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MUNİCİPAL SOLİD WASTE LANDFİLL SİTE SELECTİON USİNG MULTİ-CRİTERİA DECİSİON MAKİNG AND GIS: CASE STUDY OF BURSA PROVİNCE

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Abstract. Rapid population growth, economic development and industrialization have created many problems related to municipal solid waste management (MSWM) in developing countries like Turkey. Solid waste disposal has become mandatory because of increasingly common factors such as global warming and contamination of water resources. In recent years, this situation has revealed the need for effective management of solid waste. Suitable site selection requires evaluation and analysis of multiplefactor. Therefore, it is very important that the design of landfill site selection take into account environmental, economical and sociologicalfactors. In order to do this, the Geographical Information System (GIS) used with Multi Criteria Decision Making (MCDM) techniques is a useful tool for creating a model. One such MCDM is the Spatial-integrated Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In this study, TOPSIS was applied to integrate environmental, economical and sociological sensitivity into determine alternative solid waste landfill sites for Bursa Province, Turkey. Using the data obtained by comparing the geo-statistics, six of the most suitable landfill areas were determined. In the final stage, as a result of this study, the Kayapa district was identified as the most suitable landfill area.

Keywords: solid waste, landfill, GIS, MCDM, TOPSIS, Bursa.

Introduction

Municipal solid waste landfill site (MSWLS) selection is a difficult, complicated and lengthy process in which many factors, including environmental, social, economic and technical, must be assessed together (Eskandari *et al.* 2015; Hamzeh *et al.* 2015). In MSWLS selection, environmental factors are extremely important, considering that the bio-physical environment and ecological structures are significantly affected (Sumathi *et al.* 2008). Economic factors are also related to the process of establishing, developing and operating landfill areas (Delgado *et al.* 2008; Yesilnacar, Cetin 2005). Over time, the rapid increase in population and changes due to the development of living standards have revealed the disposal of solid waste to be an environmental problem. It is very important to take the necessary measures and precautions to eliminate this problem, otherwise, the pollution of the living environment appears to be an inevitable outcome. In order to achieve a successful solid waste disposal system, a large budget is needed (Afroz *et al.* 2011; Vijay *et al.* 2008). Today, attempts are being made to apply budget systems that can be utilized effectively. Along with the formation of storage areas, the necessity of establishing a system in which the identified solid waste landfill site is used on a regular basis is becoming increasingly important. The most significant step in municipal solid waste management (MSWM) is the selection of an suitable site, while considering the environmental, economic, sociological, technical, and political aspects. It is known that solid waste causes environmental pollution, especially in a world experiencing formidable environmental dilemmas. The MSWLS selection process is a kind of spatial application that is performed by querying, evaluating and analyzing many factors together. Site selection problems require collecting, storing in a digital environment, analyzing and presenting the complex location-based graphical and non-graphical data structure that brings together different disciplines. At this point, the geographic information system (GIS) emerges as the most appropriate tool for providing effective solutions in many different disciplines. This information

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system supplies, collects, stores, analyzes and presents the graphical and non-graphical data obtained via a reliable location-based process to the user (Yomralioglu 2010). MSWLS technique is used in many applications. The GIS related to solid waste landfills can be used effectively in the process of MSWLS (Yesilnacar *et al.* 2012; Yildirim 2012). Regarding the disposal of solid waste, there are many national and international academic studies using GIS as an effective tool (Ersoy *et al.* 2013; Gorsevski *et al.* 2012; Arıkan *et al.* 2015; Khan, Samadder 2015; Turskis *et al.* 2012; Uyan 2014; Vasiljevic *et al.* 2012; Yesilnacar *et al.* 2012; Yildirim 2012; Sumathi *et al.* 2008; Thompson *et al.* 2013).

In this study, the most suitable landfill area for Bursa Province (Turkey) was determined by GIS analysis. This study implemented raster-based site selection. The necessary factor for solid waste landfills were determined, and spatial query and analysis were performed using a spatial database of these factor. Six suitable fields were identified using TOPSIS and GIS. Many studies have been previously conducted on MSWLS selection (Bagocius *et al.* 2014; Beskese *et al.* 2015; Demesouka *et al.* 2013; Ekmekcioglu *et al.* 2010; Jakimavičius, Burinskienė, 2009b; Pazand *et al.* 2012; Sener *et al.* 2011; Gbanie *et al.* 2013; Alanbari *et al.* 2014; Ashraf *et al.* 2015; Ghinea, Gavrilescu 2016; Kahraman *et al.* 2017; Yildirim, Guler 2016; Arikan *et al.* 2017; Vucijak *et al.* 2016; Victor *et al.* 2017; Bahrani *et al.* 2016; Torabi-Kaveh *et al.* 2016; Kumar, Hassan 2013; Thomaidis *et al.* 2006; Zavadskas *et al.* 2016; Chakraborty *et al.* 2015). After identifying suitable areas for solid waste disposal, the most suitable one within six areas are found.

1. Materials and methods

A methodological process was used in determining solid waste landfill areas for Bursa Province. First of all, the factors required for spatial analysis were identified. Spatial data required to identify the solid waste storage area were obtained from the Bursa Metropolitan Municipality. Twenty-three different types of spatial data layers were used in this study. The attribute and spatial information of the resulting data used was organized and prepared for transfer to the database for analysis. In another step, for spatial analysis, the necessary information for the spatial data factor weights was obtained by using required weight factors determined by surveys conducted by experts (work in institutions and organizations in the field of solid waste, engineers work in private companies, academicians) together with information from previous studies. Necessary factors for solid waste site selection areas were determined. Then impact ratings scoring process are carried out with a survey study factors and sub-factors in terms of suitability for solid waste site selection area (Figure 1). The score values obtained from the survey were arranged to use the pairwase comparison matrices. Then using result scores, pairwise comparision matrices were created according to the degree of superiority to each other, Pairwase comparision matrices were used to determined factor weights and factor weigts are evaluated. In this section, the factor weights are obtained between 0 and 100. Then, factor weights are normalized in the range of 0–1 value and added in the table and normalized factor weights were used as input values for TOPSIS method. Then, these factor weights used as input values for TOPSIS method. Finally, a cost surface

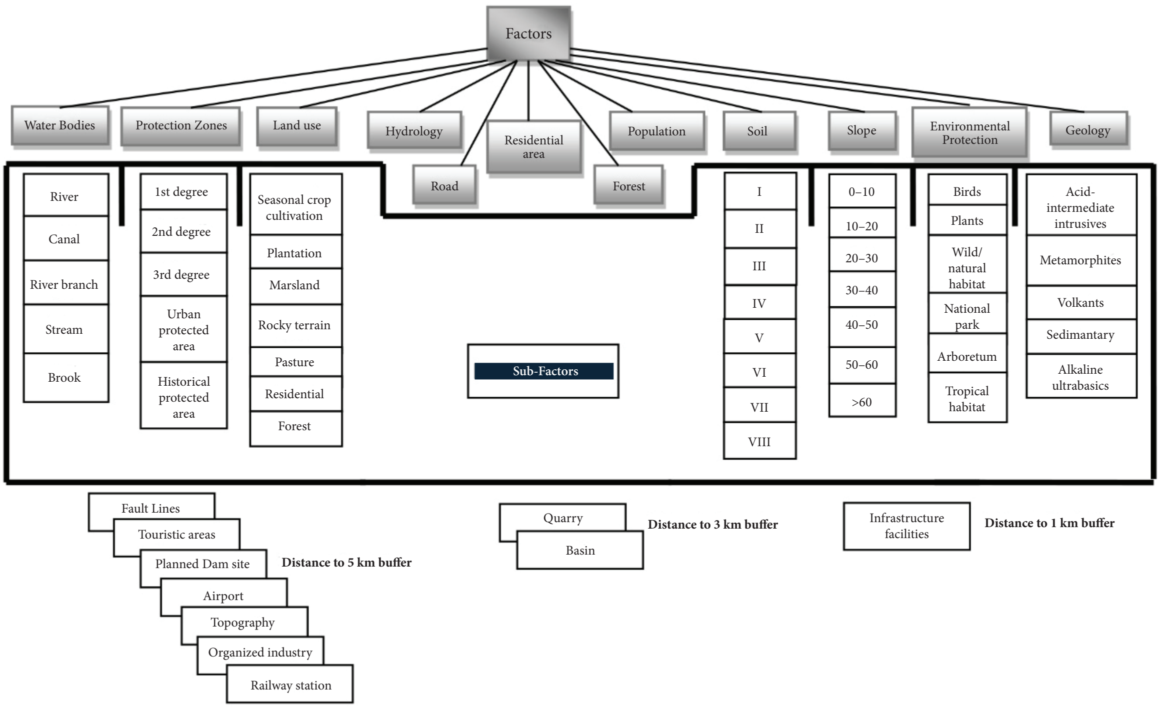


Figure 1. Factors and sub-factors

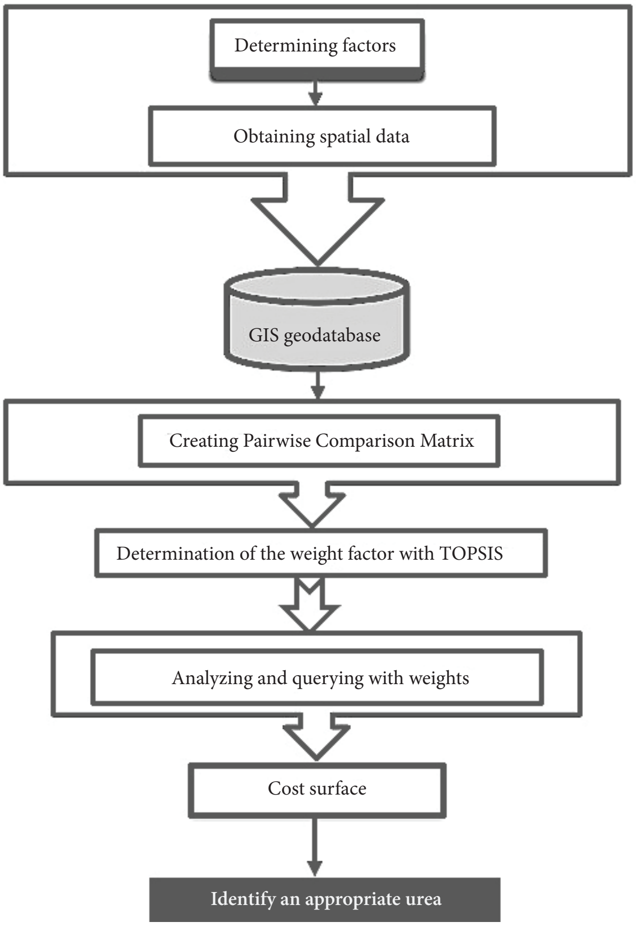


Figure 2. MSWLS methodology

map was created by querying and analyzing the determined weight values for all factors, and the MSWLS selection process was performed. A methodological diagram of the application is shown in Figure 2.

1.1. Designing possible suitable areas using TOPSIS and Cost Surface

1.1.1. TOPSIS Method

TOPSIS method firstly developed by Hwang and Yoon (Hwang, Yoon 1981) is currently used to identify solutions that are as close as possible to an ideal solution, while applying some measure of distance; consequently, indicated solutions are called compromises. The main idea of TOPSIS is that the solution should be as far as potential from the worst potential solution and as close as to the best potential solution. This method is quite simple and intuitive, presenting a satisfactory performance in many applications (Kowkabi *et al.* 2013; Wang, Z. X., Wang, Y. Y. 2014). This TOPSIS method rationality is easy to grasp and it is one of the most used techniques in the literature because of advantages about simplicity in calculation and possibility of weighting evaluation factors.

The TOPSIS method has four advantages: (1) a sound logic that represents the rationale of human choice; (2) a scalar value that accounts for both the best and worst alternatives simultaneously; (3) a simple computation process that can be easily programmed; and (4), performance measures for all alternatives that can be visualized on a polyhedron for any two dimensions.

The procedure of TOPSIS can be expressed in a series of steps (Pazand *et al.* 2012).

There are many different variables at the equation sequence of TOPSIS calculation and these variables are defined below:

D = Decision matrix

A1, ……, An = value corresponding to jth alternative

F1, ……, Fn = value corresponding to ith criteria (factor)

R(=[rij])= Normalized decision matrix

Vij = weighted normalized matrix

Wi = weight of any criteria (factor)

A+ = Positive ideal solution

A- = Negative ideal solution

Dj+ = separation measures to positive-ideal solution

Dj- = separation measures to negative-ideal solution

CCj+ = Relative closeness to the ideal solution

Step 1: Establish a decision matrix for the ranking. The structure of the matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ .. \\ .. \\ A_3 \\ . \\ . \\ A_J \end{array} \begin{array}{c} \begin{array}{ccccccc} F_1 & F_2 & .. & F_j & .. & F_n \end{array} \\ \left| \begin{array}{ccccccc} f_{11} & f_{12} & .. & f_{1j} & .. & f_{1n} \\ f_{21} & f_{22} & .. & f_{2j} & .. & f_{2n} \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ f_{i1} & f_{i2} & .. & f_{ij} & .. & f_{in} \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ f_{J1} & f_{J2} & .. & f_{Jj} & .. & f_{Jn} \end{array} \right| \end{array} \quad (1)$$

where Aj denotes the alternatives j, j = 1, 2,…, J; F_i represents the ith attribute or criterion, i = 1, 2,…, n, related to the ith alternative; and f_{ij} is a crisp value indicating the performance rating of each alternative A_i with respect to each criterion F_j.

Step 2: Calculate the normalized decision matrix R (= [rij]). The normalized value rij is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sum_{j=1}^{n} f_{ij}^2}, \quad j = 1, 2,\ldots, J; \quad I = 1, 2,\ldots, n \quad (2)$$

Step 3: Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value vij is calculated as:

$$V_{ij} = w_i \times r_{ij}, \quad j = 1, 2,, J; \quad I = 1, 2,\ldots, n \quad (3)$$

where wi represents the weight of the ith attribute or criterion.

Step 4: Determine the positive-ideal and negative-ideal solutions.

$$A^{+} = \left\{ v_1^{+}, v_2^{+}, \ldots, v_i^{+} = \left\{ \left(max\, v_{ij} \middle| i \in I' \right), \left(min\, v_{ij} \middle| i \in I'' \right) \right\} \right. \quad (4)$$

$$A^{-} = \left\{ v_1^{-}, v_2^{-}, \ldots, v_i^{-} = \left\{ \left(min\, v_{ij} \middle| i \in I' \right), \left(max\, v_{ij} \middle| i \in I'' \right) \right\} \right. \quad (5)$$

where I' is associated with the ascend factor, and I'' is associated with the descand factor.

Step 5: Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the positive-ideal solution (D^{+}_{j}) is given as:

$$D_j^{+} = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^{+} \right)^2}, \quad j = 1, 2, \ldots, J \quad (6)$$

Similarly, the separation of each alternative from the negative-ideal solution (D^{-}_{j})is as follows:

$$D_j^{-} = \sqrt{\sum_{i=1}^{n} \left(v_{ij} - v_i^{-} \right)^2}, \quad j = 1, 2, \ldots, J \quad (7)$$

Step 6: Calculate the relative closeness to the ideal solution and rank the performance order. The relative closeness of the alternative A_j can be expressed as:

$$CC_j^{+} = \frac{D_j^{-}}{D_j^{+} + D_j^{-}}, \quad j = 1, 2, \ldots, J \quad (8)$$

Since $D^{-}_{j} \geq 0$ and $D^{+}_{j} \geq 0$, then clearly $CC_j^{+} \in [0,1]$. (9)

The larger the index value, the better the performance of the alternatives. As can be seen above, TOPSIS is an efficient method in the model of Multicriteria Decision Support Systems. The factor and sub factor weights were calculated with pairwase comparision matrices using normalized values and using this standartilized values as an input values for TOPSIS method to produce raster based surface. TOPSIS method emerge as a suitable model to produce raster surface using input standarilized values.

1.1.2. GIS-Based Accumulated Cost Surface Analysis

Cost distance analysis also known as "Accumulated Cost Surface Analysis" is a popular technique that is grid dataset and relies on "cost surface" in Geographical Information Systems(GIS) applications especially including solid waste site selection. "Accumulated" emphasize that there is a building up of numbers or values. The cost of a cell on an accumulated surface represents the accumulation cost of the target's cell (Christopher 2005; Douglas 1994). Within GIS packages solutions to such problems are found using a family of algorithms known as Accumulated Cost Surface (ACS) methods for a fuller discussion of ACS methods and representational accuracy. Douglas (1994) and Eastman (1989) addressed this Accumulated Cost Surface methods and representational accuracy see of methods for ACS in their study. In this application, the value of each cell represents the cost per unit distance of crossing that cell. The ACS application is applied to raster datasets, in which the primary input surface is a complete grid of generalized costs, i.e. every cell is assigned an absolute or relative cost measure, where costs must be (positive) ratio-scaled variables (Eastman 1989; Smith *et al.* 2015). Cost Accumulated surfaces are raster models that allow you to decide which places are the most suitable areas to build planned structure, also site selection orocess. An accumulated cost surface, goes from a starting point to the destination (Bagli *et al.* 2011; Douglas 1994). Because of the advanteges of GIS-based accumulated cost surface analysis, in this study this technique was chosen to produce surface maps. Due to the factors and sub-factors, this method was used with GIS for determining the most suitable solid waste area.

2. Case study

2.1. Study area

Bursa province is located on the southeast of the Marmara Sea at 40° west longitude and 28°–30° north latitude. The Marmara Sea and the province of Yalova are located to the north, Kocaeli and Sakarya Provinces to the north-east, Bilecik Province to the east, Kutahya Province to the south and Balikesir Province to the west. Mountains constitute about 35% of the Bursa terrain. The province lacks many rivers, while the vegetation is varied according to the climatic characteristics, altitude and distance from and proximity to the sea. The land cover consists of 46% forest and 15.4% dry marginal agricultural and 2.2% irrigated agricultural areas. The study area is shown in Figure 3.

Figure 3. Study area

2.2. Data sets and pre-processing

This study was conducted for the Metropolitan Municipality of Bursa Province, and they provided 23 different map layers that were made ready for use in the GIS database: Population, flora-fauna, protected areas, residential areas, soil, land use, airports, hydrology, railway stations, geology, mine areas, forests, organized industries, touristic areas, quarries, planned dam sites, basins, streams, roads, fault lines, topography, elevation and infrastructures. Each data was obtained and stored to be ready for analysis as follows:

1. Population data for the years 2007–2014 were provided by the Turkish Statistical Institute, taking into account existing data for the last eight years in the Address-Based Population Registration System database. The population datas were transferred to ArcGIS 10.1 software and stored in point data format in this geodatabase. Population data for 2014 were added to the attribute table of geographic data layers related to residential areas and these data were used for analysis.
2. Flora and fauna data was provided as an extension of NetCAD from Bursa Metropolitan Municipality. This layer was then stored in the polygon data format and transferred to ArcGIS 10.1 software ready for analysis.
3. Four different protected areas included a dam site, a natural archaeological conservation area, a public recreation area and a historical preservation site was used in this study. Protected zones covering the overall area were transformed into spatial data layers in the ArcGIS program and made ready for use as polygon data.
4. Residential areas were digitized over the satellite image of the region and the population data of each residential area was entered into the database attribute. Residential areas were created based on a 1/25,000 scale and stored as point vector data structures in the database.
5. Soil data taken from the Ministry of Agriculture General Directorate of Agricultural Reform were transferred to the database as a polygon data layer and made ready for analysis. Information collected under the name "Soil" included great soil group (GSG) class, current land usage (CLU), land use capability class (LUCC), land type (LT), agricultural land class (ALC) and subclass (SC). The eight land use capability classes were designated as first to eighth, according to soil loss and classification.
6. A land use map was created with ArcGIS version 10.1 using data obtained from Bursa public institutions and transferred to the database as a polygon data layer; the attributes information for land use classes were entered as a layer on the ArcGIS program.
7. There are three airports located in Bursa, two civilian and one military. Airport data was digitized over the current Bursa satellite photos and topographic map and added to the database as a polygon data layer.
8. Two different areas were determined in the hydrological data of Bursa: dam reservoirs and lakes/ponds.
9. The hydrology data were transformed into a polygon data layer and transferred to the ArcGIS 10.1 geodatabase.
10. Railway station data was digitized over satellite images as a line data layer and added to the database used in the analysis.
11. An up-to-date geological map from the Bursa Metropolitan Municipality was screened and digitized, and 30 different lithological groups were determined and classified according to type of use. The classified geological map was arranged as a polygon data layer in the ArcGIS 10.1 software.
12. The mine sites of Bursa were dominated by a large, wide area covering almost the entire province. In fact, the majority of the mine sites were in areas required to be preserved under State conservation law. For this reason, mining areas in this region are operated under license. The obtained spatial data were organized as a polygon data layer in the ArcGIS 10.1 software.
13. The forested areas of Bursa were identified as covering a fairly wide range of territory. Forest areas dominated the region in almost all districts. Given the structure of and varieties in the forest areas, they were classified as regular-protected areas, damage-protected areas, rejuvenation areas, selected forests and private forests. Spatial forest data obtained from the Bursa Metropolitan Municipality were stored as polygon data layers in the ArcGIS 10.1 software.
14. Organized industrial zones were determined on the basis of intensive industrial activity and were added to the database in polygon data format for use in the analysis.
15. The touristic areas obtained from the Bursa Metropolitan Municipality satellite photos were prepared for analysis as polygon vector data layers.
16. Spatial data for quarries in this region were carried out as digitized polygons on Google Earth and then transferred to the ArcGIS 10.1 software ready for analysis.
17. Planned sites for new dams were digitized over topographical maps at a 1/25,000 scale and transferred to the database as a polygon data layer.
18. All the regional basin borders obtained from the Bursa Metropolitan Municipality made up the data added to the database as a polygon vector layer.
19. Stream (flowing water) data were obtained from current satellite image digitization as a line layer. All stream data were prepared as a single layer including main streams (rivers) and other branches.

20. Road data was obtained over the digitization of the current satellite image from the Bursa Metropolitan Municipality and added to two line layers which included major roads and other roads.
21. Fault line data was produced using ArcGIS 10.1 software as 1/250,000 scale maps.
22. A digital terrain model was produced using digitized standard topographic maps at a 1/25,000 scale using ArcGIS 10.1 software. The curves on this map were obtained at 10-m intervals. Using the topographic map, slope and aspect maps were also produced for analysis.
23. Bursa digital elevation data (DEM) produced from the contours obtained from the Bursa Metropolitan Municipality were used to create a digital elevation model analysis in the ArcGIS 10.1 software.
24. Infrastructure facilities spatial data such as gas pipilines, power transmission lines, normal train lines and telpherways obtained from Bursa Metropolitan Municipality as a line data layer.

2.3. Spatial database design

Today, the use of spatial data on a local, regional, national and international scale has become an important necessity. By contributing to the decision-making process, these data at different scales should be integrated in order to construct an organization to prevent information loss in terms of time and labor. In this context, geographical and spatial data infrastructure (SDI) expressed as interoperability of spatial data emerged, and together with this concept, some standards were set for Turkey's harmonization process with the European Union. This method has been used effectively up to the present (Aydinoglu 2009). In this study, the standards in spatial database design laid down in the European Union adaptation process were also taken into account for Turkey. In accordance with these requirements, and to increase the effectiveness of the model, factors affecting site selection and sub-factors expressing the difficulty of transition to these factors were generated according to the relevant standards. In this context, 23 data layers identifying different feature types were formed. Specified data layers were arranged in the three different vector data formats of point, line and polygon. Population and residential area data were stored in point vector data format; railway, stream, road, fault line, elevation and infrastructure facility data were stored in line vector data format; flora and fauna, protected areas, topography, soil, land use, airport, hydrology, geology, mine area, forest, organized industry, touristic area, quarry, planned dam site and basin data were stored in the polygon vector data format. Data held in separate layers in the database were then converted to raster format to be analyzed by the TOPSIS multi-criteria decision-making process.

2.4. Factor weights for study area

In this study, factors affecting landfill site selection were addressed in two stages. In the first stage, factors were identified by Clause 15 "Concerning the Landfill of Waste Directive Restrictions" (TC Official Gazette 1983). In the second stage, site selection factorwere identified by examining reports published by organizations, institutions and civil society organizations along with scientific, academic and applied studies conducted worldwide. As for the limitations specified in the regulations, data collection methods were used to obtain related spatial and nonspatial data defining separate spatial data layers. The factors identified in the identification of suitable solid waste areas and their factor weights are shown in Table 1.

Table 1. Solid waste landfill factor weights

Factors/sub-factors	Weights	Normalized Weigths	Factors/sub-factors	Weights	Normalized Weights
Water Bodies	–	–	**Protection Zones**	–	–
River	44	0.444	1st degree	41	0.407
Canal	5	0.053	2nd degree	13	0.109
River branch	26	0.262	3rd degree	8	0.079
Stream	15	0.153	Urban protected area	5	0.052
Brook	9	0.089	Historical protected area	3	0.333
Land use	–	–	**Environmental Protection**	–	–
Forest	10	0.096	Birds	38	0.378
Seasonal crop cultivation	4	0.043	Plants	28	0.275
Plantations	6	0.063	Wild/natural habitat	12	0.122
Marsland	13	0.134	National Park	4	0.038
Rocky terrain	23	0.226	Arboretum	7	0.072
Pasture	3	0.028	Tropical Habitat	11	0.114
Residential	41	0.411			
Geology	–	–	Population	14	0.138
Acid-intermediate intrusives	47	0.473	Forest	8	0.083
Alkaline ultrabasics	29	0.288	Residential areas	41	0.411
Metamorphites	15	0.149	Road	2	0.022
Volkants	5	0.054	Hydrology	23	0.229
Sedimentary rock	4	0.036			

End of Table 1

Factors/sub-factors	Weights	Normalized Weigths	Factors/sub-factors	Weights	Normalized Weights
Soil	–	–	**Slope**	–	–
I	27	0.269	0–10	3	0.031
II	25	0.251	10–20	6	0.060
III	19	0.193	20–30	8	0.081
IV	10	0.104	30–40	12	0.124
V	8	0.081	40–50	15	0.152
VI	4	0.045	50–60	18	0.185
VII	4	0.037	>60	37	0.367
VIII	2	0.020			
Railway stations			Distance to 5 km buffer		
Fault lines			Distance to 5 km buffer		
Infrastructure facilites			Distance to 1 km buffer		
Touristic Areas			Distance to 5 km buffer		
Organized İndusties			Distance to 5 km buffer		
Planned dam sites			Distance to 5 km buffer		
Topography			Distance to 5 km buffer		
Airports			Distance to 5 km buffer		
Querry			Distance to 3 km buffer		
Basin			Distance to 3 km buffer		

2.5. GIS-based accumulated cost raster surface map

The raster data model is a convenient format for performing mathematical operations on the pixels in the same layer or between pixels in different layers at the same geographic location. Due to the advantages of the raster data format, GIS software is widely used for specific functions such as surface analysis, minimum cost route determination, establishment of mathematical operations between the layers and selection of the most suitable area (Yildirim 2009). In this study, a raster-based accumulated cost surface map was produced using GIS and a cost-surface map was obtained by TOPSIS analysis using ArcGIS 10.1. Pixels having higher numerical values were taken as appropriate pixels for the most suitable solid waste area. On the map, the green-colored pixels show suitable areas for solid waste storage, the grey-colored pixels show medium suitable areas and the black-colored pixels represent unsuitable areas (Figure 4).

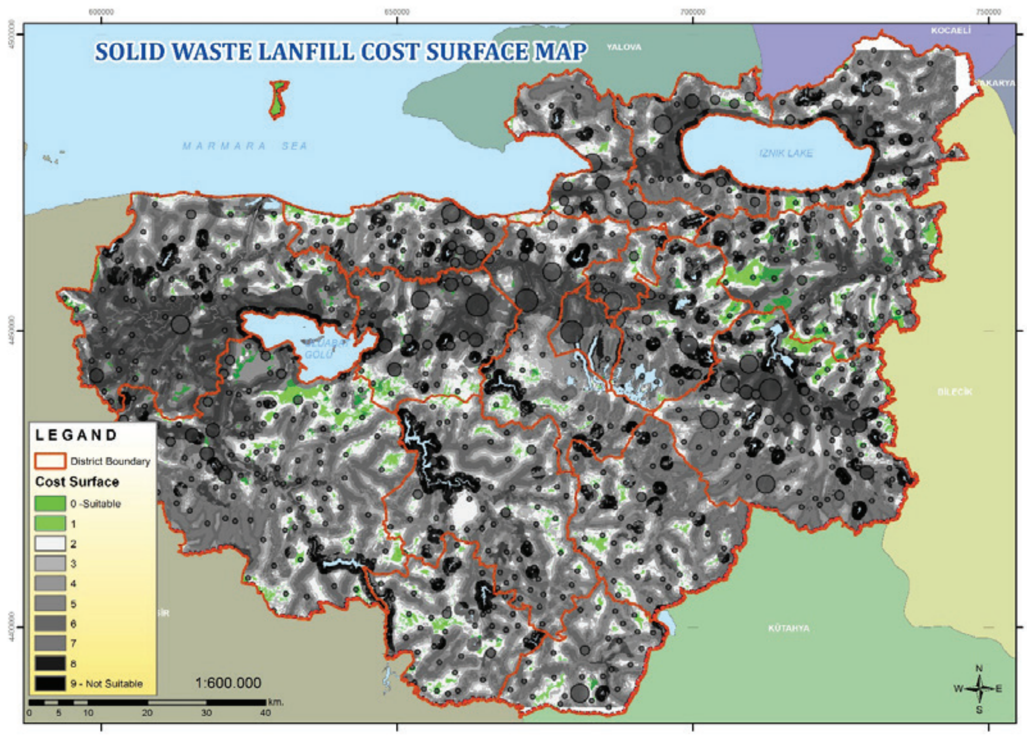


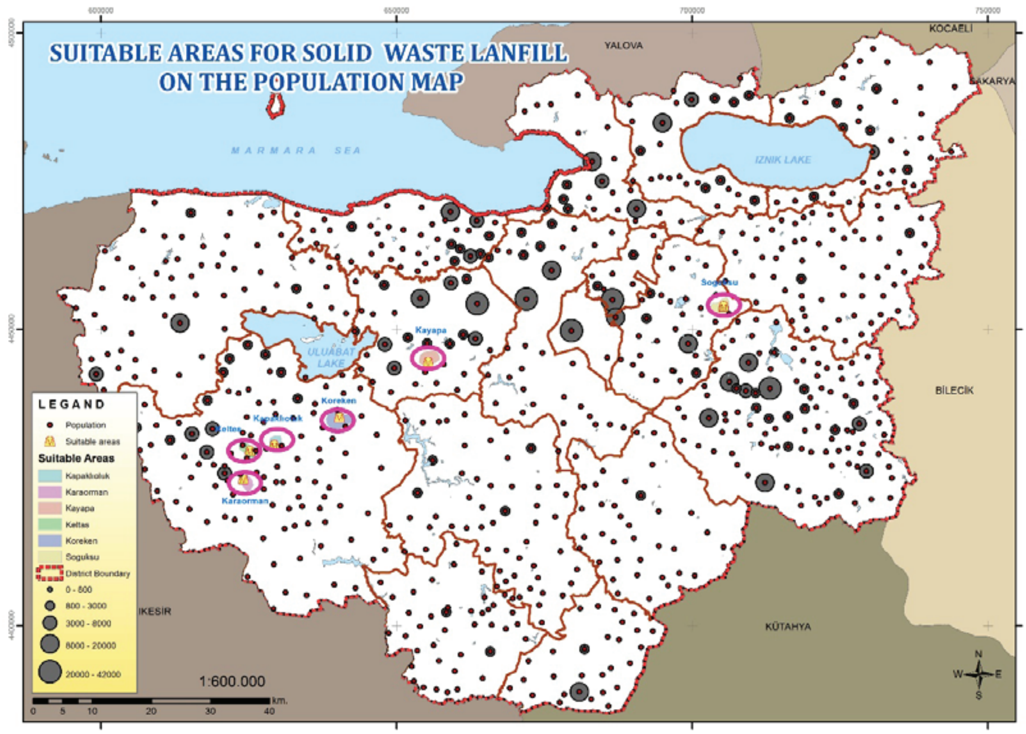
Figure 4. Bursa landfill cost surface map

3. Results

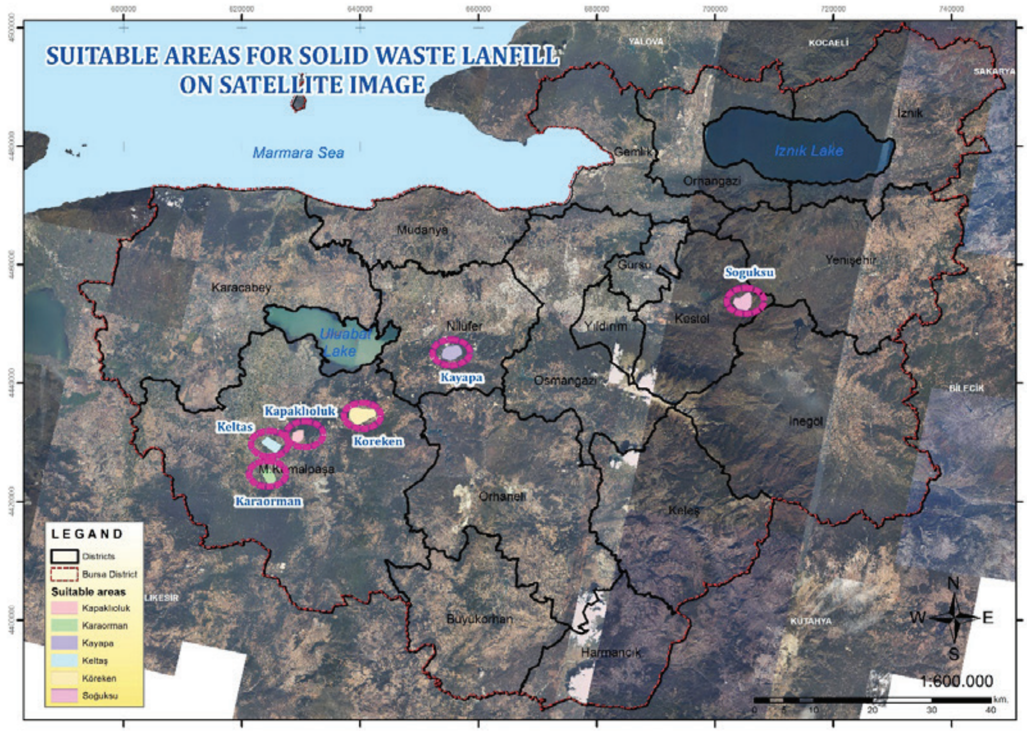
As a result of the analysis for Bursa Province, and especially relating to population, cost surface maps were generated, and in accordance with these raster-based maps, six alternative sites were identified as suitable solid waste landfill areas. These areas were also considered as choices because of the reduced transportation costs due to easy access to the provincial capital.

3.1. Suitable landfill sites for Bursa Province

Mustafakemalpasa District – Karaorman Village Area, Kestel District – Soguksu Village Area, Mustafakemalpasa District – Keltas Village Area, Mustafakemalpaşa District – Kapaklıoluk Village Area, Mustafakemalpasa District – Koreken Village Area, Nilüfer District – Kayapa Village Area were six different alternative areas for the province of Bursa (Figure 5a, b). The Karaorman village area is 95 km from the capital city of Bursa and 10 km from the city of Mustafakemalpaşa. Its population was 366 according to 2014 population data. As a result of the analysis performed when other spatial data layers were excluded from the analysis during the evaluation and restriction element, it was observed that touristic areas were located in close vicinity of the area. The Soguksu village area is 33 km from the city of Bursa and 21 km from the city of Kestel. The population numbered 10,321 according to 2014 population data. As a result of the analyses, the Soguksu village solid waste area was one of the alternatives in terms of compliance. Keltas Village Area is approximately 92 km from the city of Bursa and 7 km from the city of Mustafakemalpasa. Keltas village had a population of 145 according to 2014 population data. This area was found to be suitable as a solid waste area according to the analysis results. Kapaklıoluk Village Area is 93 km from the city of Bursa and 8 km from the city of Mustafakemalpaşa. Kapaklıoluk village is located at quite a high altitude. According to the 2014 census, this area had a population of 127. As a result of the analysis, this area was identified as a suitable solid waste landfill area. However, when the limiting factors were taken into account, restricted zones were observed around this area. In this context, this region was evaluated as a choice among the alternatives for the planned solid waste area. The Koreken village area in the district of Mustafakemalpaşa was considered another alternative site for the solid waste storage area. This area is 50 km from the city of Bursa and 25 km from the city of Mustafakemalpaşa. This village's population was 329 according to the 2014 population census. The cost surface analysis results showed this region as being another suitable site for the solid waste landfill area. In additon, when the limiting factors involving other spatial data layers were considered, no element posing an obstacle to solid waste disposal was detected for the region. In this context, Koreken village area was assesed as one of the designated alternative solid waste area sites. The Kayapa village solid waste area is 30 km from the city of Nilufer. The population in 2014 was 1291 and the village area in the district of Nilufer is quite close to the capital city of Bursa. Therefore, it is easily accesible and also a short distance to the densely populated area. As a result of the analysis, this area was chosen as the most suitable because waste transportation costs would be low.



a)



b)

Figure 5. Landfill sites for Bursa Province

4. Discussion

In this study, the MCDM method of TOPSIS was used to determine an suitable solid waste landfill area. ArcGIS 10.1 software was used to produce suitable solid waste landfill maps. Initially, the weight factors affecting the most suitable solid waste area were identified and weight values were obtained using pairwase comparison matrix, then this factor weights are used as input values for TOPSIS method. Resultant weight values were arranged in order to produce cost value for each layer pixel. Cost surface map was created using cost value and suitable solid waste pixels were determined. Then, this cost surface was divided into 10 groups using reclassify raster method according to the compliance level for suitable solid waste. The first level is the most suitable to select solid waste site selection area. Subsequently, the cost surface pixel values were classified into these divided pixels and solid waste suitable areas was evaluated over this classification. And finally, Bursa province six suitable solid waste areas were created bu ArcGIS 10.1 software using the weight data obtained TOPSIS method (Figure 6).

The accuracy, scale and timeliness of geographic data are very important in the process of solid waste site selection. In this kind of research, the result solid waste areas must also be checked by conducting field studies. In order to this, the Bursa alternative solid waste landfill sites were additionally examined and evaluated through field work. Fieldworkers checked the analyses carried out the ArcGIS 10.1 software by going to the six designated alternative solid waste areas and conducting a pre-feasibility study in order to submit the most suitable choices. As a result of the pre-feasibility study, the three most suitable areas were identified due to the field eligibility requirements as Koreken, Kayapa and Soguksu District. Following the selection suitable areas, suitability assesments were realized in terms of the proximity to all districts and reduction in the waste transportation costs. In the last stage of the study, statistical considerations were made for the six different areas (Kayapa, Soguksu, Kapaklıoluk, Keltas and Koreken) with a GIS-based landfill site selection application in ArcGIS 10.1 software. The assessment process was conducted using ArcGIS 10.1 software. The obtained values are shown in Table 2. In this context, Kayapa District consequently was defined as the most suitable landfill solid area.

This study was carried out to determine suitable area for landfill solid waste in order to create a more livable surroundings. Furthermore this studys aim was to minimize the environmental pollution and affect areas with minimum damage from solid waste. Thus, MCDM methods and GIS-based solid waste site seleciton analysis is significant important. Especially, with the latest new techniques TOPSIS provides identifying environmental factors and determining the weight of the factors using pairwise comparison matrices for solid waste site selection. This study proves that MCDM methods assessed with GIS technique offers possible solutions in the identification suitable solid waste area studies. In other future studies, it is expected to provide the same simplicity. The acquisition and use of an accurate and seamless data if supported by appropriate methods like integrated MCDM (TOPSIS) and GIS, permanent solutions

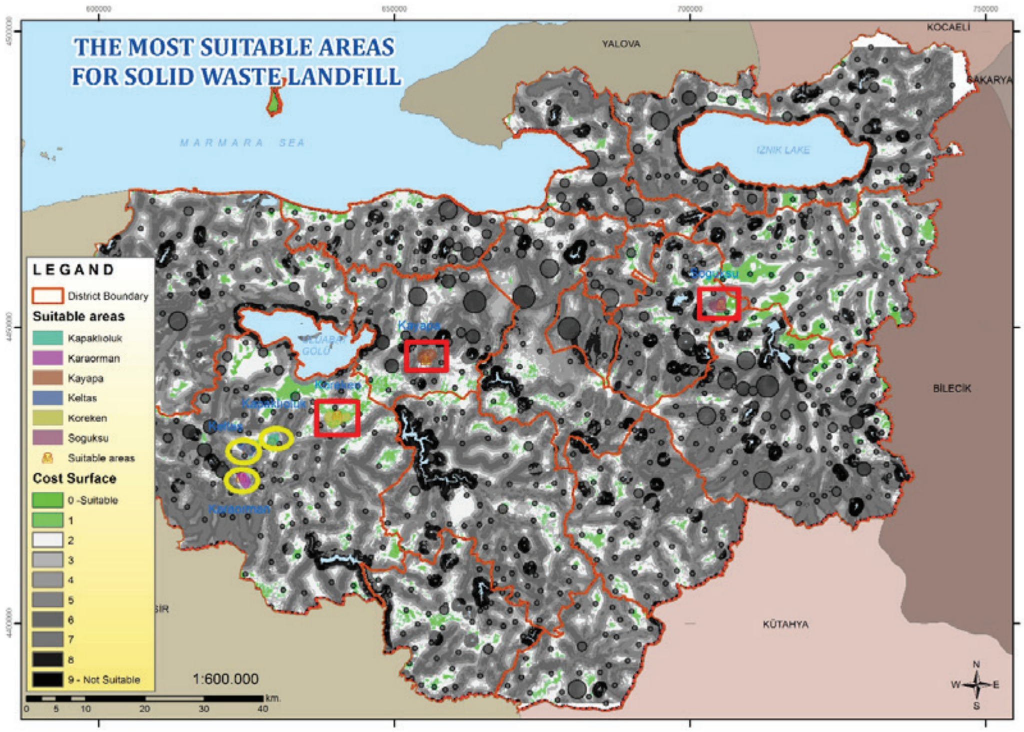


Figure 6. The most suitable solid waste landfill areas

Table 2. Statistical evaluation of alternative solid waste landfill areas

Evaluation factor	Raster GIS-based method					
	Kayapa	Koreken	Kapaklıoluk	Karaorman	Keltas	Soguksu
Distance to residential area (m)	1912.22	454.531	952.02	250.492	0	0
Average distance to rivers (m)	1015.065	1799.339	1516.176	1130.25	1292.076	1021.79
Average distance to roads (m)	904.20	359.18	0	0	319.92	0
Average slope (%)	7.51264	7.98087	13.0707	4.13935	9.75383	9.94554
Located in forested area (ha)	616.88	724.54	270.47	143.72	177.27	385.52
Distance to tourism area (m)	6537.31	5665.88	1610.17	0	2198.70	11437.19
Distance to protected area (m)	129.14	86.82	586.19	899.89	517.98	165.57

can be made fit for purpose. Our study provides constitutes an example for other future work.

Conclusions

Solid waste site selection and solid waste planning is a significant additional dimension today. The population has increased quite rapidly, so the problem of solid waste storage landfills is also increasing proportionally. Thus, the proposed alternative disposal areas could be used on the basis of population density. In order to minimize the level of transport costs, the establishment of designated waste landfill areas quite close to the capital city may be considered in this framework. This condition will contribute to the state financial status and allow fast and efficient solid waste services to be provided. And also this studies results solid waste site selection areas will contribute to the environment so as to minimize contamination of the environment. Moreover, collection of solid wastes on a regular area will provide protection of the natural environment depending on the study criterias. The effect of environmental pollution on the use of irregular solid waste will be reduced due to solid waste disposal sites and contribute to the sustainable environment.

This study In Turkey in this context, Environment and Urban Ministry published solid waste planning regulations in order to take precautions for the country's development and strategies were developed. In the light of literature review in addition to the regulations, solid waste site selection projects are carried out and planned to be done in future studies. So, Multicriteria Decision Methods integrated GIS technologies are become the most important solution technique to select suitable solid waste sites environmentally and evaluate the development of the country at the highest level.

The MCDM method integrated with GIS can be used in site selection applications to minimize economic, social and environmental problems. Because this technique is to allow the most accurate and flawless execution by evaluating several factors together and to determine these factor weights using pairwise comparison methods. The pairwise comparison method is used in site selection methods with the TOPSIS method and provides consistent factor weights to select suitable area. One of the MCDM method TOPSIS was effectively used in solid waste site selection applications based on GIS. This study has provided very positive results with the advantage of the algorithm used in the calculation cost surface.

GIS-Based Least Cost Path Analysis allow to make the most cost-effective path analysis. So in this study using consistent weights, GIS-Based Least Cost Path Analysis was carried out and cost surface is produced. this cost surface was divided into 10 groups using reclassify raster method and the solid landfill areas were assessed and six solid landfill areas were identified as suitable alternatives. All the identified areas can be utilized for solid waste landfill because they provide the necessary conditions according to the relevant legislation. Suitable areas were selected taking into consideration the factor of unacceptable areas near protected areas and areas too close to protected areas. Furthermore, designated areas were checked by performing field work in the suitable areas. Conducting geological studies and seismic analyses of an identified area is necessary in order to assess the appropriate status of that area. Briefly, it is an important point that a suitable eligibility determination of the suitable designated landfill areas also be carried out on the land. In order to determine whether the dump sites are geologically appropriate, examination of samples taken from the designated areas and a determination of their suitability via ground surveys are important considerations. In addition, it is essential to do a seismic analysis and conduct ground surveys for each of the identified solid waste landfill areas, and ultimately, it will then be possible to propose the most suitable future solid waste landfill site for Bursa. Furthermore, this study can serve as a pioneer work in future studies carried out for Bursa Province.

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