A GIS-Based Landfill Site Selection Approach Using Spatial Multi-Criteria Decision Making Methods

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ABSTRACT

Decision-making is a process that starts with the problem of detection and covers activities that are carried out up to the recommendation. All decision-making processes start with the diagnosis and identification of a decision problem. The ability of data storage, management, administration and analysis of Geographical Information Systems (GIS) is a great support in the course of problem definition. The spatial multi-criteria analysis is sharply distinguished from traditional multi-criteria decision-making methods due to its geographical component. Spatial multi-criteria analysis requires not only the values of alternatives but also their geo-references, unlike traditional multi-criteria decision-making methods. Spatial multi-criteria analysis can be considered as the process of reaching the final decision by combining and transforming the geo-data used as input. Data is processed to enable decision making using GIS and multi-criteria decision-making methods. Analytic Hierarchy Process (AHP), which is one of the multi-criteria decision-making methods, is a general measurement theorem. It has been used in broadly in many various decision and planning projects. The rationality of the AHP; to focus on the problem-solving goal, to develop an integrated model of the relationship and effects of the problem, to know and experience those who have dominant and prior influence among the relations in the structure, to reach the best agreement by permitting among the differences. As an example of spatial multi-criteria decision-making methods, the site selection analysis of solid waste landfill site has been carried out using AHP and GIS methods for Istanbul province in Turkey. A total of 11 factors were used in the study, under the two main classification parts like environmental and economic. Environmental factors; land use, geology, settlement areas, surface waters, population density, airports and protected areas. Economic factors are a slope, solid waste transfer stations, land values, and highways. The identified factors are separated by sub-criteria according to the appropriateness of solid waste landfill site, and values are assigned. As a result of the study, using the power of GIS functionality, the digital data sets leading to the decision-makers were created.

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INTRODUCTION

Today, in order for societies to carry out a qualified lifestyle, the needs, methods and principles are determined first and they are tried to be applied with the most appropriate resources, techniques and methods in the most appropriate way according to their targets. Urban solid waste management, which has an important place in environmental services in this context, is a serious issue in the whole world. Geographical Information Systems (GIS) is one of the most important technological tools used to solve environmental problems and has an effective role in processes where spatial information is directed (Yomralıoğlu, 2000). The urgent solution of environmental problems has been understood more in recent years and much effort has been made to produce realistic solutions to the problems. Instead of material-minded thoughts, studies involving multi-criteria methods are seen (Hokkanen and Salminen, 1997). In developing countries, the increase of human population and related human activities accelerated urbanization (Sumathi et al., 2008). As a result of increasing population, change of consumption patterns, economic growth, change of income, urbanization and industrialization, solid waste production and diversity have increased (Ngoc and Schnitzer, 2009). Waste management and waste disposal alternatives are a complex process involving decision makers and related parties. Choosing the most suitable landfill site; administrative constraints and regulations, as well as physical process conditions and environmental, economic, health and socio-cultural effects (Sadek et al., 2006; Yıldırım, 2012).

In the work done by Monsef (2015), an alternative landfill site for the Red Sea, a rapidly growing tourist area in recent years, has been identified by using GIS and AHP methods. Different criteria such as transportation routes, airports, surface waters and residential areas were used in the study. As a result of the study, three alternative landfill sites were identified. In the study carried out by Djokanovic et al. (2016), a complex process, the determination of the landfill site, has been evaluated from the viewpoint of geological engineers. In this study, alternative landfill sites for Pancevo region of Serbia were identified using GIS and AHP methods. As a result of the study, it was determined that 62% of the region was unsuitable and 12% was very suitable. Nascimento et al. (2017) used MCDM and GIS methods to conduct a study within the US state of California. 61 landfill sites in the area were evaluated. Using the developed model, 61% of the landfill sites are found to be in suitable and very suitable classes.

MATERIALS AND METHOD

In this study, a region covering the administrative borders of Istanbul, which is the most populous province of the country, located in the northwest of Marmara region of Turkey, was selected as a study area. The same limits were used for all criteria used in the spatial analysis. Figure 1 shows the elevation map of Istanbul, which was selected as a study area.

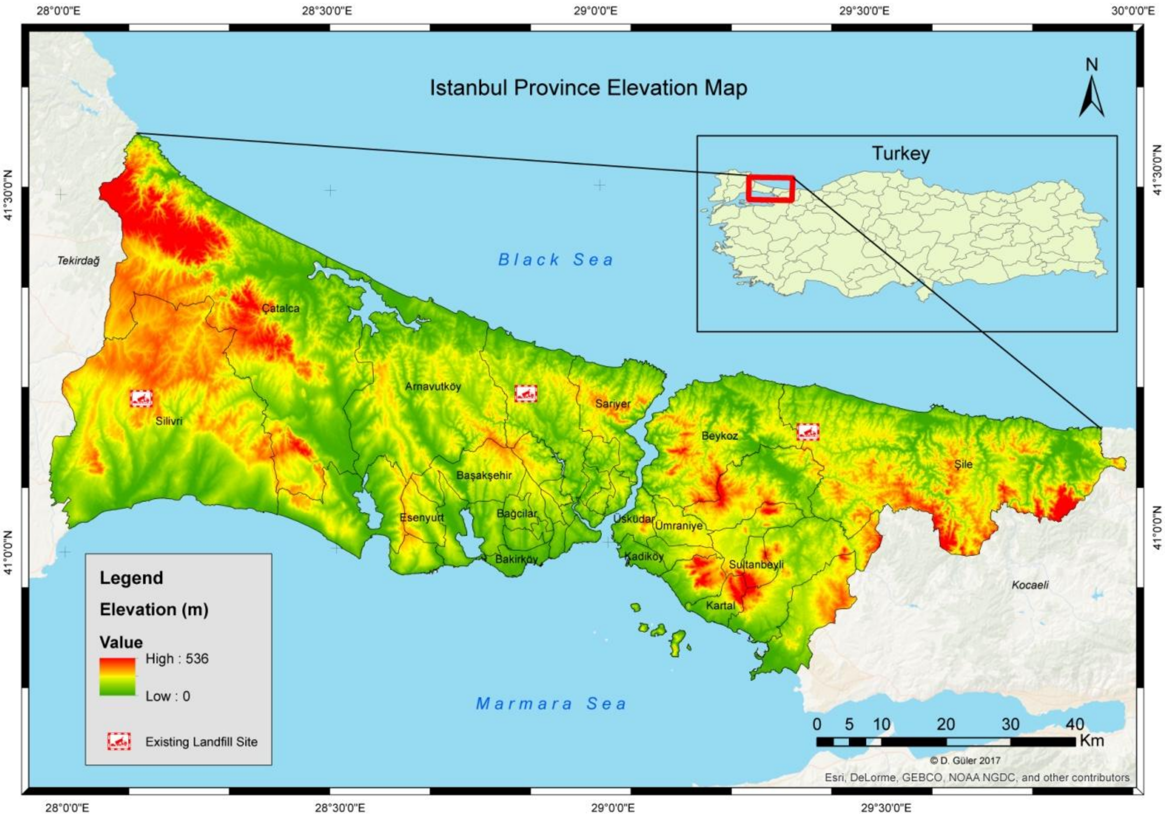

Figure 1. Istanbul province elevation map (Guler, 2016).

In the study conducted, the criteria used in the AHP method were evaluated by the literature survey together with the restrictions specified in the country's regulation. In addition, the criteria to be used were determined considering the characteristics of the study area. 11 criteria were used in the study, with two main categories, environmental and economic (Guiqin et al., 2009; Şener et al., 2010; Donevska et al., 2012; Vasiljevic et al., 2012; Yal and Akgün, 2013; Shahabi et al., 2014; Baba et al., 2015; Yıldırım and Güler, 2016). Environmental factors; land use, geology, settlement areas, surface waters, population density, airports and protected areas. Economic factors are a slope, solid waste transfer stations, land values, and highways. Values are assigned in the range of 0 to 5 to meet the standard for all criteria. The appropriate AHP hierarchy model created in the study is shown in Figure 2.

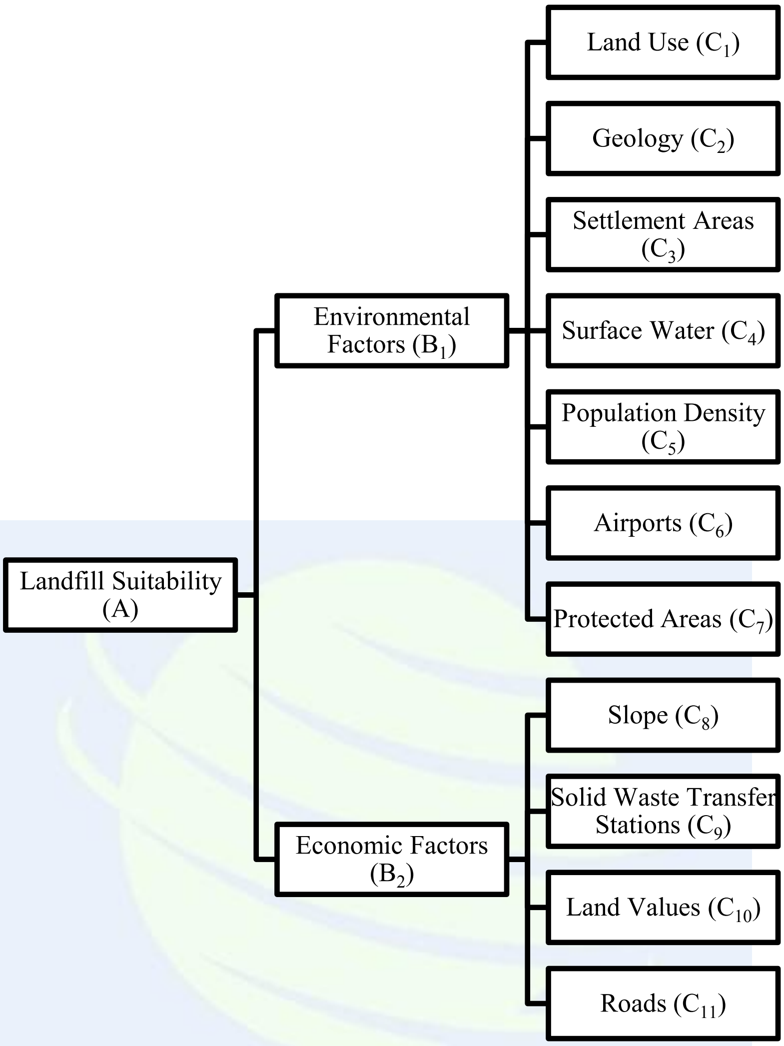

Figure 2. Hierarchy model of landfill suitability.

The geological data for Istanbul was obtained from Orr & Associates, Australia. Data containing population density was obtained from Istanbul Metropolitan Municipality (IMM). The existing airports in Istanbul for the airport criteria and the coordinate information for the new airport planned for operation in 2018 were obtained via Google Maps and the layer to be used was created by transferring to the GIS environment. Spatial data for protected areas in Istanbul were obtained from the General Directorate of Nature Conservation and National Parks. The slope classes were formed by analyzing the digital elevation model of ASTER fitting in GIS. Data on solid waste transfer stations in Istanbul have been obtained from IMM Waste Management Directorate. Information including land values was created by processing and adapting the data shared by the Revenue Administration. Data for roads have been obtained from the EU project named Trans-Tools. In the study, each set of geographic data corresponding to each criteria was produced separately and subjected to spatial analyzes. The weight matrix for the criterion is shown in Table 1.

Table 1. Criteria weights of all factors.

Goal A	Hierarchy B	Hierarchy C	W
A	B1	C1	0.10477125
		C2	0.08172525
		C3	0.13240050
		C4	0.14761500
		C5	0.04514850
		C6	0.11738175
		C7	0.12095775
	B2	C8	0.13515775
		C9	0.06337700
		C10	0.02935350
		C11	0.02211175

Since the Consistency Ratios (CR) obtained in the comparison matrices formed in the AHY are below the desired value of 0.10 in the theorem, the calculated weights can be evaluated and used significantly.

The "Model Builder" module included in the ArcGIS software used in the study has created a model for the landfill site. The model is prepared according to the instructions used in the study. Different studies will be able to perform site selection with different criteria using the same model.

RESULTS

In this study, using the 11 criteria, the most suitable alternative landfill site for Istanbul was selected. With the help of GIS-enabled spatial analysis, result maps in raster data format have been produced. In the study, the pixel size was taken as 30X30 meters. Areas obtained as a result of analysis; classified as unsuitable, less suitable, appropriate and very appropriate. In the light of legal restrictions, 80% of the study area is classified as unauthorized area. 1% of the study area is not suitable, 4% is less suitable, 13% is suitable and 2% is very suitable. As a result of the evaluations, the most suitable area in terms of land use and environmental conditions was determined as Silivri district of Istanbul near E-80 highway and Çerkezköy districts. The presence of a highway near the area will also reduce costs for solid waste transported from stations. The area is far away from settlements. Figure 3 shows the current Silivri Yemen Landfill Site opened in 2016 near the area indicated by number 1. As it is aimed to find alternative sites for the future, area 1 has a high degree of suitability when the other existing fields lose their function.

A total of three landfill sites are currently operating in Istanbul. These are Kömürcüoda on the Anatolian side and Odayeri and Silivri Seymen on the European side. The landfill sites that are in use are made to service by choosing the location according to the environmental and legal features in the construction years. Whether or not the existing landfill sites are included in, the appropriate areas found in the results obtained in the study are also examined. İstanbul-Odayeri landfill site is located within the appropriate region obtained as a result of the work. The Silivri Seymen landfill site is in the forest area from the characteristics of land use in operation. For this reason, there are areas classified as unauthorized areas in the study. The current site is located at a very short distance to the appropriate areas obtained in the study. The landfill site in Kömürcüoda is also located in the forested area like Silivri Seymen and is not allowed. The area where the landfill site is located in Kömürcüoda very close to the less appropriate classification obtained in the study.

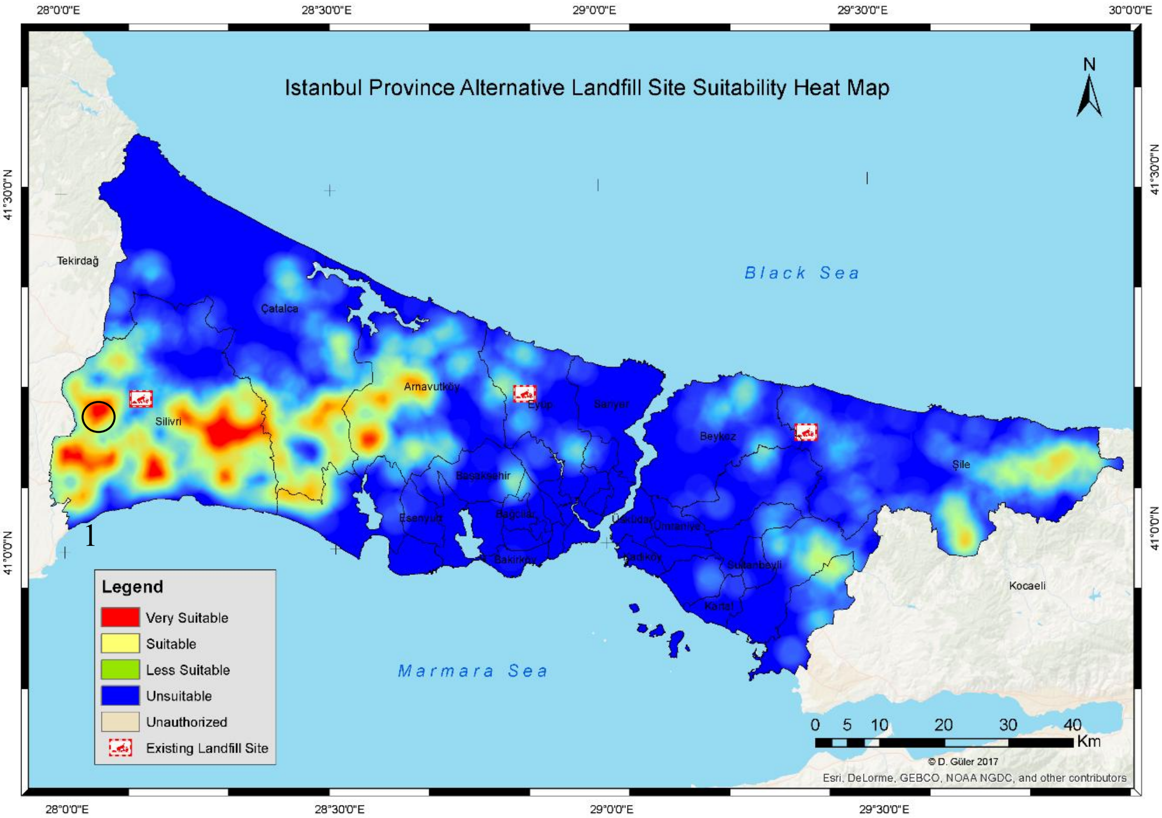

Figure 3. Istanbul province alternative landfill site suitability heat map (Guler, 2016).

The pixel values of the data used in the study and the pixel size according to the studies in the literature were chosen as 30X30 meters. Analysis results were obtained by transforming the data of the criteria of highways, airports, solid waste transfer stations and protected areas in the vector data format into raster data of 30-meter pixel size. The model was resampled and the model was resumed by selecting the pixel size 100X100 meters. When the result data generated by the model is examined, it is seen that the classification values generated by the 30-meter pixel size are very close to the 100-meter pixel result of the percentages in the study region.

In the AHP approach, environmental criteria were calculated at 75% and economic criteria at 25%. These weights determined by examining the studies in the literature were changed in the name of model analysis and the results were also re-evaluated. Considering the creation of an economic scenario, the environmental criteria were taken into consideration as 25% and the economic criteria as 75%, and the weights of the sub-criteria were recalculated. The model was reworked by recalculating the weights and yielding results for the economic scenario.

CONCLUSIONS

Today, with the rapid population growth, the urbanization process is accelerating and it is seen that the amount of solid waste in social consumption is increased as a natural result. In order to solve the environmental problems that arise in this context, regular storage, which is one of solid waste disposal methods, is preferred. However, the most appropriate location for this purpose is a complex and difficult positional problem for decision makers. In this study, alternative location selection analyzes of the landfill site were carried out with effective analysis capacities of geographic information systems. By creating a dynamic model with GIS based, it is possible to provide faster and more accurate results. The province of Istanbul is taken as an example and the suitability of the existing landfill sites by the output obtained from the model is examined. It can be seen that in case of work to be done, it can be beneficial by arranging the created model according to the working region or the properties of the data to be used. It has once again been confirmed that GIS is an important tool in solutions to environmental problems with its large volume geographical availability. The GIS-integrated AHP has been found to be an effective decision support method, particularly for the detection of landfill sites.

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