Municipal solid waste landfill site selection for the city of Şanlıurfa-Turkey: an example using MCDA integrated with GIS

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Municipal solid waste landfill site selection for the city of Şanlıurfa-Turkey: an example using MCDA integrated with GIS

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A municipal solid waste (MSW) management system needs solid waste management (SWM) techniques where the presence of a sanitary landfill is vital. One of the most important issues of sanitary landfilling is to locate the facility to an optimal location. Despite the versatility and case-dependent nature of conventional expert-based site selection procedures, the number of sites to be chosen increases with increased population forcing a number of constraints. Consequently, constraints and environmental regulations mechanically mask unsuitable areas, leaving very little areas to be assessed. This turns the situation into a challenging issue for a geographical information system (GIS) used with multi-criteria decision analysis (MCDA), to select optimal site.

The study aims to apply MCDA integrated with GIS to select possible sites of a MSW landfill with the same expert and same cognitive parameters while compared with the already present one. Results of this study revealed that conventional expert-based methods could not always evaluate all constraints at the same time and map reproduction is limited when parameter maps are changing rapidly in time. In order to produce cognitive and reproducible analyses, GIS with MCDA integration offers a good solution for site selection issue and forms a good alternative for conventional methods.

Keywords: municipal solid waste (MSW); landfill; site selection; geographical information systems (GIS); multi-criteria decision analysis (MCDA)

1. Introduction

Solid waste management is a complex process involving the incorporation of much information from different disciplines with many parties either responsible or affected by the results. From the point of view of utilized technologies, many innovative solutions associated with the control of generation, handling, storage, collection, transfer, transportation, processing, and disposal of solid wastes have been advanced to address this problem. All of these processes, either innovative or classical, have to be carried out within existing legal regulations and social guidelines that protect the public health and the environment while being aesthetically and economically acceptable. For the disposal process to be responsive to public attitudes, the disciplines that must be considered include administrative, financial, legal, architectural, planning, and engineering functions. All these disciplines must
communicate and interact with each other in a positive interdisciplinary relationship for an integrated solid waste management (ISWM) plan to be successful. The US Environmental Protection Agency (EPA) has identified four basic management strategies for ISWM (EPA 1991): (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills. Landfills are one form of waste management that nobody wants but everybody needs. Furthermore, there are simply no combinations of waste management techniques that do not require landflling to make them work. Among the four basic management options, landfilling is the only management technique that is both necessary and sufficient (Kreith and Tchobanoglous 2002).

Consistent with the development of human civilizations, land disposal of waste has been practiced for centuries. In the past it was believed that leachate from waste is diluted by soil and groundwater; hence, contamination of groundwater was not considered an issue. Thus, disposal of waste on all landforms (e.g. gravel pits, ravines, and abandoned mine quarry) was an acceptable practice. Within the last decade, several studies indicated that especially uncontrolled landfills pollute groundwater, surface water, soil, ambient air quality, etc. (Mor et al. 2006, Reyes-López et al. 2008, Chattopadhyay et al. 2009), yielded a result that not every land piece is suitable to be used as a landfill.

The municipal solid wastes (MSWs) in Turkey are regulated and accomplished by the Ministry of the Environment and Forestry, as per MSW Control Regulations (Ministry of Environment and Forestry of Turkey 1991). Despite the presence of a legally responsible authority and regulatory base, the MSW management in Turkey is not integrated among its constituent partners. As a result of this, MSWs generated in Turkey are presently being disposed in 22 sanitary landfill facilities, in four composting plants, and in three incineration plants, whereas the number of municipalities receiving waste services is 3115 (TURKSTAT 2009).

One of the most important stages of sanitary landfilling is site selection. The conventional/manual expert based site selection procedure is the most widely used method in many developing and developed countries throughout the world (Bagchi 2004, Yeşilnacar and Çetin 1999, 2005, 2008, GAP 2009). For the conventional/manual expert-based site selection, usually a circle indicating a ‘search radius’ (the maximum distance the waste generator is willing to haul the waste) is drawn on a road map of the region, keeping the waste generator (a city or industry) at its center. This search radius is increased if potential sites could not be located within the search area. If more than one waste generator is involved (e.g. several cities within a county) then a compromise location acceptable to the waste generators is used as the center. Then, a final landfill site is determined after the candidate sites are screened according to the regulatory site selection criteria and optimizing data such as geology, hydrology, topography, transportation, potential earthquake damage and land use, etc. (Bagchi 2004).

In recent years, geographical information systems (GIS) has been found to play a significant role in the selection of optimal sites for waste disposal. The advantage of a GIS-based approach for siting arises from the fact that it not only reduces time and cost of site selection, but also provides a digital data inventory for long-term monitoring of the site (Kontos et al. 2005). There have been many applications of GIS for identifying potential waste disposal sites (Kao 1996, Mutthia et al. 1996,

The integration of GIS and MCDA is a powerful tool to solve the landfill site selection problem. While GIS provides efficient manipulation and presentation of the data, MCDA supplies consistent ranking of the potential landfill areas based on a variety of criteria by dividing the decision problems into more smaller understandable parts, analyzing each part separately and then integrating the parts in a logical manner (Malczewski 1997, Şener et al. 2006). The implementation of MCDA with GIS results in incorporating a greater number and variety of environmental parameters to site selection process than conventional methods. The efficient data analysis of MCDA joined with ease in reproducibility and speed of GIS surpasses the conventional methods.

Most of the research published is focused on new improvements on methodologies while glorifying the expert knowledge citing that all GIS applications are tools to ease the decision-makers’ decisions, at the same time all proposed methodologies were applied to select completely new landfill sites. This study aims to apply GIS integrated with MCDA methods to select a landfill site of a municipality and at the same time judging the already present one that was selected by conventional expert-based methods. In order to achieve this goal, 14 different layers were produced and evaluated by experts. All of the layers were treated separately and weights were assigned by experts, who knew the local conditions and took part in the selection process of the already used site. In order not to complicate the process and to mimic the experts’ conventional selection process the fundamental MCDA, the simple additive weighing (SAW) approach was used throughout the analyses.

The test site was chosen as Şanlıurfa municipality (city center with 468,993 population according to the census of 2008), which had a previously selected landfill site with expert-based methods, where the use of land resources was crucial (Figure 1). The study area was within the GAP project (Southeastern Anatolia Project, commonly referred to by its Turkish acronym ‘GAP’), which is to develop water and land resources of the region and consequently planned as a package comprising 13 projects envisaging irrigation schemes and hydraulic power plants in the basins of the Euphrates and the Tigris. The extent of the study area was selected in accordance with the Şanlıurfa Territorial Plan approved by the GAP Administration on 8 May 2002.

2. Materials and methods

2.1. Input data

In this study, 14 different input map layers including elevation, slope, settlements (urban and village), roads (highways and small roads), airport, infrastructure (power
lines), geology/lithology, aquifers, surface waters (perennial and intermittent streams), industrial sites (organized and small industrial sites), land use were evaluated and prepared to be included in the analysis within GIS environment. Although earthquake-related information was an important factor in siting of a landfill, in the vicinity of the area there was no active fault and the area also lay in the third-degree earthquake zone; hence, no damage was expected (Gülkân et al. 1993). ArcView v.9.0 and TNT-MIPS v.6.4 software were used in this study to process and create map layers. A common reference system coherent with national mapping standards, Universal Transverse Mercator with European Mean Datum-1950, is used in all of the maps. Raster data model was decided to be used, hence regarding the working scale, every input map whether raster or vector is resampled or rasterized with a 25 m grid size. Although the vector data model could produce spatially more accurate results, the speed and versatility are compromised relative to raster data models. Every unique condition has to be represented by new boundary conditions, resulting in a large number of smaller polygons, of which the topological management would be increasingly hard with increasing number of criterion. The layers, used buffer zones, and rankings were concisely presented below according to the order of importance and priority of each criterion for analyses.

2.1.1. Settlement areas
The urban and village settlements were digitized from the 1/25,000 scale land use plans. After the digitization process, different safe distances from the urban and village settlement areas were determined, respectively, by analyzing literature. The distance from urban centers should be at least 2–5 km and the distance from isolated houses should be at least 500 ms to locate a landfill site (Siddiqui et al. 1996, Cantwell 1999, Şener 2004, Şener et al. 2006, Yeşilnacar et al. 2008). By considering all the suggested safe distances in the literature and local information of city growth rate, minimum distances from the settlement areas in the study area were determined as at least 2 km for urban centers and at least 1 km for villages. These distances were
used to create buffer zones around previously digitized settlement areas, which were later excluded from further analyses in the study. After exclusion of absolutely unsuitable areas for a landfill site, the remaining areas were ranked according to their suitability. The layers of urban and villages settlements were ranked as suitable or unsuitable by assigning values 1 and 0, respectively (Table 1) and presented in Figure 2a, b.

2.1.2. Land use

The 1:100,000 scale land use plan maps obtained from General Directorate of Rural Services (GDRS 1995) was scanned, imported to GIS environment, registered and then digitized. The land use types were grouped and ranked according to their suitability for a landfill site (forest areas and first or second degree agricultural areas were avoided, low quality agricultural fields, barren land, etc. are preferred) and the resultant vector map was then rasterized (Figure 2c; Table 1).

2.1.3. Aquifer

In order to assess the possible effects of landfill to groundwater potential of the region, an aquifer layer had to be introduced among the layers. Through combining the geological, topographical and hydrogeological maps, which had been obtained from General Directorate of Mineral Research and Exploration (GDMRE 1974) and General Directorate of State Hydraulic Works (GDSHW 1972), respectively, the study area was divided into three different hydrogeological classes according to the water bearing properties of the rocks and the aquifer properties. Three classes (minor aquifer, major aquifer and non-aquifer) were proposed and their rankings were obtained from literature (Baban and Flannagan 1998, Şener 2004, Şener et al. 2006, Yeşilnacar et al. 2008) (Table 1; Figure 2d).

2.1.4. Geology

The geological information and map of the study area was compiled from available reports (GDSHW 1972, GDMRE 1974, Yeşilnacar 1995). The compiled geological map was scanned, registered and digitized. In the study area, there were seven different lithologies, ranging from Cretaceous units to Quaternary alluvium and were mainly composed of sedimentary and volcanic units (Figure 2e). The lithologies were grouped and ranked according to their suitability for a landfill site considering lithological properties (Table 1). The resultant ranked vector map of lithology was then converted to a raster map to be included for analysis (Figure 2f).

2.1.5. Surface water

In order to include hydrological information (surface water criteria), perennial and intermittent streams were digitized as lines from 1:25,000 scale topographical maps. A limit of 125 m was appropriate for intermittent streams whereas 350 m was used for perennial streams as a mask (Şener 2004, Şener et al. 2006, Mongeon and Webb...
Table 1. The summary of the input layers used in the analysis.

<table>
<thead>
<tr>
<th>Layer name</th>
<th>Source map</th>
<th>Buffer zones</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlement–Village</td>
<td>1/25,000 scale land use plan</td>
<td>0–1000 m</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1000 m</td>
<td>1</td>
</tr>
<tr>
<td>Settlement–Urban</td>
<td>1/25,000 scale land use plan</td>
<td>0–2000 m</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;2000 m</td>
<td>1</td>
</tr>
<tr>
<td>Landuse</td>
<td>1/100,000 scale land use plan maps</td>
<td>Unsuitable</td>
<td>0</td>
</tr>
<tr>
<td>Aquifer</td>
<td>Geological/topographical/hydrogeological maps</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Major aquifer-Qal-Tpa</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor aquifer-Tmp-Tem</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-aquifer-Tvol-Tkg-Kmb</td>
<td>10</td>
</tr>
<tr>
<td>Geology/lithology</td>
<td>Geological maps</td>
<td>Qal-Tpa</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tmp-Tem</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tvol</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tkg-Kmb</td>
<td>1</td>
</tr>
<tr>
<td>Surface water–perennial stream</td>
<td>1/25,000 topographic maps</td>
<td>0–350 m</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td>&gt;350 m</td>
<td>1</td>
</tr>
<tr>
<td>Surface water–intermittent stream</td>
<td>1/25,000 topographic maps</td>
<td>0–125 m</td>
<td>0</td>
</tr>
<tr>
<td>Elevation</td>
<td>Digital 1/25,000 topographic contours</td>
<td>0–125 m</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>500–650 m</td>
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<td></td>
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<td>&lt;500 m</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>&gt;650 m</td>
<td>0</td>
</tr>
<tr>
<td>Slope</td>
<td>Digital 1/25,000 topographic contours</td>
<td>0–5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6–10</td>
<td>4</td>
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<td></td>
<td>11–15</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;15</td>
<td>0</td>
</tr>
<tr>
<td>Airport</td>
<td>1/25,000 topographic maps</td>
<td>0–1500 m</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1500 m</td>
<td>1</td>
</tr>
<tr>
<td>Infrastructures–power lines</td>
<td>1/25,000 topographic maps</td>
<td>0–30 m</td>
<td>0</td>
</tr>
<tr>
<td>Roads–highways</td>
<td>1/25,000 topographic maps</td>
<td>0–500 m</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500–1000 m</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000–2000 m</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;2000 m</td>
<td>1</td>
</tr>
<tr>
<td>Roads–small roads</td>
<td>1/25,000 topographic maps</td>
<td>0–100 m</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–500 m</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500–1000 m</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;1000 m</td>
<td>1</td>
</tr>
<tr>
<td>Industrial sites</td>
<td>1/25,000 scale land use plan</td>
<td>Organized and small industrial districts/sites</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>
(a) Buffer zones determined for urban settlement
(b) Buffer zones determined for village settlement
(c) Classes determined for land use
(d) Classes determined for aquifer
(e) Geological map of the study area and its environs

(Qgr gravel, sand, silt; Tvol basalt; Tps sandstone, siltstone, lacustrine limestone with light gray, white, and greenish gray; Temp light gray, yellow colored, hard, fine and thick bedded, clayey, fossiliferous limestone; Tem light gray, yellowish, compact and thick bedded, local dolomite, clayey limestone, partially cherty, with nodule; Tkq grayish-green, dirty yellow, marl-sandstone banded, local limestone; Kmb local limestone lenses, banded chert and nodule)

(f) Classes determined for lithology

Figure 2. The layers used in the analysis.
Figure 2. (Continued)

(g) Classes determined for perennial streams
(h) Classes determined for intermittent streams

(i) Classes produced for the elevation criterion
(j) Classes determined for Slope criterion

(k) Buffer zones determined for airport
(l) Buffer zones determined for powerlines
2008, Yeşilnacar et al. 2008). The classes and related rankings were presented in Table 1. The reclassified vector map of surface water was then rasterized and presented in Figure 2g, h).

2.1.6. Elevation
The elevation data was derived from the 1:25,000 scale topographical maps provided from General Command of Mapping, Turkish Army. The study area was covered by partially eight 1:25,000 scale topographical maps. A Digital Elevation Model (DEM) was created with 25 m pixels. Two distinct areas were observed as the areas below 500 m were generally gentle sloping valuable agricultural fields whereas areas higher than 650 m were partly mountainous and steep in slopes. In order to protect valuable agricultural fields and to avoid mountainous regions elevations between 500 and 650 m, they were defined as suitable areas for a landfill site and the remaining areas
(<500 m and >650 m) as unsuitable by assigning 1 and 0, respectively (Table 1; Figure 2i).

2.1.7. Slope
Slope map was calculated from the Digital Elevation Model. The slope map was reclassified into fewer classes, which is a continuous raster of 90 classes by definition. Areas with slopes greater than 15% were not suitable to allocate landfills (Oweis and Khera 1990, Leao et al. 2001, Allen 2002). The appropriate slope for constructing a landfill was about 8–12%, because too steep slopes would make it difficult to construct and maintain where too flat slopes would affect the runoff drainage (Lin and Kao 1999). High slopes can favor leachate drainage to flat areas and water bodies causing contamination. Based on these, slope map was classified into four groups. The groups (0–5, 6–10, 11–15, >15 degrees), related rankings were shown in Table 1, and the reclassified slope map was presented in Figure 2j.

2.1.8. Airport
There were different values related to the safe distances from airports like 3048 m according to Bagchi (2004) and 3000 m and 1500 m according to EPA (1991). By considering these suggested values, the safe distance for an airport was determined as 1500 m. The location of the airport was digitized from the 1:25,000 scale topographical maps and necessary buffer zones were calculated. The resultant layer of airport was reclassified with appropriate values (Table 1) and rasterized as shown in Figure 2k.

2.1.9. Power lines
All high voltage power lines should have a buffer of 30 m on both sides to avoid disrupting the infrastructure (Cantwell 1999). The high voltage power lines were digitized from the 1:25,000 scale topographical maps and buffer zones were created. The layer of power lines was classified as suitable or unsuitable for a landfill site by assigning values 1 and 0 respectively to the buffer zones (Table 1) and then rasterized as shown in Figure 2l.

2.1.10. Roads
The source of road network was digitized from the 1:25,000 scale topographical maps. Like in the case of settlement areas, the roads were subdivided into two distinct layers according to their attributes (highways and other smaller roads). The reason for this division was the necessity of applying different buffer zone distances according to the importance of the roads. No landfill should be constructed within 300 m of any state or federal highway, primarily for aesthetic reasons (Bagchi 2004). All roads including primary, secondary, regional and third class roads should be avoided and have a buffer of at least 30–100 m on both sides (Cantwell 1999, Leao et al. 2004). On the other hand, distances greater than 1 km from main roads and highways should be avoided (Allen 2002), whereas the landfill site should not be placed too far away from existing road networks to avoid the expensive cost of
constructing connecting roads (Lin and Kao 1999). Distance from main access roads should be smaller than 3 km (Allen 2002) and between 0.2 km and 10 km of a major road (Baban and Flannagan 1998). By considering these suggested values, the buffer zones and related ranks were determined and classified as suitable or unsuitable separately for highways and small roads that were shown in Table 1 and the resultant maps were rasterized as shown in Figure 2m, n.

2.1.11. Industrial sites

The industrial sites were digitized from the 1:25,000 scale land use plans (GAP 2002). Organized industrial districts and small industrial sites were both considered unsuitable and assigned a value of 0 (Table 1). The final resultant map was also rasterized and presented in Figure 2o.

2.2. Analysis

In order to utilize the expert’s contribution to the site selection problem, the ‘simple additive weighting method (SAW)’ was selected to be applied, as one of the experts took place in the selection process of the previous site.

However, before the application of the SAW method, the areas restricted by rules, regulations and physical constraints should be excluded. These certainly unsuitable areas had already been assigned zero during the data preparation stage. To prepare a mask of unsuitable areas, all data layers were multiplied by each other so that if any pixel has a value of zero coming from any layer, then the value of that pixel would become zero, which means that the pixel was unsuitable as a landfill site (Şener et al. 2006). If any of the parameters in Table 1 was unsuitable that pixel was marked as unsuitable regardless of any suitable score from other parameters (Figure 3).

The SAW method is the simplest and most commonly used multi-attribute decision technique based on the weighted averages (Janssen 1992, Eastman 1993, Malczewski 1997). The decision maker directly assigns the weights of ‘relative importance’ to each thematic map layer. A total score is obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative of that attribute, and summing the products over the attributes. When the overall scores are calculated for all of the alternatives, the alternative with the highest score is chosen (Kolat 2004). The decision rule evaluates each alternative, $A_i$, by the following formula Equation (1) (Malczewski 1999):

$$A_i = \sum_j w_j x_{ij}$$

where $x_{ij}$ is the score of the $i^{th}$ alternative with respect to the $j^{th}$ attribute, and the weight $w_j$ is the normalized weight. The weights represent the relative importance of the different layers.

The first step of a GIS-based SAW method is defining the set of evaluation criteria (Malczewski 1999, Şener et al. 2006). Although the evaluation criteria are selected, the scores of individual criterion ranks might be given on different scales; hence, they must be standardized to a common dimensionless unit. For this process,
the score range procedure is applied. In the score range procedure, the standardized scores are calculated by dividing the difference between the maximum raw score and a given raw score by the score range Equation (2) (Şener et al. 2006):

\[ X'_{ij} = \frac{X_{ij}^{\text{max}} - X_{ij}}{X_{j}^{\text{max}} - X_{j}^{\text{min}}} \]  

(2)

where \( X'_{ij} \) is the standardized score for the \( i^{\text{th}} \) alternative and \( j^{\text{th}} \) attribute, \( X_{ij} \) is the raw score (ranking), \( X_{j}^{\text{max}} \) and \( X_{j}^{\text{min}} \) is the maximum and minimum scores for the \( j^{\text{th}} \) attribute, respectively. This procedure is applied to every input raster to be included in analyses (Malczewski 1999).

The individual layer weights \( W_{j} \) were assigned by the expert and standardized (Table 2). All individual criterion maps were added up together in SAW method, using Equation (1) in order to form the resultant score map for landfill suitability, where higher scores mean more suitable areas.

Figure 3. Mask prepared to exclude the restricted areas (white are masked areas that are unsuitable for landfilling at least for one variable).
The score value histogram of this resultant map was evaluated and the output values were divided into five classes using natural breaks. The masked areas with a value of zero are defined as restricted areas for landfill siting. The other classes in terms of increasing suitability were ‘unsuitable,’ ‘suitable but avoid,’ ‘suitable,’ and ‘most suitable’ classes. The output map produced by the method of SAW is given in Figure 4. The area belonging to ‘unsuitable’ class covers 33.3%, ‘suitable but avoid’ class covers 55.9%, ‘suitable’ class covers 5.7%, and ‘most suitable’ class covers 5.1% of the unmasked area.

3. Results

After the generation of an output map through SAW method, a number of candidate site clusters with the highest scores were selected (Figure 4). When the resultant map was examined it was seen that suitable areas for landfill siting were clustered in three zones.

The candidate site 1 was along the northeast part of the city center with the largest cluster size. Although this site contains a significant amount of ‘most suitable’ pixels, there were some constraints that were not included in layers. The most important restriction of this candidate site was that it was within or near the recharge area of Harran Plain where the use of land resources was crucial for agricultural and water management purposes (Figure 1).

The candidate site 2 was in the north section of the city center. There were several restrictions in the site as well. These were as follows: the distance to the city center was too far (approximately 25 km), it was in the direction of the prevailing wind, it was in the catchment area of the country’s largest dam lake, and it was in the nearest inlet port of the tunnels that convey the irrigation water to Harran Plain.

The candidate site 3 was south of the city center and within a distance of 10–12 km, with no significant extra constraints. Storage area of the candidate site 3 was calculated as approximately 800 hectares, the adequate area for storage for 150,001–500,000 population was reported as 15–50 hectares (Tarhan and Ünlü 2005), which supported that areal extent of candidate site 3 was sufficient. Although it was
dominated by ‘suitable but avoid’ class, it was within suitable distance for haulage of wastes with adequate extent, it was appropriate beyond the scope of geological and hydrogeological conditions, it was suitable in terms of the prevailing wind, it was not within a future urbanization area, it did not have any harm to the irrigation fields, and it had no expropriation cost because of public property.

4. Discussion and conclusions
Although the methods used were fairly straightforward, field checking, detailed geotechnical and hydrogeological investigations should be carried out to give a final decision for suitable sites in landfill siting, before any engineering design. Not only geological parameters but also unmappable political, social and financial/economical constraints should be considered at evaluation and further design stages once the candidate sites are found.

The SAW method was used to locate the candidate landfill sites with similar conditions from the input data layers. The input layers were produced by a ranking method, which includes ranking of every class in a map under consideration in the order of the decision-maker’s preferences. When applying the GIS-based expert
dependent SAW procedure, the weights were directly assigned between 1 and 10 by the expert. Although this is a very fast and accurate process, it is directly dependent on the experts’ knowledge, experience and the degree of involvement in the local conditions. Experienced experts equipped with sufficient local information are still indispensable.

The already selected and recently completed Şanlıurfa MSW sanitary landfill site with conventional selection methods is at the north of candidate site 3. Although at its planning date, it lies far enough from the city center – about 8.50 km, today as the city had grown at an unexpected speed, the distance of the facility to the nearest residence area is reduced down to nearly a few kilometers. Furthermore, the present site is also found in the excluded areas of this study, which indicates that in conventional siting procedures some criterion had not been considered. When the location of the present site was examined, not only mainly because of urban settlement, but partly because of elevation, geology, land use and aquifer layers the previous site was classified as unsuitable. This results in a landfill site that clearly was unsuitable beyond the scope of public health, hygiene, public reactions, noise, dust, and odor.

Results of this study revealed that the conventional expert-based methods could not always evaluate all of the constraints simultaneously at the same time and reproduction in these methods is limited when parameter maps are changing rapidly in time. In order to produce cognitive and reproducible analyses, GIS with MCDA integration offers a good solution for landfill site selection issue and forms a good alternative for conventional methods. It is evident that these integrated methods would be fairly useful from the point of sustainable environment, if they could become statutory obligations.

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