An ecological based approach for determining suitable landfill : The case of Kilis / Turkey

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Paper received: 27.04.2019

Revised received: 11.09.2019

Accepted: 12.12.2019

Abstract

Aim: The present study aimed to develop an ecologically based approach to determine appropriate locations for landfill sites.

Methodology: This study was conducted in Kilis, where the population is increasing and under risk due to wrong area management. This study consists of the processes of determining-evaluating the criteria of selecting sites and mapping these criteria with holistic approach. In the process of determining the criteria, Analytical Hierarchy Process (AHP), which is one of the multi-criteria decision making (MCDM) methods and in the mapping process, Geographical Information System (GIS) technology was used. In the study, the main criteria for selecting areas for landfill sites were determined to be aspect, proximity to settlements, proximity to seasonal and dry streams, proximity to main roads, land capability classes, rock type and soil water permeability. "Suitable landfill sites" related to the study area were mapped based on these criteria.

Results and Interpretation: As a result, the map of suitable landfill sites produced in this study is an important ecological guide and its necessity for spatial planning should be ensured.

Key words: Analytical Hierarchy Process, Geographical Information System, Kilis, Landfill, Suitable analysis

How to cite : Çoban, A., D. Demiroğlu and A.A. Karadağ: An ecological based approach for determining suitable landfill : The case of Kilis / Turkey. *J. Environ. Biol.*, **41**, 445-452 (2020).

Introduction

The world population is growing rapidly and resources becomes limited as the land is not elastic. In the beginning of the 21st century, world population was 1.6 billion and it has increased to 7.6 billion in the middle of 2017 (Steiner, 2014; UN, 2017). The global population size is expected to be 8.4 -8.7 billion by the year 2030 and 9.4 - 10.2 billion by 2050 (UN, 2017). Furthermore, while 55.3% of the world population lives in urban areas, this rate is expected to rise to 60% by 2030 (UN, 2018). This rapid increase in the population, especially of the urban population leads to various problems. One of these problems is the solid waste issue. Solid waste is solid materials and treatment sludge that must be disposed of by their producer and eliminated regularly in order to protect the environment and well-being of the society (Official Gazette, 1991). Annual solid waste production is expected to increase by 70% in 2050 (3.40 billion tons) compared to 2016 (2.01 billion tons) (Kaza *et al.*, 2018). This situation brings the storage and disposal issue of solid waste to an important point as improper disposal of solid waste may cause epidemics (malaria, cholera, dysentery, etc.) and environmental pollution of water, soil, air pollution, etc. (Çay *et al.*, 2007; Khan *et al.*, 2018; Aydemir Karadağ, 2019). Therefore, various solutions are developed to reduce the problems regarding to storage and disposal of solid waste. Landfill and proper site selection is one of these solutions (Çay *et al.*, 2007). Landfill is a method that ensures the prevention of negative effects of gases and leaks on air, soil, groundwater and surface water that may occur during the disposal of wastes (Official Gazette, 2010). Landfill site selection is important for the sustainability of urban infrastructure systems and these sites must comply with the environmental, social, technical and health requirements and local laws (Kontos *et al.*, 2005; Vasiljevic *et al.*, 2012). On the basis of this objective, both landfill site selection and determination of criteria in this process are subject to a wide range of studies (Makropoulos and Butler, 2006; Çay *et al.*, 2007; Küçükönder and Karabulut, 2007; Guqin *et al.*, 2009; Şener *et al.*, 2010; Effat and Hegazy, 2012; Kara and Doratli, 2012; Majumdarve *et al.*, 2017; Aydemir-Karadağ, 2019).

In view of the above, the present study aimed to develop an ecologically based approach to determine suitable landfill sites in the province of Kilis, which has received heavy migration since 2011 due to conflict in Syria, therefore facing various problems in spatial planning and area management and environmental problems (air, water, soil and environmental pollution, etc.).

Materials and Methods

This study was carried out in the contiguous area of Kilis province (Fig. 1). In this context, the primary data of the study comprised of 1:25.000 scale digital Kilis topography map (2017), 1:25.000 scale digital Kilis soil map (2017), 1:25.000 scale digital Kilis geology map (2017) and scientific and institutional studies (institutional report, article, thesis, project etc.) related to the field. Secondary data were similar studies regarding landfill site selection, MCDM, AHS etc. ArcGIS 10.5 software was used in the evaluation and analysis which take place in the study method.

The study area is located in the transition zone between the Mediterranean and Southeastern Anatolia regions. It was surrounded by Turkey-Syria border to the south, Gaziantep-İslahiye to the west and north-west, Gaziantep center to the north and northeast and Gaziantep-Oğuzeli to the east (General Directorate of Spatial Planning-GDSP, 2017). The study area is located between 38°27'-38°01' N latitude and 36° 38'-37°32' E longitude in the UTM (WGS 84 zone 37N) coordinate system and covers an area of 201,70 km². When the natural landscape elements of the study area were examined, the elevation in the study area varied between 510-970 m and the elevation in the city center was 640 m, therefore, the topography was rugged terrain. The dominant aspect of the area is south-east (18.23 %) and south (21.97%). The total area of the sunny aspects (south, southwest, southeast and west) in the study area was 118.52 km². Hydrological characteristic of the study area has been formed by Akpınar, Kocaboğan, Narlıca, Sinnep and Söğüt rivers and Seve Dam (Anonymous, 2017; General Command of Mapping-GCM, 2017). The 0.,15% of the study area belongs to class I, 46.15 % is

Fig. 1 : Location and boudaries of study area.

to class II, 10.63 % is class III, 13.29 % to class IV, 9.33 % to class VI, 8.17 % to class VII and 4.45% to class VIII, respectively, in terms of land capability (The General Directorate of Agricultural Reform-TGDAR, 2017). As the study area takes place in the transition zone in terms of plant geography, it is located both in Mediterranean flora region and in intersection point of Iran-Turan sub-region and Mesopotamia; redpine, mixed forest, scrub, cultivated plant and steppe formation types are found in the region. The average annual temperature was 17.1°C. The lowest average temperature in Kilis was 5.7°C in January, the highest temperature was 28.2°C in July, the average annual humidity was 54.2%, the average annual rainfall was 489.1 mm, the highest rainfall in winter and the lowest rainfall was in summer months. The dominant wind direction of the area was south-southwest (Turkish State Meteorological Service-TSMS, 2018).

The study area was a district of Gaziantep city until June 1995 and it became a province on 3rd of June 1995 (Kilis Provincial Culture and Tourism Directorate, 2017). In 2018, the population of the study area was 142.541 (Turkish Statistical Institute-TSI, 2019). The study area which is located in the Turkey-Syria border was heavily influenced by the conflict in the Syria. From the beginning of the war in 2011 to the present day, many Syrian refugees have arrived to Turkey and Kilis is one of the most affected cities by this influx of refugees. The number of Syrian refugees living in Kilis is 114.788 in total. When compared to Kilis population, the refugees account for 80.53 % of (Turkish population General Directorate of Migration Management-GDMM, 2019). Kilis provides accommodation to refugees as much as its own population. The economy of the study area consists of agriculture, livestock, industry and tourism (Silkroad Development Agency, 2018). 82.87% of the study area is agricultural area, 7.01% is settlement and transportation area, 4.73 % is afforested area, 3.37% is pasture and 2.02 is other areas (industry, protected areas, recreation and water bodies). The amount of waste generated and collected in the study area was 60.225 tons / year. The annual average waste composition of the area was 34% organic, 29% plastic, 15% metal, 13% paper, 6% glass and 3% ash (Anonymous, 2018).

This study determines and evaluates the criteria for landfill site selection, holistic analysis of these criteria and mapping process. In this context, the study was based on the previous studies of Çay *et al.* (2007), Küçükönder and Karabulut (2007), Guşin *et al.* (2009), Şener *et al.* (2010), Effat and Hegazy (2012), Kara and Doratli (2012), Şengün *et al.* (2018) and Aydemir-Karadağ (2019).

The first stage of the study comprised of determination and evaluation of site selection criteria, selection of these criteria, determination of suitability value (SV) and suitability coefficient (SC) processes. While determining site selection criteria, studies on this subject and legal structure were examined and criteria for landfill site were selected. While determining suitability value

(SV); again studies on this subject and legal structure were examined, evaluated on a 5-point scale (5 very suitable, 4 suitable, 3 moderately suitable, 2 hardly suitable, 1 not suitable) according to conformity of sub-criteria belonging to each criteria (Table 1). In the determination of the SC value, 6 experts (1 landscape architect, 1 urban and regional planning expert, 1 agricultural engineer, 1 forest engineer, 1 environmental engineer and 1 civil engineer) were consulted. A set of semi-structured questionnaire / interview about bilateral comparison of site selection criteria on a document was prepared and answered by the experts. Later, SC values were determined by evaluating the matrices in these documents within the scope of AHP. The consistency ratio of each matrix calculation results was less than <0.10 and the SC's obtained from matrix results were consistent.

Bilateral comparisons method in the context of AHP, which is one of the MCDM methods were used. AHP developed by Saaty (1987) is a general measurement theory. It is a non-linear framework for conducting both deductive and inductive thinking (Saaty, 1980; Saaty, 1987). AHP which is one of the MCDM methods is accepted as a powerful tool for solving the problem of landfill site selection (Guşin *et al.*, 2009; Şener *et al.*, 2010; Kara and Doratli, 2012; Aydemir-Karadağ, 2019).

The second stage of the study comprised of the processes of preparing the data based on criteria and mapping with holistic analyses. These processes include GIS-based studies. In the process of data preparation, firstly the main criteria (aspect, rock permeability, soil permeability, land capability classes) selected in order to be used for site selection were converted to raster data.

Suitability Scale: 1: Not Suitable, 2: Hardly suitable, 3: moderately suitable, 4: Suitable, 5: Very suitable

Later, the UD values determined according to sub-criteria were recorded to database with reclassify. In the formation of proximity maps (proximity to settlements, seasonal and dry streams, mainroads), first the data were converted to raster data, later the distances determined on the basis of criteria were transferred to the distance-euclidean distance analysis database and recorded to database with reclassify afterwards. Soil permeability, large soil groups and soil characteristic combination of the area were mapped by a holistic assessment based on the runoff curve number which was developed by USDA Natural Resources Conservation Service in 1972. Obtained data were converted to raster data and reclassified based on SV values (Uzun *et al.*, 2015). Following data preparation, based on the values obtained by AHP, SV values were determined by overlapping all the data with weighted overlay sum analysis. In the classification the score ranges were classified from the highest to the lowest in the form of very suitable, suitable, moderately suitable, hardly suitable and not suitable; and this classification was expressed as a map afterwards.

Table 1 : Landfill site selection main suitability criteria, sub-criteria, suitability value (SV) and suitability coefficient (SC) value

Criteria		SV	SC	Reason
Main	Sub			
Aspect	Flat	5	0,03	Decaying occurs faster in the aspects with higher temperatures (Karadağ et al., 2018).
	East			
	South			
	Southeast			
	Southwest	4		
	West			
	North			
	Northeast			
	Northwest	1		
Rock permeability	Basalt	5	0,20	Geologically, materials have different suitability for for selection as landfill sites (Elahi and Samadgar, 2014). For example, highly fractured quartzite which shows a secondary porosity feature, makes the ground water susceptible to pollution in terms of intense fracture and aquifer properties. Due to these properties quartzite is not suitable for landfill (Fagbohun and Aladejana, 2016). Landfill should be built on an impermeable floor that is not thick enough, and without cracks in order to prevent groundwater pollution (Ezzouaq and Chouaouta, 2002). Alluvial and limestone beds have high potential for water adsorption and are not suitable for landfills. Ophiolite and metamorphics are impermeable. Therefore they are the most suitable lithological units for a landfill site (Sener et al., 2010). The geological environment can be classified according to the natural structure and permeability of the area. These classes are (1) Alluvial materials-Sand, gravel and pebblestone-slits (2) Limestone, chalk and generally fragmented rocks/soils (3) Heterogeneous and less permeable areas and (4) Impermeable areas (Chang et al., 2008).
	Pebblestone	3		
	Sandstone			
	Mudstone			
	Sandstone	2		
	Mudstone -			
	Limestone			
	Old alluvial	1		
Land capability classes	Alluvial		0,20	
	Limestone			
Land capability classes	VI. Class	5	0,28	Agricultural lands should not be used out of their purpose. Landfill sites should not take place in, I. ve II. class lands (Sharifi et al., 2009; Yesilnacar and Cetin, 2005). In addition, these areas should not be considered within the boundaries of the great plains protection area.
	VII. Class	3		
	IV. Class	2		
	I.-II.-III.-VIII. Class	1		
Soil- Water permeability	Very Low	5	0,16	Soil permeability is very important in terms of how much pollutant passes from the landfill to the soil (Aydi et al., 2016; Effat and Hegazy, 2012). This criterion explains the risk of groundwater pollution when a landfill is to be constructed in areas with high permeable layers (Demesouka et al., 2013). Lower soil layers with lower permeability provide more favorable conditions for construction of landfills (Eskandari et al., 2015).
	Low	4		
	Moderate	1		
	High			
Proximity to dry and seasonal streams	Very High		0,18	
Proximity to settlements	e" 1001	5	0,09	In Turkey, landfills can not be built on the protected areas where the dumping and storage of solid waste is forbidden in the regulations regarding the protection of water sources where fresh water is provided and to be provided (Official Gazette, 1991). In the context of "regulation to protect fresh water basins" dated 28 october 2017 and published on official gazette with the number 30224; according to the article 9-3/8 bend 9 (absolute protection), article 10-2/9/10 (short distance protection), article 11-2/ bend 9 (medium distance protection); 0-1000m landfills are not permitted. Since it carries a flood risk for any type of usage to be brought to river and dry river beds, the opinion of General Directorate of State Hydraulic Works (GDSHW) is required (GDSHW Flood Legislation).
	0 – 1000 m	1		
Proximity to settlements	e" 2001 m	5	0,09	Due to problems such as water, air and visual pollution, insects, vermin, fire and noise; Landfills should be at a distance from urban and rural settlements in order to avoid concerns in public areas (Barakat et al., 2017). Construction of a landfill close to a residential area creates negative effects on public health, land value and future development of cities (Nas et al., 2010; Kahraman et al., 2018). The distance limit of urban areas to landfill sites should be 5-30 km. The distance of landfill sites from the city centers should be at least 2-5 km (Siddiqui et al., 1996). Depending on the hazardous situation of pollution sources, residential areas should be at a
	1501 - 2000 m	4		
	1001 – 1500 m	3		
	501 – 1000 m	2		
	0 – 500 m	1		

cont.....

Proximity to
mainroads

901 – 1200 m

5

0,06

distance from sources of pollution. For example; solid waste landfills cannot be placed closer than 500 m to a residential area, and buffer protection zones must be established at certain distances around residential areas or settlements (Bagdanavičiūtė and Valiūnas, 2013).

When constructing a new road infrastructure between the residential areas and the potential landfill, the distance to the main roads should be considered (Donevska *et al.*, 2012). Solid waste landfills should not be built within 300 m of highways. However, to avoid high construction costs, these areas should not be too far from the existing road network (Aener *et al.*, 2006; Nas *et al.*, 2010; Khanlar *et al.*, 2012). Smell, noise, dust and aesthetic problems caused by landfills close to the highway affect the tourism, drivers and passengers negatively (Saatsaz *et al.*, 2018).

Results and Discussion

Firstly, the criteria for the selection of landfill site, within the framework of legal structure, expert opinions and scientific studies, were determined as aspect, proximity to settlements, proximity to dry and seasonal streams, proximity to main roads, land capability classes, rock type and water soil permeability. The SV values obtained within the legal framework and within the scope of the study are given in Table 1. SC scores were obtained as a result of AHP evaluation based on expert opinions. Priority order of main suitability criteria was determined by AHP bilateral comparisons method. When Table 1 was examined, the highest suitability coefficient was obtained by the land capability classes, with the value of 0.28. Land capability classes were followed by

rock type, proximity to dry and seasonal streams, water soil permeability, proximity to settlements, proximity to main roads and aspects, with the values of 0.20; 0.18; 0.16 and 0.09, respectively. Suitability maps for each criterion were produced on the basis of criteria given in Table 1 (Fig. 2).

For the mapping of landfill sites in the study area, every suitability map in Fig. 2 was subjected to "Weighted Overlay Sum" analysis and total suitability score of Landfill site was calculated. When the overlay map database was examined, 4.84 and 1.00 scores were determined as maximum and minimum, respectively. These scores were classified as: 4.08 – 4.84 very suitable; 3.31 – 4.07 suitable; 2.55 – 3.30 moderately suitable; 1.78 – 2.54 hardly suitable and 1.00 – 1.77 not suitable; thus suitability map for

Fig. 2 : Suitability map of landfill site selection criteria.

Fig. 3 : Landfill suitability map.

landfill site selection in Fig. 3 was obtained. When the database of this map was examined, 0.23 % of the study area was determined to be very suitable, 4.66 % was determined to be suitable, 14.91 % was determined to be moderately suitable, 45.96 % was determined to be hardly suitable and 34.24 % was determined to be not suitable.

Suitable sites are concentrated to the north of Kilis city center, to the east of Beşikkaya village, to the north-east of Karacaören village and to the south-west of Küplüce village. When the obtained map was examined on the basis of present usage map (Çoban, 2019), very suitable area that showed distribution to the south-east of Tanburalı village, overlapped with afforestation, recreation and agricultural areas. Therefore, aforementioned area was not considered very suitable for being used as a landfill site. Very suitable area located south-west of Küplüce village, is being used as agricultural land. When the land capability class of aforementioned area was examined, it was

determined to be a VI class land. This area was used as agricultural land despite being unsuitable for agricultural activities. This area, which was found unsuitable for agricultural activities, was found to be very suitable for being used as a landfill site.

In addition, the very suitable area to the north-west of Oylum village was concluded to be hardly suitable, since it overlaps with settlement area. Suitable area that shows distribution to the north of Kilis city center overlaps with afforestation, recreation and agricultural areas; the suitable area to the east of Beşikkaya village overlaps with pasture and agricultural lands. Areas to the east of Beşikkaya village belong to class VI in terms of land capability. These areas were then used for agricultural activities due to afforestation, recreation and agricultural area, north of the Kilis city center; due to containing pastures and class VI areas in terms of land capability being close to these pastures, east of Beşikkaya village were not considered suitable for being used as landfill sites. The suitable area to the

north-east of Karacaören overlaps with agricultural land. This area has a land capability class of III. Class III areas in terms of land capability are fertile areas for agricultural activities. Therefore, it was determined that this area was not suitable for being used as a landfill site. The suitable area that shows distribution to the south-west of Küplüce village overlaps with afforestation and agricultural areas. Meanwhile the part that overlaps with afforestation area can not be considered suitable for using as a landfill site; the part that overlaps with agricultural area can be used as a landfill site. This area used for agricultural activities belongs to class VI in terms of land capability. Therefore, it was concluded that aforementioned area is suitable for using as a landfill site. According to the results obtained based on AHP analysis, two different areas in the category of "very suitable" and "suitable" in terms of suitability for being used as a landfill site, were marked with black frame in Fig.3.

As also stated by Majumdar *et al.* (2017), MCDM comes in handy for evaluating expert opinions; also in this scope, combination of MCDM methods with AHP and GIS makes it possible to express opinions spatially and produce stronger data, as stated by Makropoulos and Butler (2006). Different criteria are taken into account while determining the areas to be used as landfill sites. While selecting landfill sites, Kara and Doratlı (2012) used criteria like distance from waste production centers, distance from roads, slope, distance from surface waters, distance from groundwater areas, distance from environmentally sensitive areas, vegetation types, fertility, soil permeability, distance to settlements, distance to cultural sites and distance to quarries. Şener *et al.* (2010) carried out the selection of landfill sites using the criteria like: geology/hydrology, land usage, slope, elevation, aspect, distance to settlements, surface waters, roads and preserved areas (ecological, scientific and cultural).

The landfill site selection model presented in the study has directive quality for spatial planning, especially on regional scale in terms of conservation of natural processes, development of ecology based plans and designs, production of spatially expressable data and giving legally defensible decisions. For this reason, the necessity of maps produced by similar methods in spatial planning and decision-making processes should be ensured as such spatial data is an ecological guide to sustainable places.

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