Selection of Landfill Site using GIS and Multicriteria Decision Analysis for Beyşehir Lake Catchment area (Konya, Turkey)

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Abstract- Many developing countries are struggling to provide a proper waste management system due to increasing population and urbanization. Also, waste management system is not regulated sufficiently in Turkey. At present, there are various techniques used for solid waste management such as landfill, thermal treatment, biological treatment, recycling etc. The landfill is the most common mode for the disposal of solid waste. But, landfill site selection is quite complex process and it depends on several criteria and regulations. In this study landfill site selection is performed by using Multicriteria Decision Analysis (MDA) and Geographic Information System (GIS) for the Beyşehir Lake catchment area. The Beysehir Lake is the largest freshwater lake and drinking water reservoir in Turkey but there isn't sanitary landfill site in the basin. Hence, the appropriate landfill site should be selected in point of water quality in the Beyşehir Lake. In order to determine landfill site several criteria were examined such as distance from settlements, distance from surface waters, distance from protected areas (ecologic, scientific or historic), geology/hydrogeology, landuse, distance from roads, slope and aspect. The MDA was used to measure the relative importance weighting for each criterion. Each map layers were formed with the aid of GIS and final suitability map was created by overlay analyses of each criterion map. According to obtained results, high and low suitable areas were determined in the study area.

Keywords: Beyşehir Lake, Geographic Information System, Landfill, Multicriteria Decision Analysis, Site selection

Coğrafi Bilgi Sistemleri ve Çok Kriterli Karar Analizleri Kullanılarak Beyşehir Göl Havzasında (Konya - Türkiye) Katı Atık Depolama Yer Seçimi

Özet- Birçok gelişmekte olan ülkelerde artan nüfus ve şehirleşmeye bağlı olarak uygun bir atık yönetim sistemi oluşturulmaya çalışılmaktadır. Ancak, ülkemizde uygun bir atık yönetim sistemi yeterince düzenlenmemiştir. Günümüzde, katı atık yönetiminde depolama, geri dönüşüm, termal arıtma, biyolojik arıtma gibi yöntemler kullanılmaktadır. Ancak, düzenli depolama yer seçimi oldukça karmaşık bir süreç olup çeşitli kriterlere ve düzenlemelere bağlıdır. Beyşehir Gölü Havzası için atık sahası yer seçimi yapılması amaçlanan bu çalışmada Çok Kriterli Karar Analizi ve Coğrafi Bilgi Sistemi (CBS) kullanılmaktadır. Beyşehir Gölü, Türkiye'nin en büyük tatlısu gölü ve içme suyu kaynağıdır. Ancak, göl havzası içerisinde katı atıklar için düzenli depolama alanı bulunmamaktadır. Bu nedenle, havza için uygun depolama yer seçiminin yapılması zorunlu görülmektedir. Çalışmada, depolama alanı yer seçimi için yerleşim alanlarında uzaklık, yüzey sularından uzaklık, koruma alanlarından uzaklık (ekolojik, bilimsel ve tarihi), jeoloji / hidrojeoloji, arazi kullanımı, yollarda uzaklık, eğim ve bakı gibi kriterler değerlendirmeye alınmıştır. Her bir kriterin göreceli önem dereceleri Çok Kriterli Karar Analizi kullanılarak belirlenmiş, her bir kriter haritası ise CBS teknolojilerinden yararlanılarak hazırlanmıştır. Oluşturulan her bir kritere ait tematik haritaların overlay analizi yapılarak sonuç haritası elde edilmiştir. Elde edilen sonuçlara göre havzada depolamaya en uygun olan ve uygun olmayan alanlar belirlenmiştir.

Anahtar Kelimeler: Beyşehir Gölü, Çok Kriterli Karar Analizi, Coğrafi Bilgi Sistemleri, Depolama, Yer seçimi

1. INTRODUCTION

Nowadays, solid wastes are serious problems having the first priority of the environmental problems. There are various techniques used for waste management such as landfilling, thermal treatment, biological treatment, recycling etc. (1). The collection, processing, transport and disposal of solid waste are all important aspects of waste management for public health, aesthetic, and environmental reasons (2). It is essential to dispose the solid waste to a landfill without creating a hazard to public health (3). Hence, one of the major problems in waste management is appropriate site selection for waste disposal.

The disposal site mustn't damage to the biophysical environment and the ecology of the surrounding area (4, 5, 6). Also economic factors and geomorphologic features must be considered during site selection for the solid wastes (7). Several techniques can be found for site selection of solid waste disposal in literature (1, 8, 9, 10, 11, 12, 13, 14).

To determine the most proper landfill site for a region, many criteria should be considered. The MDA is widely used method for site selection process. It is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. Unlike methods that assume the availability of measurements, measurements in MDA are derived or interpreted subjectively as indicators of the strength of various preferences (15). The main objective of MDA is the design of mathematical tools to support the subjective evaluation of a finite number of decision alternatives under a finite number of criteria in order to find the best choice (16).

GIS combines spatial data (maps, aerial photographs, satellite images) with quantitative, qualitative and descriptive information databases (1). The overall GIS-supported landfill site selection process contains two primary screening steps: (i) exclusion of areas unsuitable for landfill, prescreening step or GIS step, and (ii) weighting (ranking) of remaining areas, i.e. decision analyses step (4, 17, 18,19, 20). The integration of GIS and MDA is a powerful tool to solve the landfill site selection problem, because GIS provides efficient manipulation and presentation of the data and MDA supplies consistent ranking of the potential landfill areas based on a variety of criteria (9). The main objective of this paper is to determine the most appropriate landfill site for the Beyşehir Lake catchment area by integrating the Geographic Information System (GIS) with the Multicriteria Decision Analysis (MDA). In order to determine suitable landfill site eight criteria were considered such as distance from settlements, distance from surface waters, distance from protected areas (ecologic, scientific or historic), geology/hydrogeology, landuse, distance from roads, slope and aspect.

2. MATERIAL AND METHOD

The Lake Beyşehir catchment area is located within the Lake District in the southwest of Turkey and covers an area of 4167 km^2 (Fig. 1). It is one of the most essential water sources especially in domestic and irrigation water supplies. As the lake is a supply of fresh water for human consumption, its water quality is controlled by Turkish "Water Pollution Control Regulations" (21). The Lake Beyşehir has been a first-degree Specially Protected Area since 1991 and has been completely surrounded by two National Parks since 1993, namely the Beyşehir and Kızıldag National Parks (22). There are conservation statutes as "1st, 2nd, and 3th degree Natural Protected Areas" and "Archeological Protected Areas" in the basin (21). Although it has protected statues, the lake has a number of problems such as variations in water level due to inappropriate water policy over growth up aquatic macrophytes in the lake ecosystem, uncontrolled fishing, urbanization and water pollution (23). Therefore, environmental selection of the appropriate landfill site is very crucial.

In this study, the methodology which is integration of GIS and MDA was used and applied to the Lake Beyşehir catchment area. The eight criteria were considered such as distance from settlements, distance from surface waters, distance from protected areas (ecologic, scientific or historic), geology/hydrogeology, landuse, distance from roads, slope and aspect. These basic criteria and subcriteria were selected by taking relevant international literature and Turkish regulations (24) into consideration.

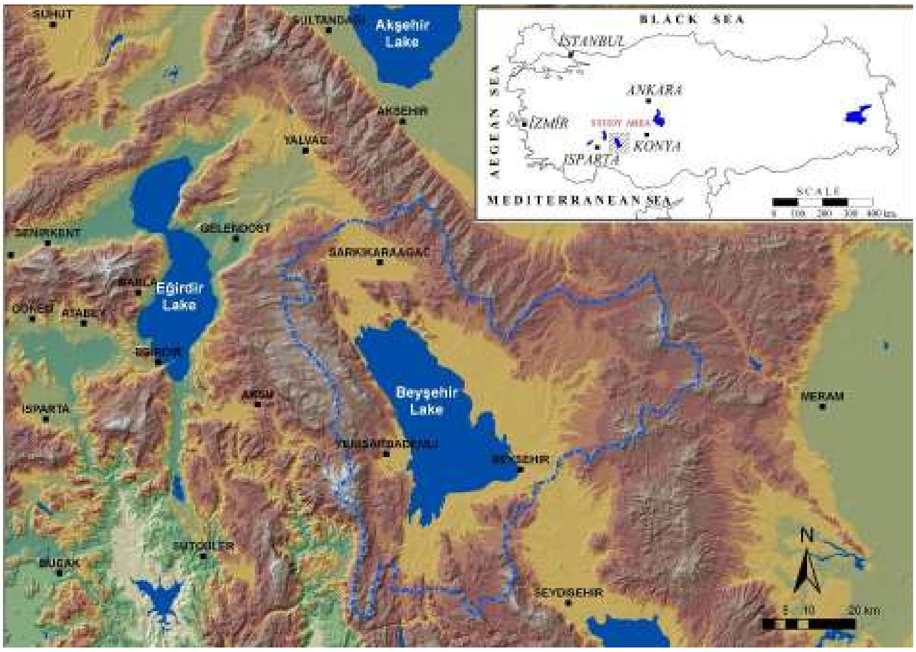

Figure 1. The location map of the study area

ArcView 9.0 software was used for imaging and analysis of spatial data. Additionally, several GIS analyses such as buffer zoning, neighboring computation, cost distance and overlay analysis were used. In order to evaluate site selection criterion, MDA was used to measure the relative importance weighting for evaluation criteria. Because, MDA is to divide the decision problems into more smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner (25).

The ranking and weight values were assigned to each criterion to determine Landfill Suitability Index (LSI). LSI was calculated by means of multiplication of each criteria weight with each subcriteria weight.

$$LSI = (Ac_{wi} \times Asc_{wi}) + (Rc_{wi} \times Rsc_{wi}) + (Sc_{wi} \times Ssc_{wi}) + (LANc_{wi} \times LANsc_{wi}) + (GHc_{wi} \times GHsc_{wi}) + (SETc_{wi} \times SETsc_{wi}) + (PAc_{wi} \times PAsc_{wi}) + (SWc_{wi} \times SWsc_{wi})$$

Where:

LSI : Landfill suitability index

Ac_{wi} : Weight index of aspect criteria
Asc_{wi} : Weight index of aspect subcriteria
Rc_{wi} : Weight index of roads criteria

Rsc_{wi} : Weight index of roads subcriteria
Sc_{wi} : Weight index of slope criteria
Ssc_{wi} : Weight index of slope subcriteria
$LANc_{wi}$: Weight index of landuse criteria
$LANsc_{wi}$: Weight index of landuse subcriteria
GHc_{wi} : Weight index of geology-hydrogeology criteria
$GHsc_{wi}$: Weight index of geology-hydrogeology subcriteria
$SETc_{wi}$: Weight index of settlement criteria
$SETsc_{wi}$: Weight index of settlement subcriteria
PAc_{wi} : Weight index of protected area criteria
$PAsc_{wi}$: Weight index of protected area subcriteria
SWc_{wi} : Weight index of surface water criteria
$SWsc_{wi}$: Weight index of surface water subcriteria

Rankings varies between 0 (no constraint) and 10 (total constraint). Weights are generally assigned according to the relative importance of each criterion. Ranking and weight values of each criterion are summarized in Table 1. The assigned weights can be changed according to properties of the study area. Hence, there is not any standard for this topic. The weights were assessed by taking into account the possibility of modifying the natural conditions of the sites and suggested for only this study area. The map layers were formed in the GIS environment and final suitability map was created by overlay analyses of each criterion map. In order for the output map to be meaningful and consistent, map weights had to add up to 100% and the attribute scores had to be chosen using a scheme that was the same for each map (14).

3. RESULTS AND DISCUSSION

In this study, evaluation criteria were determined depend on relevant Turkish Solid Waste Control Regulations (1991) and international literature. There are eight criteria that were considered when selecting a landfill site in the Lake Beyşehir catchment area. These are distance from settlements, distance from surface waters, distance from protected areas (ecologic, scientific or historic), geology/hydrogeology, landuse, distance from roads, slope and aspect. Each criterion was explained below in detailed.

Distance from settlements: According to Turkish regulations (24) landfill cannot be located within 1000 m of settlement areas. Therefore, an area with a 1000 m buffer zone was scored as 1 and buffer zones greater than 4 km were scored as 9 (Table 1, Fig 2)

Distance from surface waters: According to Turkish regulations (27) and international literature (1,14,26) landfill site should not be placed near any surface water. In the study area such a zone has been created around lakes, springs and rivers of a 500 m buffer zone was scored as 1 and buffer zones greater than 2 km were scored as 7 (Table 1, Fig 3).

Distance from protected areas: According to Turkish regulations (28), protected areas such as national parks, archeological areas etc. are not suitable for landfill siting and landfill site should not be placed within these areas. Hence, a weighting of 9 is applied if >1000 m away and 1 for <250 m away (Table 1, Fig 4).

Geology/Hydrogeology: Geology map of the basin was prepared to benefit from field previous investigations (29, 30, 31). The six lithologic units such as alluvium, limestone, volcanics, flysch, ophiolite and metamorphics were grouped and mapped. According to aquifer properties of the lithologic units, the buffer zones were created. Alluvium and limestone have large water potential and are not suitable for landfill siting. Hence, the lowest ranks were assigned to these units such as 1 and 2 respectively. Also, metamorphics are impermeable unit so this unit was scored as 8 (Table 1, Fig 5).

Landuse: To evaluate landuse properties of the study area, the 1:100 000 scale landuse map was taken from Management of Agriculture and Village Works. According to landuse of the region, Forest and rocky areas were scored as 1, dry agricultural areas was scored as 5 (Table 1, Figure 6).

Distance from roads: The landfill site should not be placed too far away from existed road networks (14). Also, it can be reached by alternative roads under all weather conditions. Hence, a weighting of 6 is applied if >1000 m away and 1 for <250 m away (Table 1, Fig 7).

Slope: Land slope is basic parameters for the construction of a landfill site (1). The appropriate slope for constructing a landfill is about 8–12% (17). Therefore, the steep areas (> 20) were assigned a grade of 1 and the slightly sloping areas (0-10) with a grade of 5 (Table 1, Fig. 8).

Aspect: Settlements must not be affected from the odor which is originated from the wastes. Therefore, wind direction of the basin was taken into consideration. The wind frequency percentages data were obtained from the National Meteorological Agency of Turkey. In the basin, SW and NE winds are the dominant winds. So, these directions lowest weight values (Table 1). The spatial results are represented in Fig. 9.

In present study, the high weights were given to the criteria of distance from settlements and distance from surface waters. But, aspect and slope criteria were assigned with low weights. Eight map layer s were prepared by GIS. The final suitability map was derived by overlay analyses of ArcGIS Spatial Analyst (Fig. 10).

Initially forbidden areas were extracted by masking and then the land suitability of the study area was calculated by the LSI. Calculated LSI is varies between 1,45 and 13,6. The very high and very low suitable areas were determined. Pixels with 1,45 (colored yellow) are considered as very low suitable and are excluded from the alternative candidates sites to be examined as disposal areas. On the other hand pixels with values around 13,6 suggested sites that are likely to be more suitable and are colored red (Fig.10).

Table 1: The summary of the rankings and weights used in the landfill site selection

Criteria	Subcriteria	Weight	Ranking	Area (%)
Aspect		0,05		
	SW		1	14,39
	NE		1	11,69
	N		2	9,54
	NW		2	11,18
	SE		2	12,17
	W		3	15,70
	E		4	14,14
	S		5	11,19
Slope		0,10		
	> 20o		1	74,680
	10-20o		3	18,950
	0-10o		5	6,370
Distance from roads		0,10		
	> 1000 m		1	62,090
	750-1000 m		2	7,943
	500-750 m		4	8,893
	250-500 m		5	9,980
	< 250 m		6	11,093
Landuse		0,20		
	Rocky		1	10,259
	Forest		1	22,927
	Garden		2	1,316
	Heath		3	15,994
	Pasture		3	15,376
	Water Agricultural		4	4,400
	Dry Agricultural		5	29,728
Geology / Hydrogeology		0,30		
	Alluvium		1	16,892
	Limestone		2	36,731
	Volcanic		4	0,405
	Flysch		5	36,150
	Ophiolitic		7	2,252
	Metamorphic		8	7,570
Distance from protected area		0,30		
	< 250 m		1	2,036
	250-500 m		3	2,259
	500-750 m		5	2,443
	750-1000 m		7	2,582
	> 1000 m		9	90,679
Distance from surface water		0,40		
	< 500 m		1	10,208
	500-1000 m		2	9,939
	1000-1500 m		4	9,600
	1500-2000 m		6	8,981
	> 2000 m		7	61,272
Distance from settlement		0,40		
	< 1000 m		1	6,575
	1000-2000 m		3	16,008
	2000-3000 m		5	16,506
	3000-4000 m		7	13,894
	> 4000 m		9	47,017

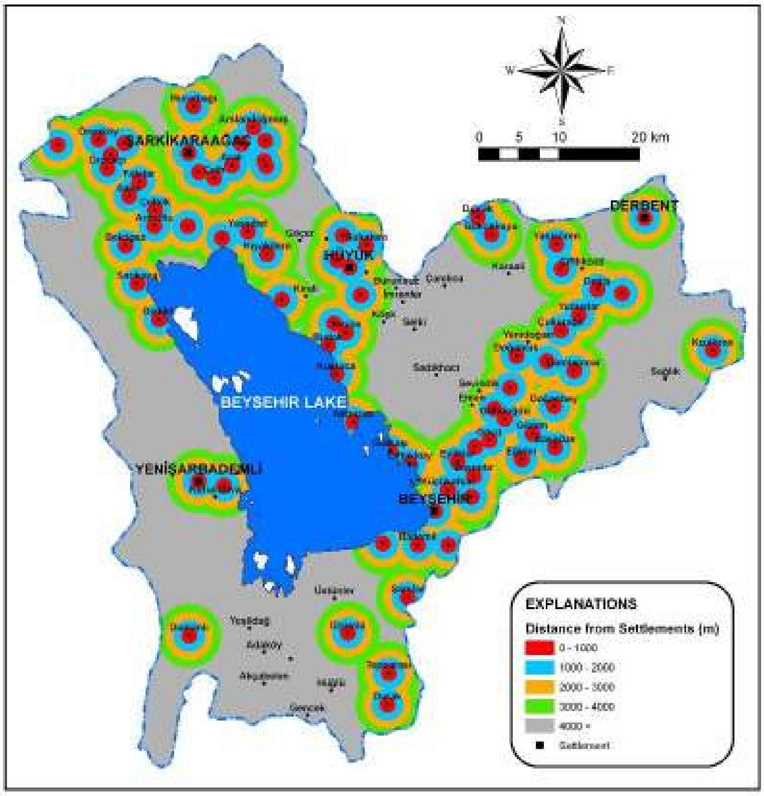

Figure 2. Map of the Distance from Settlement Area

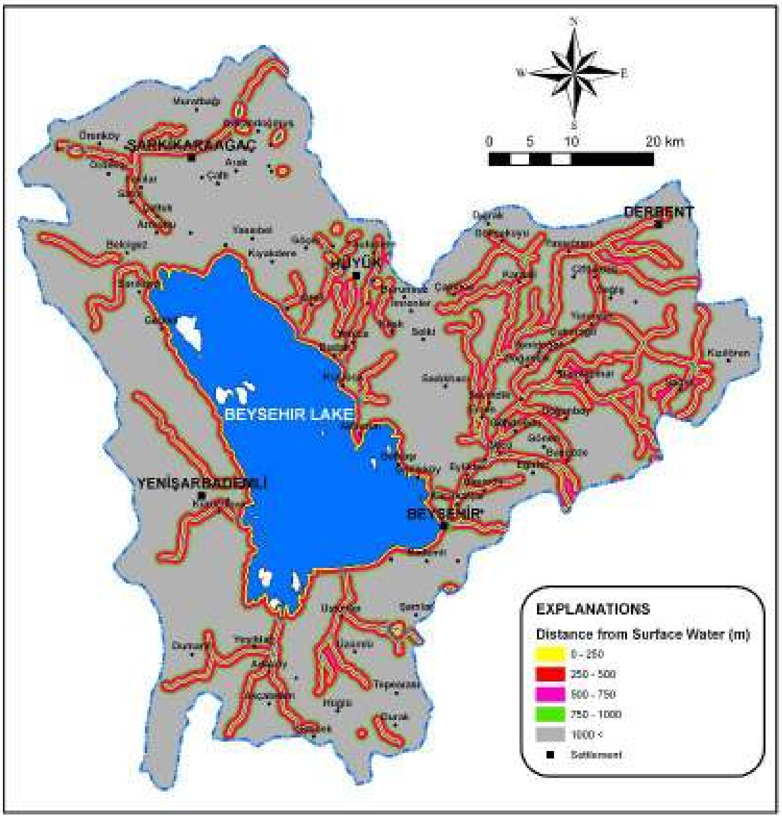

Figure 3. Map of the Distance from Surface Waters

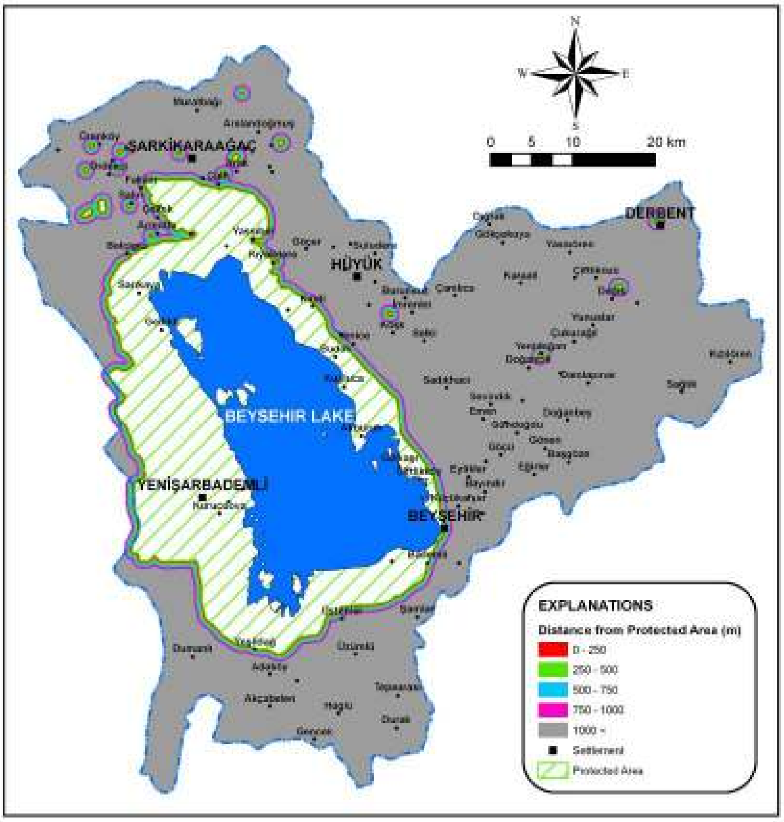

Figure 4. Map of the distance from protected areas

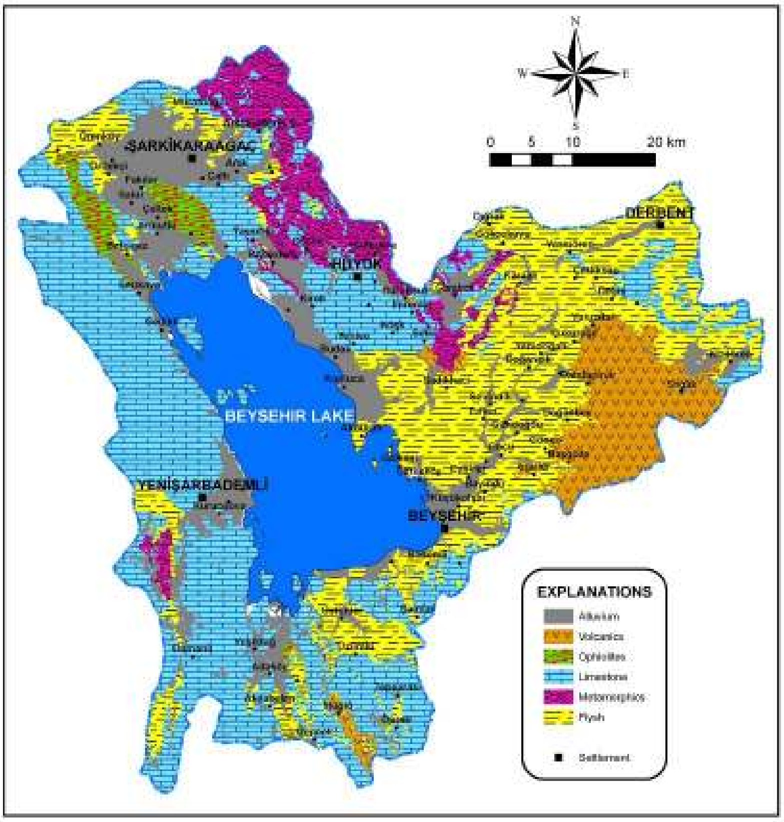

Figure 5. Geology map of the study area

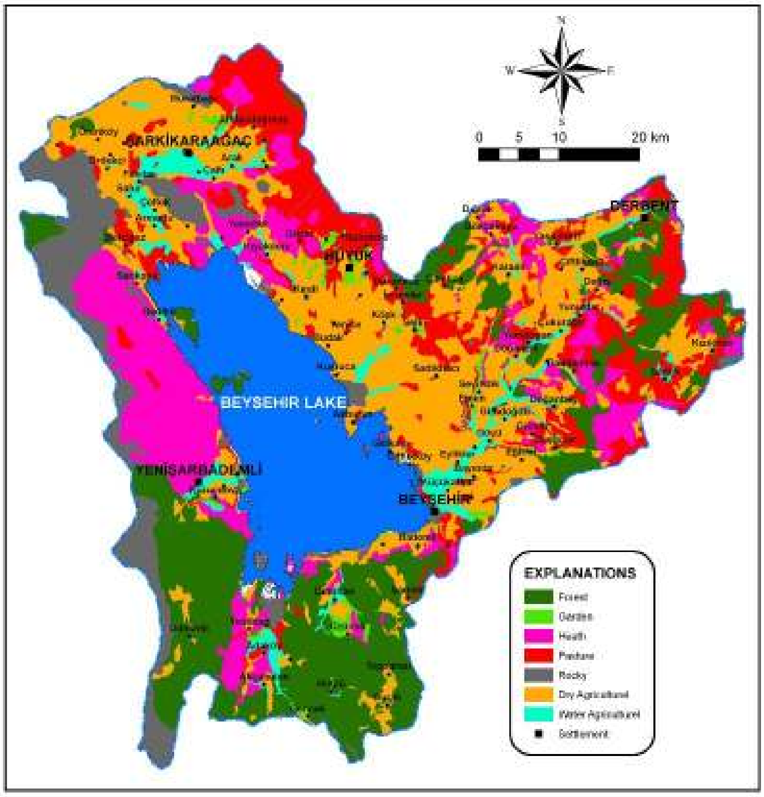

Figure 6. Landuse map of the study area

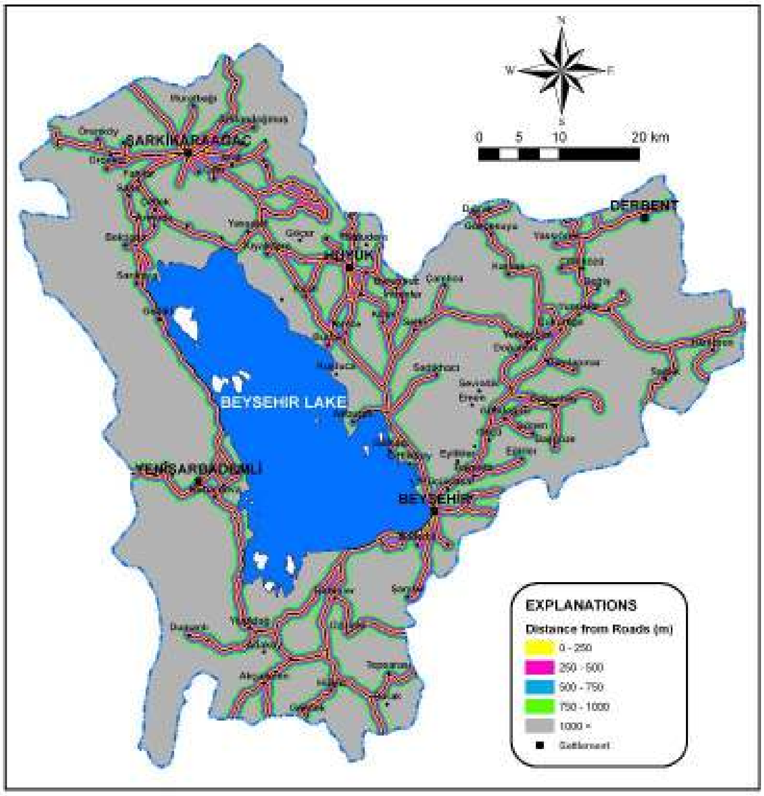

Figure 7. Map of the distance from roads

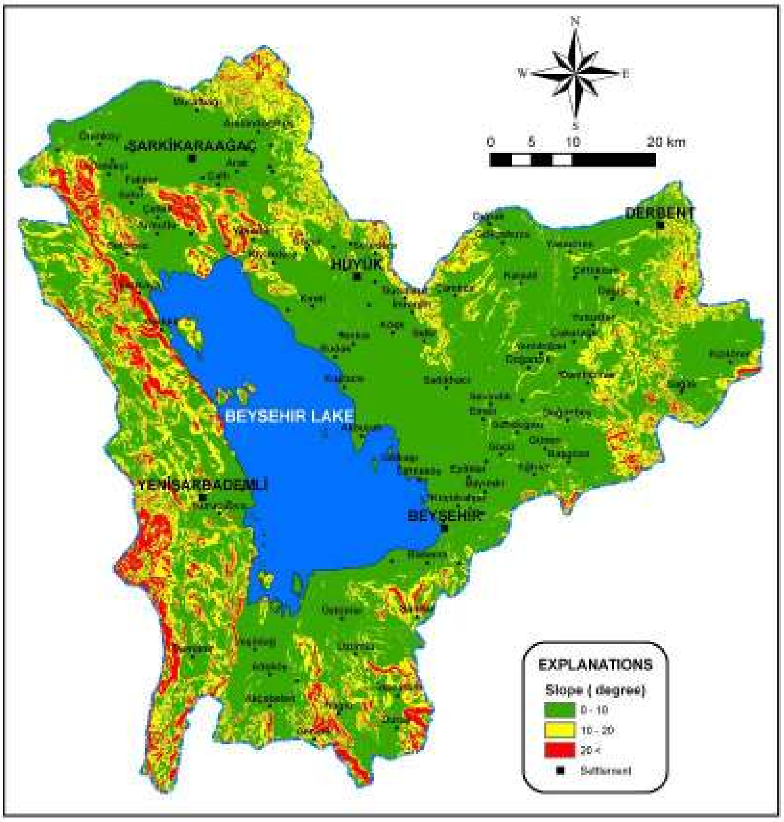

Figure 8. Slope map of the study area

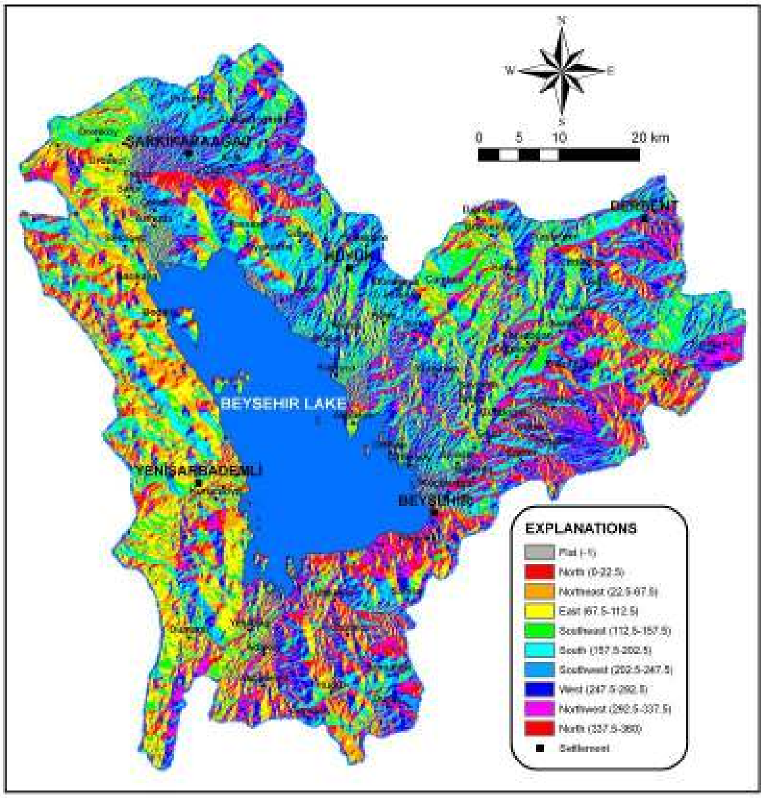

Figure 9. Aspect map of the study area

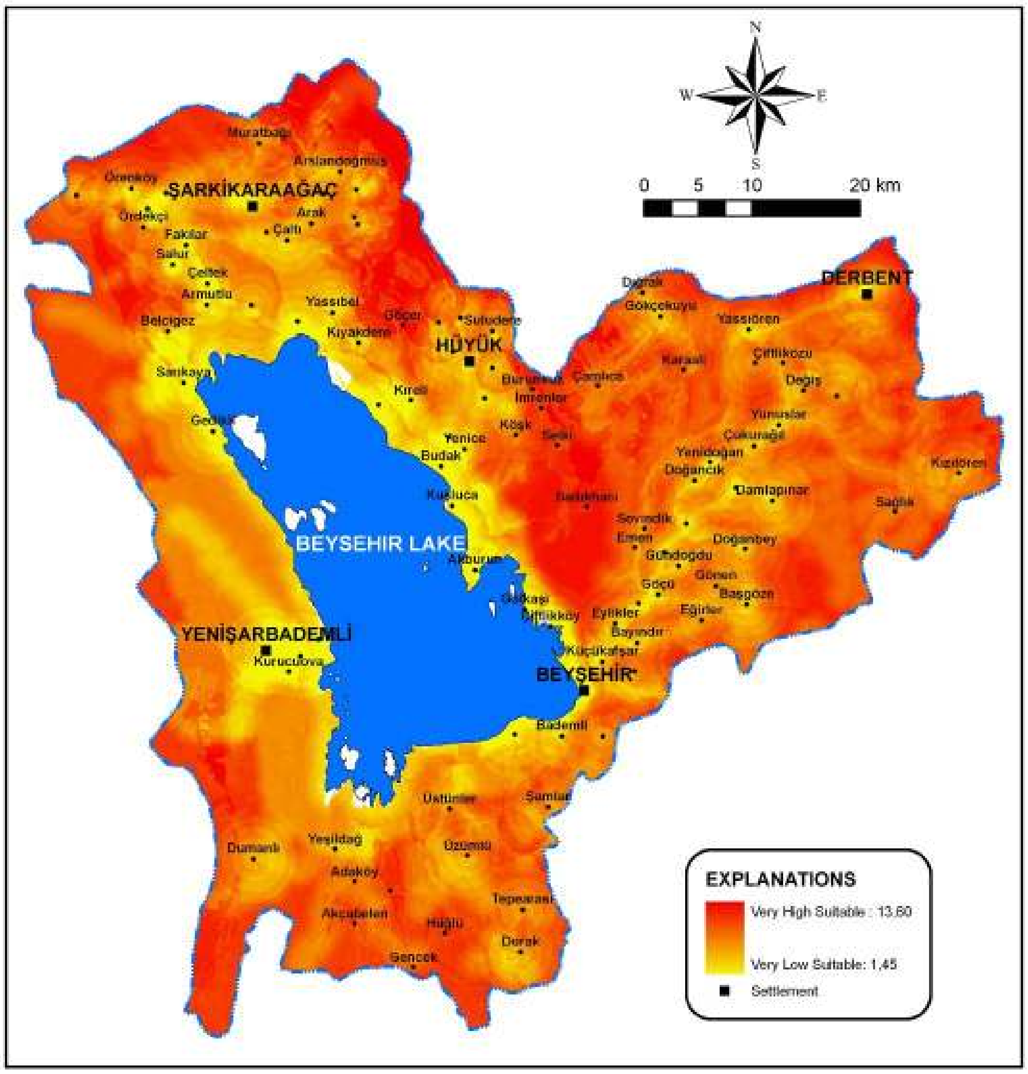

Figure 10. The landfill suitability map of the study area

4. CONCLUSION

In the present study the landfill site selection for municipal solid waste was performed using GIS and MDA methods. For this aim, eight evaluation criteria were determined and their ranking and weights were assigned. The criteria maps were prepared in GIS environment using obtained numerical values. The final suitability map was prepared using overlay analyses and high – low suitable regions of the study area were determined. This study shows that suitable areas are quite limited for landfill siting in Beyşehir Lake catchment area. In general, the regions where around the lake is unsuitable for landfill siting. Also, near the surface waters were determined as unsuitable areas.

The north and east of the lake were determined as high suitable areas in the region. These places are dry agricultural areas and have 0-10^{o} slope. The flysh and metamorphic units are overlay in there. Furthermore, these places are away from surface waters and protected areas. The transportation is quite suitable for waste transport. However, detailed field studies should be performed for the final site selection.

The presented study is very helpful tool to aid decision makers. But, detailed field studies should be performed for the final site selection. Also, urgent preventions should be taken for every kind of activity within the area to protect the lake.

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