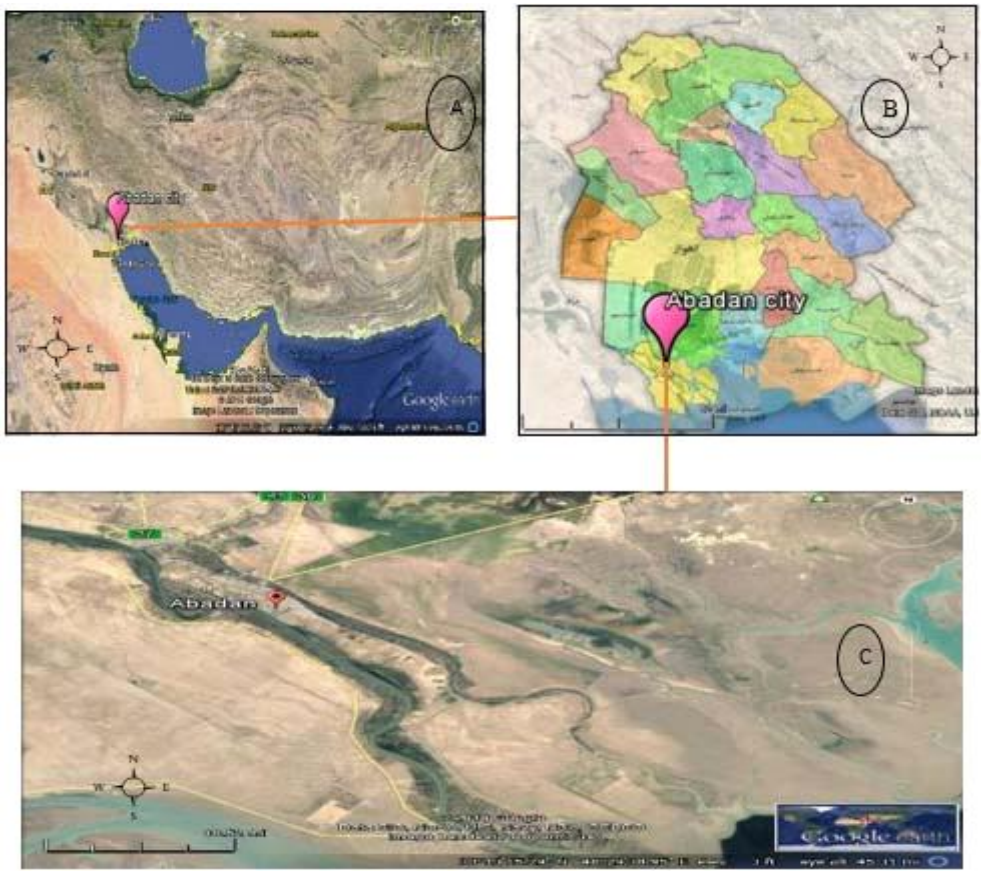

Fig. 1: Geographical location for the region under study in Khuzestan province and Abadan city

assigning the relative weight to them. Ultimately, by overlaying effective layers of information, the most appropriate location is determined. A decision is a choice made from two or more alternatives (Çimren *et al*., 2007).

Decision-making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow reasonable choice to be made among them. AHP, which is a basic multi-criteria decision-making approach, is a strong and simple way to decide if the conflicting decision criteria make it difficult to choose between the options. This multi-criteria evaluation method was first introduced by Saaty (1980) and so far, had several applications in different sciences (Zebar Dast, 2001). A basic method for AHP test is the binary comparison. In order to perform a binary comparison method, first, every individual under study criteria are compared in pairs and the relative importance of each criterion to another is evaluated and according to the scoring Table 2, scores of 1 to 9 are assigned to them and entered into a matrix.

To determine the importance of each criteria to one another, relevant specialist and officials' comments, relating books, reports, and previous researches are used. As the result of integration and combination of the criteria and applying the layers in AHP method, the final map of the site selection was prepared. The process of site selection includes the following steps: preparing needed digital data using GIS software, determine toe effective parameters in site selection process, application of Analytic Hierarchy Process to determine the relative weight of effective parameters, simple weight scoring for identifying the suitability index, determine the suitable areas for landfill (ZebarDast, 2001). Developing a hierarchical structure for locating the landfill was the most important stage of the process of AHP, because by analyzing difficult and complex issues and converting them to a simple form, they can comply with the mind and the nature of man (Çimren *et al*., 2007). The Hierarchical Structure is a graphical representation of complex issues that are real which at its pick the issue's main goal is and in the next level are the criteria and the sub criteria.

In this study, to develop a hierarchical structure of waste disposal landfill in Abadan Province, a structure based on goal, criteria and sub-criteria is used. In the hierarchical structure process, the greatest weight is given to the layer with the most effect on determining the goal. In other words, the weighting criterion to each unit of information is also based on the role that the each criterion is operating within the layer (Lopez and Zinck, 1991). The framework of the study is shown in Fig. 2.

Table 2: comparison of criteria for scale (Çimren *et al*., 2007)

Importance	Numerical Rating
Equal importance	1
Equal to moderate importance	2
Moderate importance	3
Moderately to strongly importance	4
Strong importance	5
Strong to very strong importance	6
Very Strong importance	7
Very to extremely strong importance	8
Extreme importance	9

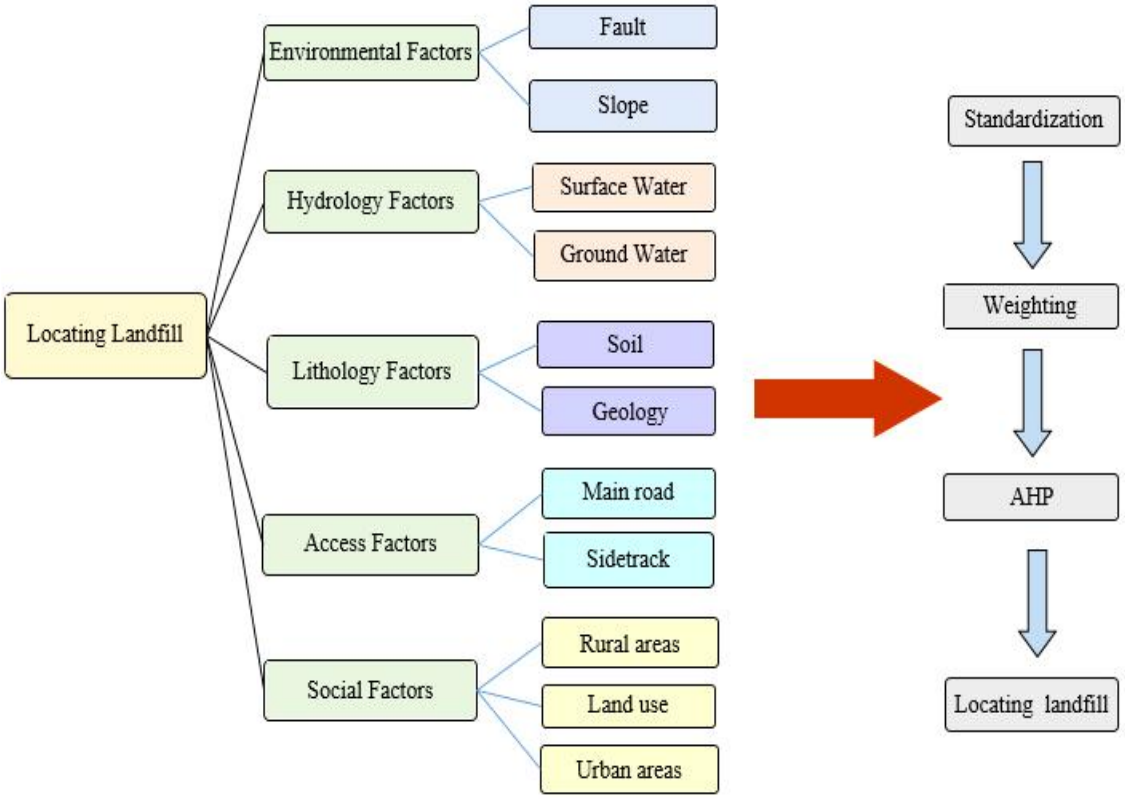

Fig. 2: Framework of the study

RESULTS AND DISCUSSION

The results of the following weighted criteria of the study area based on the opinions of experts and the results derived from analysis of AHP are shown in Table 3. Among those criteria, the Hydrologycal criteria with the most important and geological criteria, with the least of importance were ranked Fig. 3. In terms of the coefficient of conflict, the results were valid and in accordance with Saaty (1980) comment. In the Table 3 among the sub-criteria, the distance from the urban areas (access factors) have the most importance.

The maps of surface water, distance from an urban center, the distance to the transportation lines, geology, land use, the distance from the village, the soil, the rainfall are shown in the order form of Figs. 4 to 10. Then the reviewed criteria with respect to the achieved weights were combined in the ArcGIS software 9.2 and ultimately the map locating the optimal location of waste disposal site was prepared for the study area (Fig. 11).

Surface water: One of the most important layers to determine the optimal placement of the landfill is the surface water layer, so that the more distance of surface water from the landfill takes the higher rating (Fig. 4).

Distance from residential areas: The distance from the residential areas, either urban or rural must be

Table 3: The final weight of the criteria and the sub-criteria used for the site selection

Criteria	Relative Importance of Weight
Social factors	0.059
Access factors	0.096
Hydrology factors	0.492
Lithology factors	0.051
Environmental factors	0.302

considered. So in order to comply with the existing criteria, the distance maps were drown (Figs. 5 and 6).

Transportation access lines: Map of all major and minor roads throughout the city was determined using a topographic map. The appropriate distance of the waste disposal area and the transportation lines is shown in (Fig. 7). The soil map: The soil of this province were classified into three groups, after the rating, the map of soil layer was prepared (Fig. 8).

Rainfall map: Rainfall map of the study area (Abadan province) based on the rainfall map of state of Khuzestan has been produced. Pattern of Rainfall in the area is very important in landfill site selection. The area with less rainfall is more appropriate place for landfill (Fig. 9). Land use map: It is noticeable that when considering a land for urban waste disposal, it is usually a land with no better land use (Fig. 10). The proper waste disposal site for the city of Abadan. Fig. 11 illustrates the full map of the area.

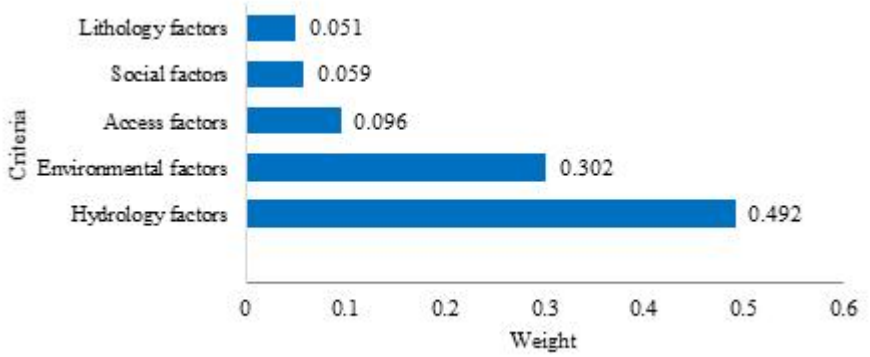

Fig.3: The determination of the weight of the criteria in the Analytic hierarchy process

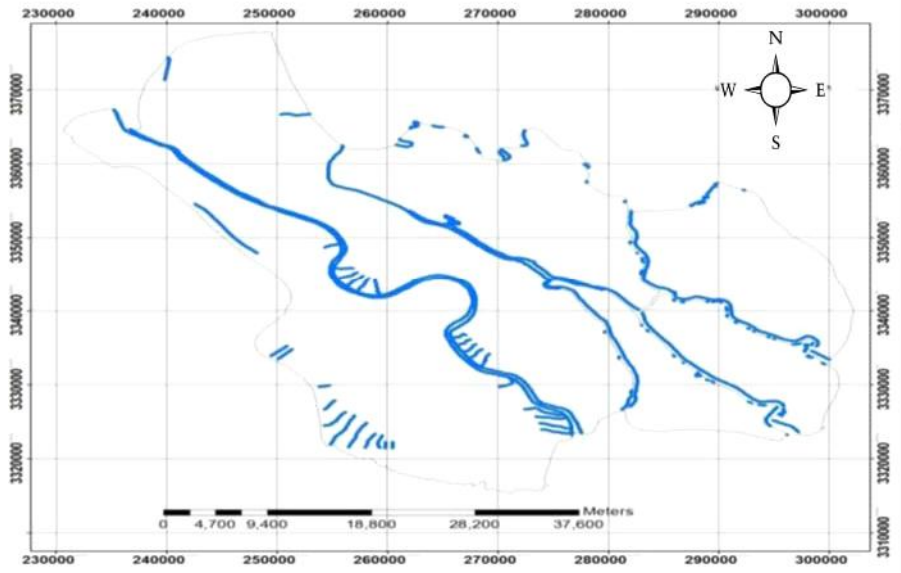

Fig. 4: Surface Water

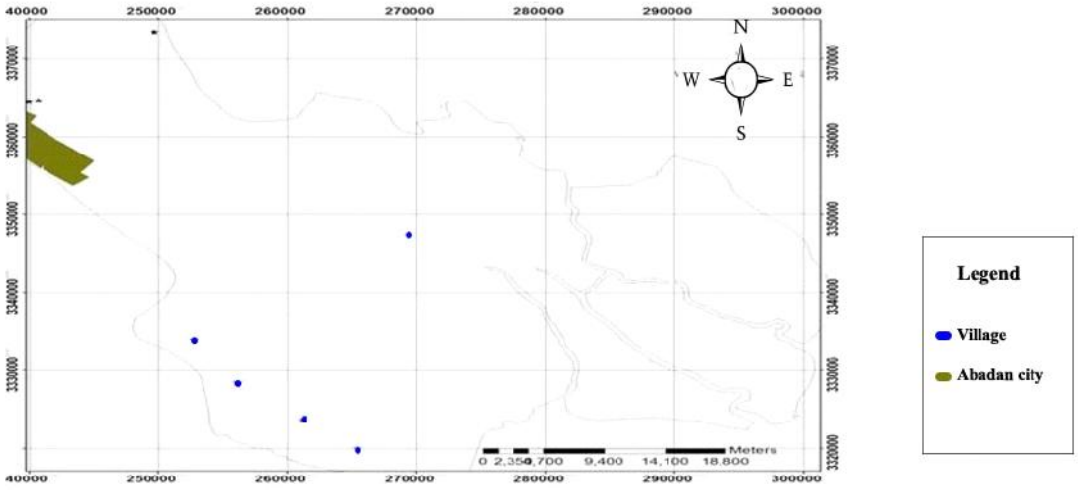

Fig. 5: Rural and urban areas

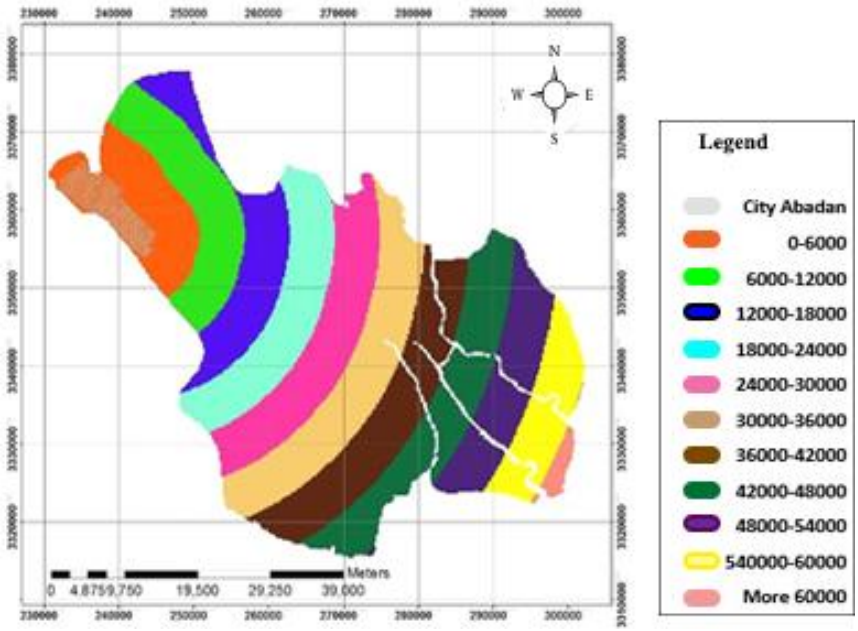

Fig. 6: Distance from urban area

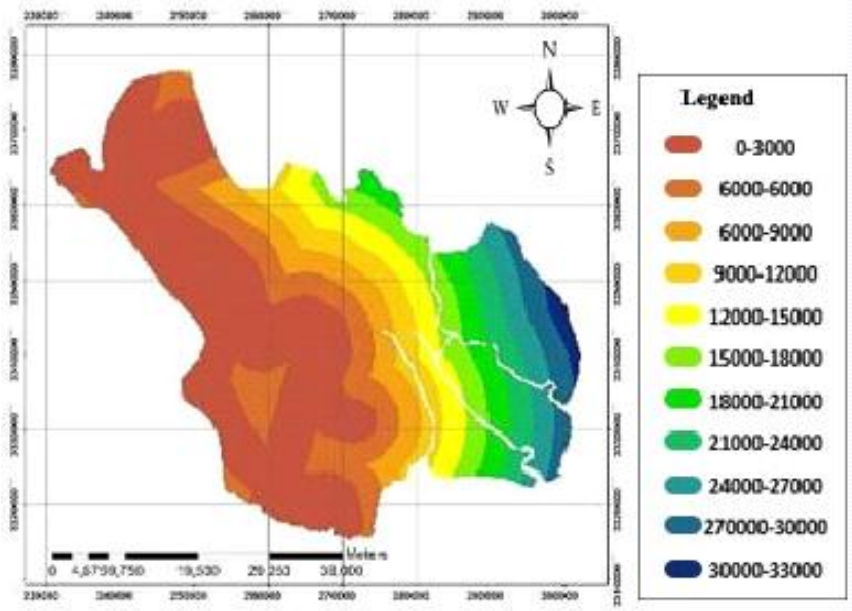

Fig. 7: Distance from transportation lines

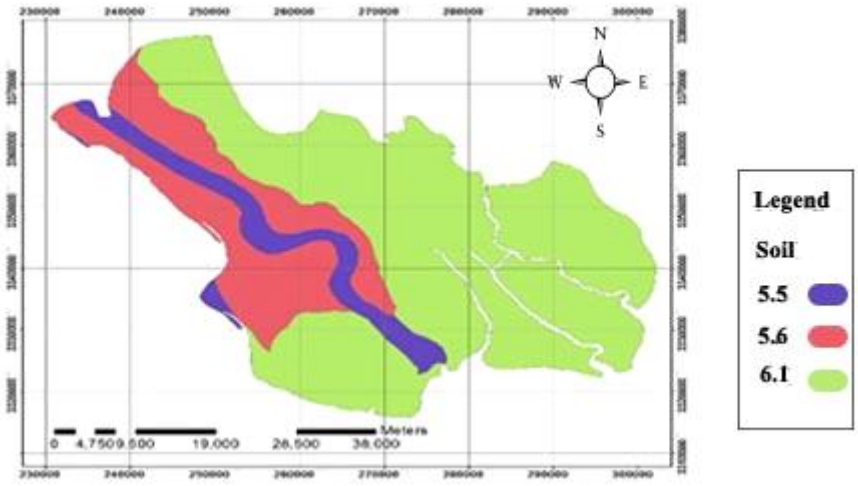

Fig. 8: Soil of region

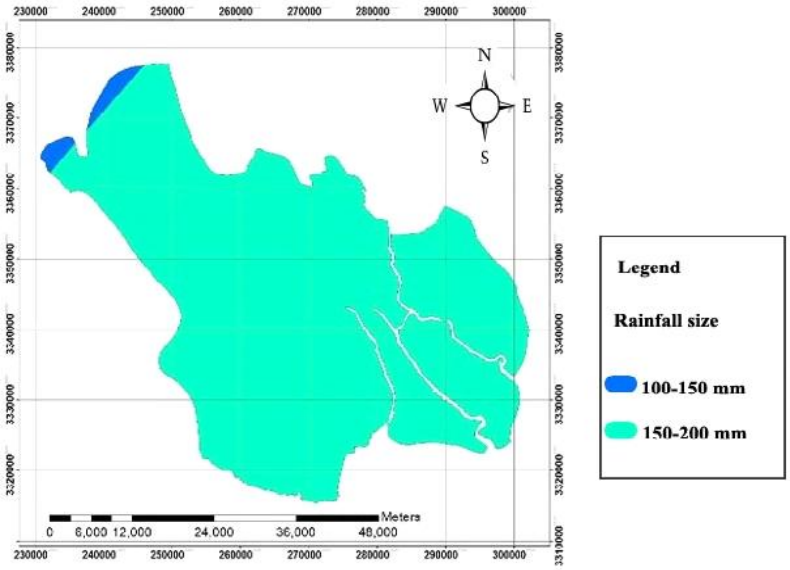

Fig. 9: Rainfall size

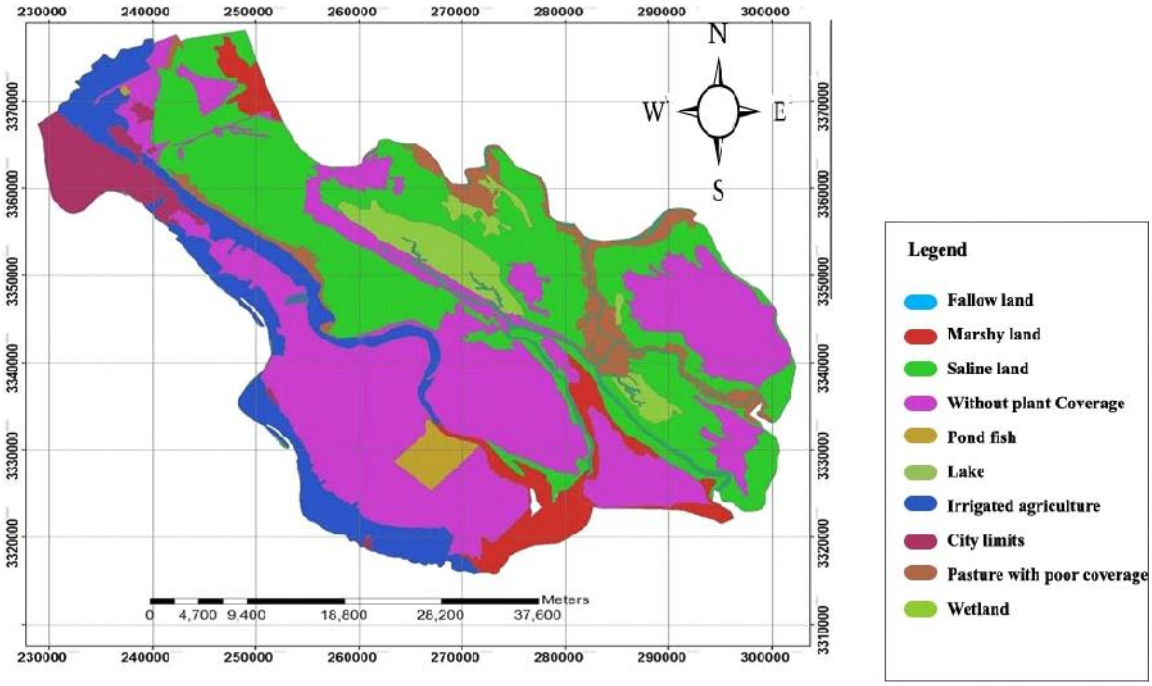

Fig. 10: Land use of region

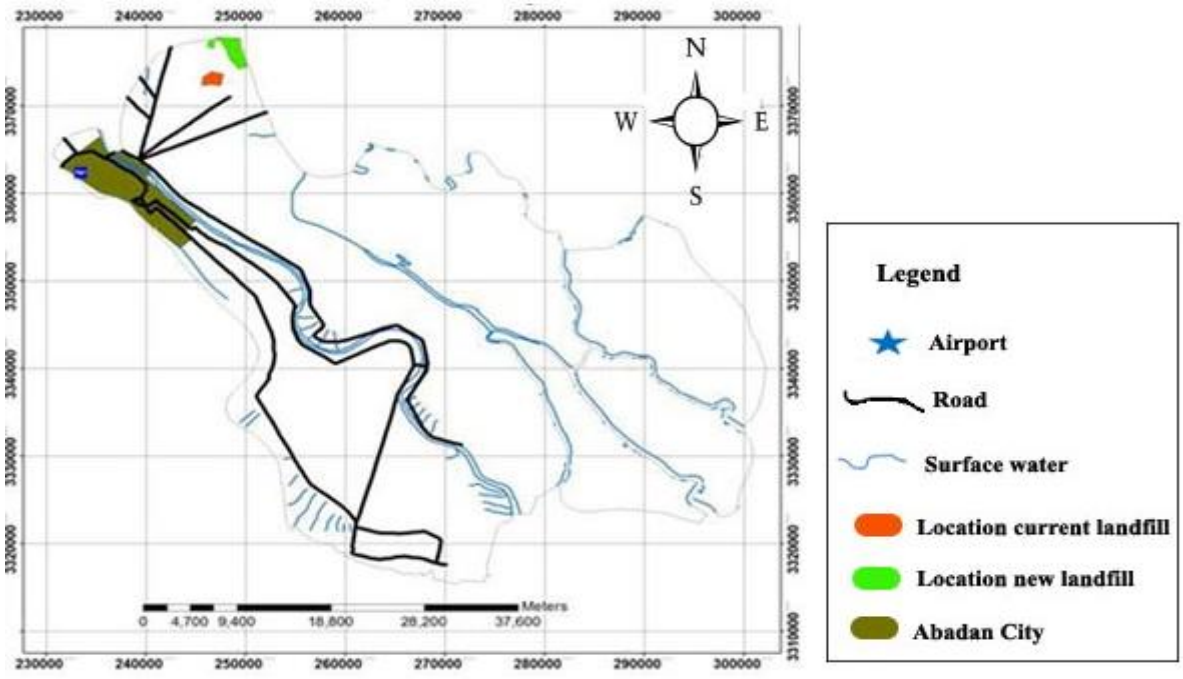

Fig. 11: the final map of the location of waste disposal site using the hierarchy analysis.

CONCLUSION

The present study has been performed in 2016 to determine the proper location for disposing of urban waste in Abadan, Khuzestan province, Iran. The average daily production rate of waste in Abadan is 300 tons, which apparently this amount is increasing due to growing urbanization rate. The current waste disposal site in Abadan, does not meet with this amount of daily waste and on the other hand, lack of proper urban waste management system as well as lack of the establishment of mandatory standards, had forced urban waste management to plan a new site selection for waste disposal.

In this study, the landfill site selection was performed with the aid of GIS and AHP techniques. The combination of GIS and AHP tools were used to determine the new waste landfill location. Different layers of information were combined together and the suitable waste disposal was identified. Although the capabilities of GIS in simplifying, reducing costs and time in the process of decision-making is clear but,
The need of field visit, study, and examine all the limitations and opportunities of the designated location remain. In order to eliminate any unnecessary cost before the implementation of the landfill site, field study can be very helpful in combination with the standard maps.

The present study offers a siting methodology for the region. In addition, it allows the decision maker to perform decision analysis functions and support them in solving the waste management problems in the city of Abadan.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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