

# An environmental geomorphologic approach to site selection for hazardous wastes

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**Abstract** Geomorphological features are essential parts of the environment and they represent an important conditioning factor for the development and distribution of certain biological assemblages, as well as for a variety of human activities. However, environmental geomorphology usually receives very limited or no attention at all in the process of environmental impact assessment (EIA). Nevertheless, the site selection process for hazardous wastes in environmental impact studies for individual projects plays an essential role. In order to determine the most suitable site in a region for municipal/hazardous wastes, several criteria are used, including geology, groundwater condition, climate, and land use. The present work describes a methodology taking advantage of environmental geomorphological features, and reducing these criteria in the site selection procedure in land disposal of waste; in addition, a case study is presented to demonstrate the applicability of the proposed methodology. The validity of the adopted site screening method is explained. This methodology comprises the use of a single geomorphological map to locate suitable landfilling sites for hazardous waste, instead of using separate maps for geological features, climatic features (temperature, precipitation, and speed and direction of the prevailing wind), slope and erosion. Furthermore, the present study is compared with a previous study performed in the GAP region, where the use of land resources is crucial for agricultural and water management purposes.

The application of the described selection process and the verified method in this region shows that the adopted method and detailed criteria are valid.

**Keywords** Environmental geomorphology · Regional site selection · Landfilling · Hazardous wastes · Disposal · GAP Project

## Introduction

Since the beginning of human history, people and their practices have changed the face of the earth (Giardino and Marston 1999). Geomorphological features are essential parts of the environment and they represent an important conditioning factor for the development and distribution of certain biological assemblages, as well as for a variety of human activities. However, environmental geomorphology usually receives very limited or no attention at all in the process of environmental impact assessment (EIA) (Rivas et al. 1997). Environmental impact studies for individual projects will normally be expected to cover the following items (Cavallin et al. 1994):

- description of the main characteristics of the project;
- estimation of residues and wastes likely to be created by the project;
- analysis of the aspects of the environment likely to be affected by the project;
- analysis of the likely significant effects of the proposed project on the environment;
- description of the measures envisaged to reduce harmful effects (this may be extended to include a consideration of alternatives to the proposed project and the reasons why they were rejected);

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- assessment of compatibility of the project with environmental regulations and land-use plans;
- list of possible alternatives for project location or facilities with fewer negative effects.

Thus, both environmental geomorphologists and environmental geologists working together can contribute considerably to geoscientific practices with regard to investigations at all the stages of waste management.

Solid wastes are divided into two categories: hazardous and municipal/domestic/non-hazardous. Simply defined, a hazardous waste is a waste with properties making it dangerous or capable of having a harmful effect on human health or the environment (EPA 2002). The problem of hazardous waste generation, storage, treatment, transport, recycling, recovery and safe disposal has become an issue of major international concern, particularly for developing countries (Khan and Anjaneyulu 2003). Most of these hazardous wastes generated in developing countries are presently being disposed of either in uncontrolled dump sites or municipal waste dump sites (Visvanathan 1996). Therefore, site selection procedure for hazardous wastes in environmental impact studies for individual projects plays an essential role. In order to determine the most suitable site in a region for municipal/hazardous wastes, several criteria such as geology, groundwater condition, climate, land use, etc., are used.

Many studies published in recent years (Al-Bakri et al. 1988; Frantzis 1993; Siddiqui et al. 1996; Yesilnacar and Cetin 2005; Kontos et al. 2005; Al-Jarrah and Abu-Qdais 2006; Şener et al. 2006; Banar et al. 2007) have not given sufficient attention to the environmental geomorphologic features in the site selection process of municipal/hazardous wastes in the management and planning of municipal/hazardous wastes. The present work describes a methodology taking advantage of geomorphological map/features and reducing the number of these criteria/maps in the site selection procedure in land disposal of waste. In addition, a case study is presented to demonstrate the applicability of the proposed methodology.

### Case study

The Southeastern Anatolia Project (Turkish initials “GAP”) region is specially chosen for this research due to the following reasons. There are two free trade zones in the region, in Gaziantep and Mardin. Seven organized industrial districts (OIDs) have already been completed while there are twelve others in the investment program. As of early 2006, there are ten OIDs and twenty-five SISs (small industrial sites) operating in the region. Twelve more SISs are in progress with relevant construction works. Furthermore, there are nine provinces and more than 200 districts

and small district settlements in the region. The hazardous and municipal wastes in Turkey are conducted by the Ministry of Environment and Forestry, as per Hazardous Wastes’ Control Regulations and Solid Wastes’ Control Regulations, which went into effect in Turkey upon their publication in the Official Gazette, 27 August 1995, and 14 March 1991, respectively. However, as yet, the hazardous/municipal wastes generated from OIDs and SISs, and the settlements in the region are disposed of indiscriminately in uncontrolled areas. The only one municipal solid waste disposal facility as required by the regulations is located in the city of Gaziantep in the region.

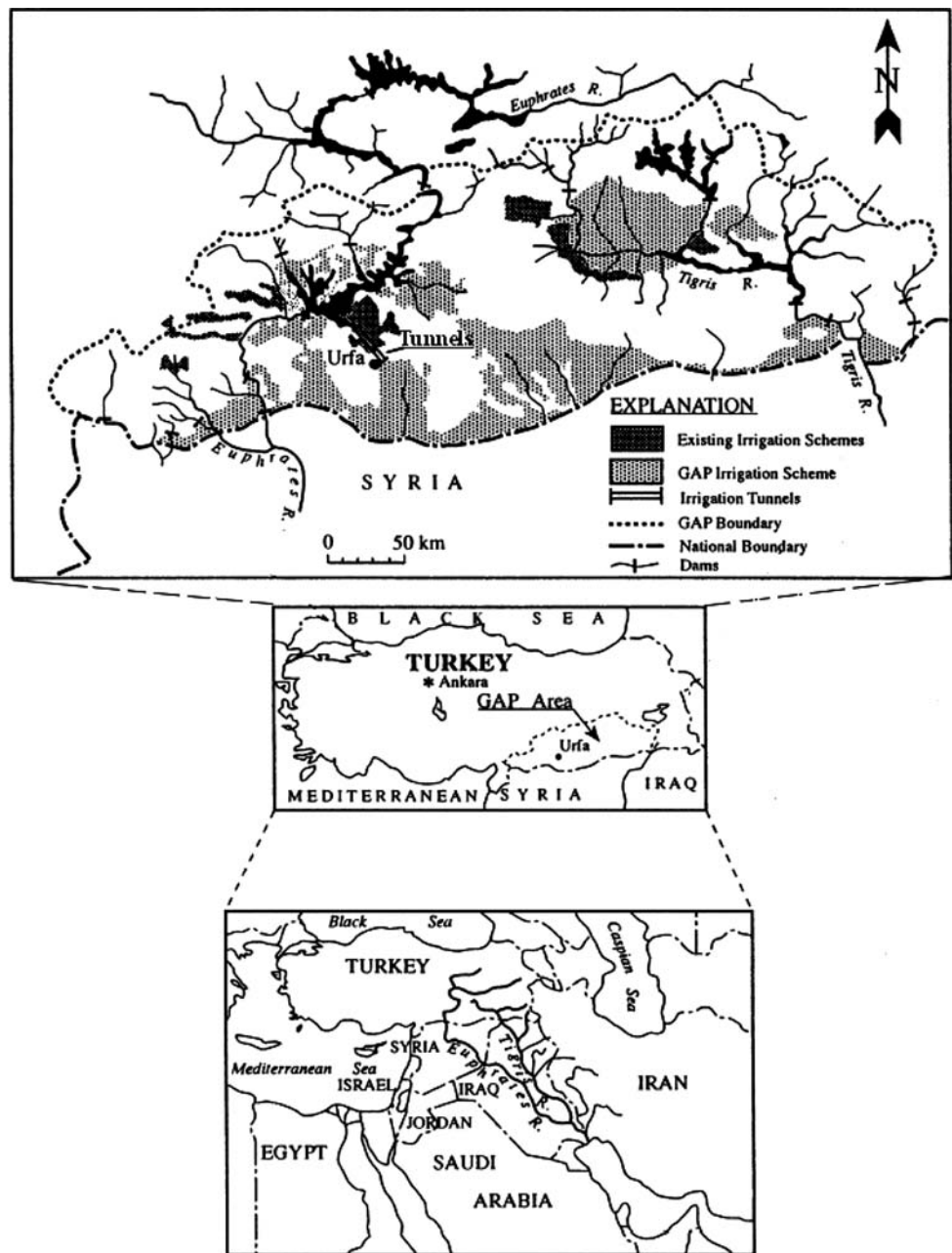
### Study area

The GAP is a regional development project aiming at the full fledged socio-economic development of what is called the “Upper Mesopotamia” or the “Fertile Crescent”, which once witnessed one of the earliest civilizations in the world (Fig. 1). Sustainability is the philosophy underlining the GAP, which has human wealth and well being as its focus. Having all its details scrupulously planned and implemented, the GAP is one of the greatest projects of Turkish Republic. As an integrated regional development project based upon the concept of sustainable human development, the GAP covers investments in fields such as urban and rural infrastructure, agriculture, transportation, industry, education, health, housing, tourism, etc. as well as dams, power plants and irrigation schemes on the Euphrates and Tigris. The water resources development component of the program envisages the construction of 22 dams, 19 hydraulic power plants and the irrigation of 1.7 million hectares of land. The project is growing rapidly, attracting various industrial activities, especially in construction, transportation, urbanization and agricultural areas (GAP 2006).

### Methodology

The primary objective of a site selection process is to assure that new facilities are located at intrinsically superior sites that, by virtue of their natural features and land use setting, provide a high degree of protection to public health and the environment. In this respect, the land use setting and natural features function as an additional line of defense if the facility’s operations are not performed as planned. Proximity to sources of waste generation is another important criterion. A site selection process usually proceeds through a phased approach. It begins with the use of regional screening techniques to reduce a large study area, such as an entire state or region, to a manageable

**Fig. 1** Location map of the study area



number of discrete search areas. Because of this screening, the search areas should have higher probabilities of containing suitable sites. The next phase evaluates discrete search areas in more detail and identifies candidate sites within them. These candidate sites are then evaluated in even more detail at a site-specific level of analysis to provide the basis for selecting a site for the facility. The overall site selection process is thus one of the increasingly intensive analysis of progressively smaller areas (LaGrega et al. 2001). In land disposal of hazardous waste, a number of criteria, such as local geology, climate, topography, groundwater conditions, cover soil suitability, and human encroachment, must be considered (Cetin 1995).

A study was performed by Yesilnacar and Cetin (2005) on a regional scale. In this study, the overlayer technique was used as the methodology for preparing a final site selection map including all of the maps. This technique is an approach that includes various features (geology, topography and soil, climatic conditions, etc.) of the region studied and makes joint comparison possible through transparencies of the maps. For the final site selection, ten of the map sections described above was used. Each of these maps was scored in terms of site selection on a scale of 1 (very good) to 5 (very poor). The sections, plotted on a transparent film, were superimposed on each other (Fig. 2). Geographical Information System (GIS) was not used in

this study because of financial and technical limitations. Although image processing software was used in transferring the maps into an electronic environment and in overlaying, a significant portion of the work was carried out manually with extreme care.

For the present study, a single geomorphologic map was used instead of separate maps for geological features, climatic features (temperature, precipitation, speed and direction of the prevailing wind), slope and erosion, since geomorphology is the study of landforms, including their origin and evolution, and the processes that shape them.

#### The site selection

The geomorphologic, active fault, and earthquake zoning maps were converted into 1/500,000 scale for comparative evaluation. The original dimensions of the converted maps were 50 × 100 cm. For evaluation of maps of various scales to be used in the study, a scanner was used to transfer the maps to an electronic environment. A 24-bit color depth and 300 dpi resolution was used. Conversion of all map pieces to the study scale and the combining of them were performed with various image processing software. All of the evaluations were summarized on the map of final site selection (composite map).

#### Base map (GAP Project Development Plan)

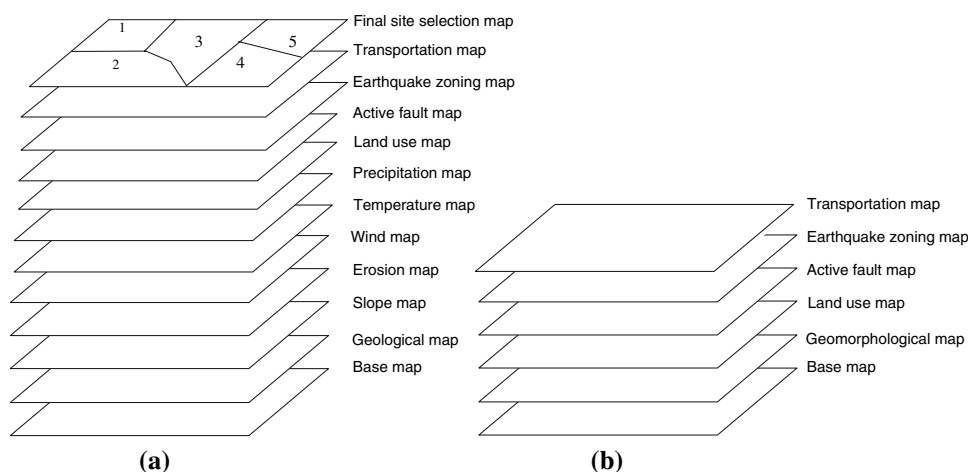
The 1/500,000-scale GAP Project Development Plan map prepared by DSI (1994) was used in order to protect water and land resources, which compose the primary goal of GAP, out of the evaluation. In this plan, the water and land resources development project is shown in four stages (Fig. 3): in operation, under construction, in planning and

final plan, in reconnaissance and master plan stages. For the purposes of the study, the four stages indicated in this map were combined. The combined stages and the areas, which are unsuitable for sanitary landfilling at least for one variable, including settlements (urban centers and villages), roads, railways, airports, wetlands, infrastructures (pipelines and power lines), etc. were masked and excluded from the evaluation. This plan plotted on transparent film serves as a base map composing the evaluation in all phases of the study (Fig. 4).

#### Geomorphology

The term *hazard* is often associated with different agents or processes. Some of those include atmospheric, hydrologic, geologic, biologic and technologic. Specifically, natural hazards are considered within a geological and hydrometeorological conception, where earthquakes, volcanoes, floods, landslides, storms, droughts and tsunamis are the main types. These hazards are strongly related to geomorphology since they are important ingredients of the Earth's surface dynamics. Hazards are the result of sudden changes in long-term behavior caused by minute changes in the initial conditions (Scheidegger 1994). In this sense, geomorphic hazards can be categorized as endogenous (volcanism and neotectonics), exogenous (floods, karst collapse, snow avalanche, channel erosion, sedimentation, mass movement, tsunamis, and coastal erosion), and those induced by climate and land-use change (desertification, permafrost, degradation, soil erosion, salinization, and floods) (Slaymaker 1996; Alcantara-Ayala 2002). From this point of view, the contribution of geomorphology is crucial in the prevention of natural disasters/geohazards and in risk assessment and management programs in developing countries in particular, as is the role of environmental geomorphological studies, at the stages of

**Fig. 2** Overlay procedure. **a** Previous study, **b** this study





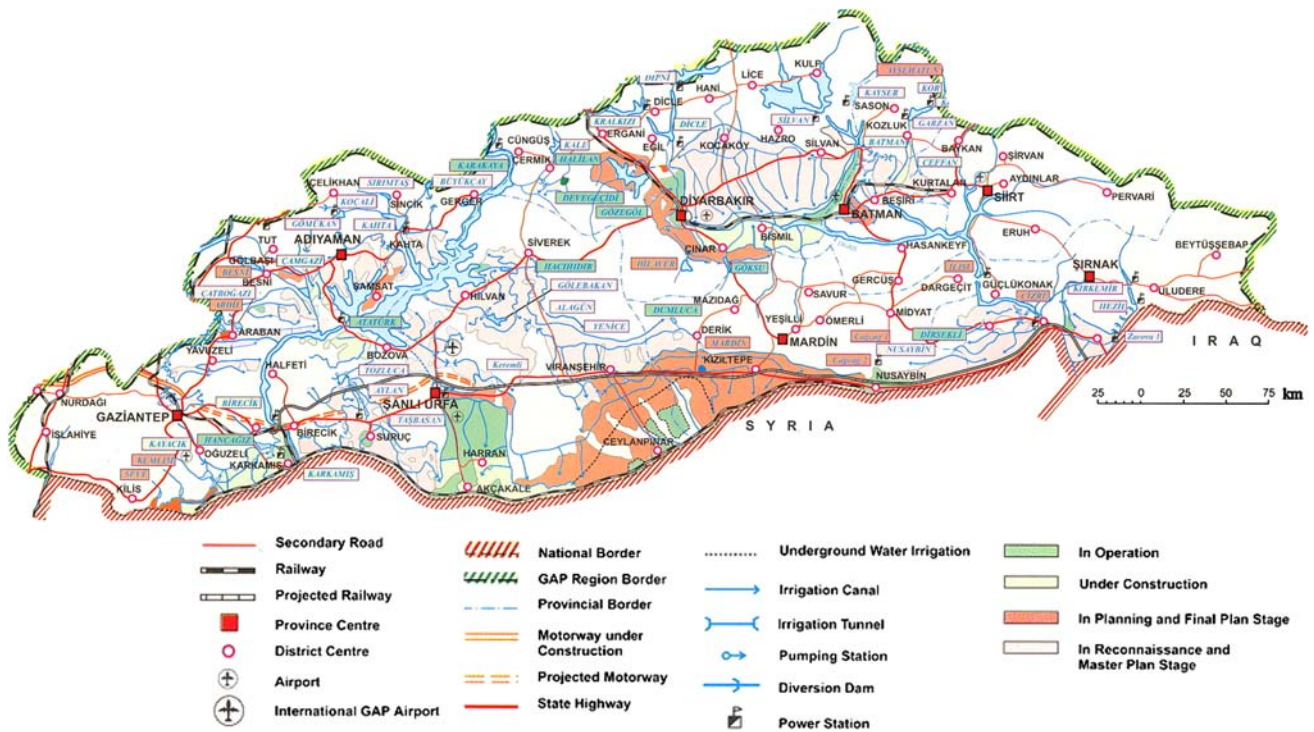


Fig. 3 GAP development plan

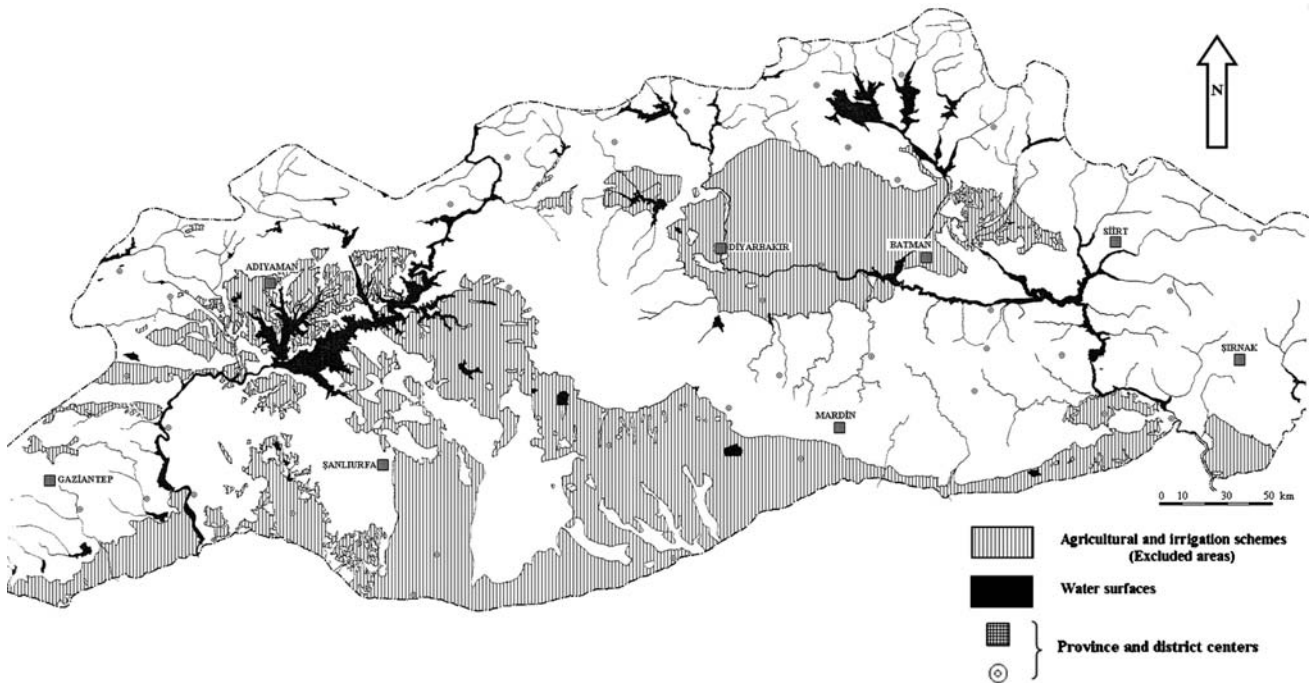
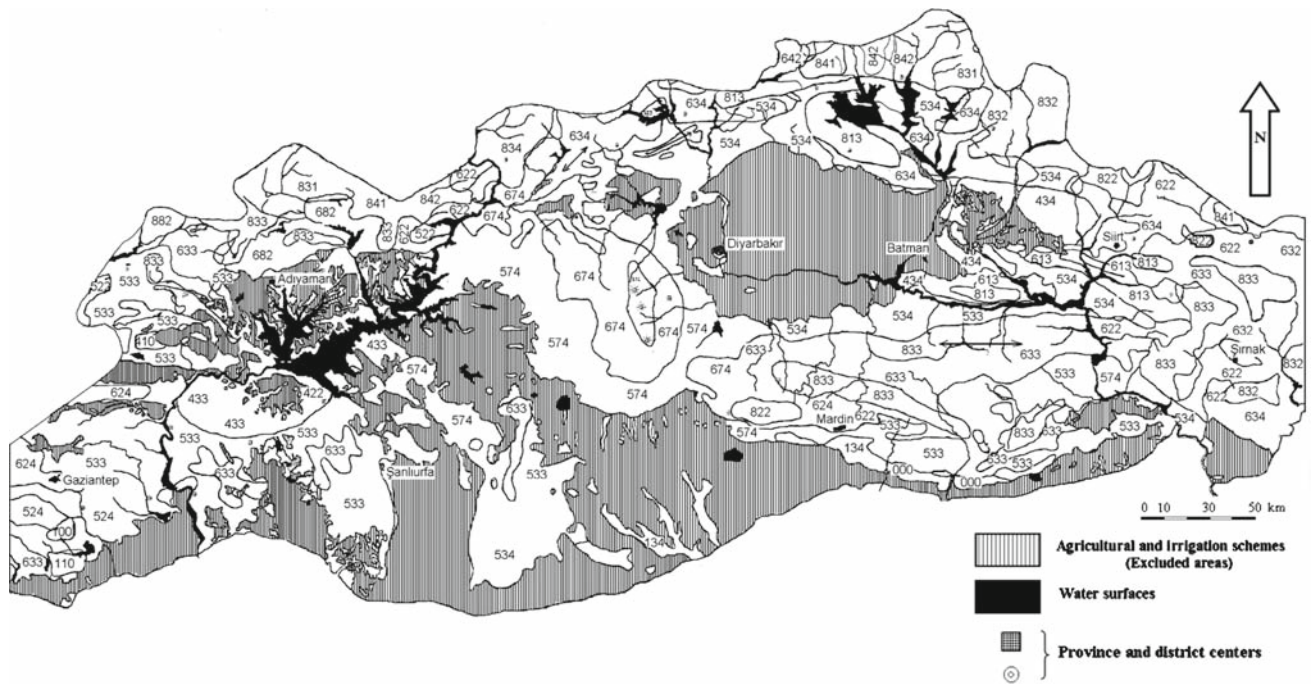


Fig. 4 Base map used in the study

preliminary investigation and master plan, planning, design, application and operation of environment and infrastructure investments or schemes. In this context, this work focuses on the role of environmental geomorphology

in the preliminary stage of an environment scheme in a developing country.

Main characteristics of the geomorphological map printed by MTA (General Directorate of Mineral Research and



Relief Classes (First figure)			Lithology influencing the landforms (Second figure)	
	Round crested forms	Sharp crested forms	Causing round, low relief	Causing sharp, high relief
Mountains	832 8. Flat topped	9. Sharp crested, high	8. Ophiolite, serpentine	9. Plutonic rocks
Hills	673 6. Flat topped	7. Sharp crested, moderate high	6. Volcanic tuffs, ignimbrite	7. Volcanic lava, agglomerate
Plateaus	524 4. Low plateaus on Neogene (Pliocene)	5. High plateaus on older formations	4. Schist, gneiss	5. Alternating schist, gneiss, marble, quartzite
Valleys and depressions	2. Subsequent depressions	3. Large valleys	2. Alternating clay, marl, limestone	3. limestone, marble
Basin's	110 0. Alluvial plains	1. Basins with terraces	0. Alluvium	1. Sandstone, conglomerate, flysch formations
Stage of structural evolution influenced the landforms (Third figure)				
1. Crystalline – Mesozoic	} Basement	} Alpine orogenic belts	} Paleotectonic	←→ Anticlinal hills
2. Folded Mesozoic				
3. Folded lower Tertiary				
4. Folded to horizontal Upper Tertiary (Neogene)	} Covering formations	} Neotectonic	☼ Caldera	
0. Quaternary formations			☼ Volcanic cone, large	
			☼ Volcanic cone, small	

Fig. 5 Geomorphological map of the GAP area

Exploration) (1991) used in the study are as follows: (1) relief classes, (2) lithology influencing the landforms, and (3) stage of structural evolution influencing the landforms (Fig. 5). Assessments of the geomorphologic features in the studied area are carried out in the Results section.

Land use

There are official land classifications in Turkey designating the proper use for every piece of land according to its

qualities. Land is classified into eight groups according to the nature of its top soil, its slope and other properties. Land types 1–3 are reserved for agriculture. Types 5–7 are suitable for forestry and pasture. In between, there is type 4, which may or may not be used as agricultural land, depending on the climate and the socio-economic conditions of the area. Type 8 designates land not suitable for any productive use but has to be planted in order to prevent floods and avalanches (TEMA 2007). Thirty-four percentage (2,468,596 ha) of the land in the region comprises land of the most favorable type for agriculture, of classes 1–3. If

class 4 land is included, then 43.5% of the land in the GAP region (3,160,654 ha) is suitable for agriculture (Table 1). The areas outside of these with land use and agricultural importance are very limited. With this restrictive factor taken into consideration, fertile and valuable lands of classes 1–3 were avoided, and evaluations were concentrated on lands of classes 4–8. Absolute agricultural areas (classes 1–3) harboring flora and fauna, are vitally important and unsuitable not only for waste storage but also for all industrial and urbanization activities (Fig. 6). For the present study, when these fertile lands were used out of aim, the situation was somewhat different. This is because when the storage area completes its lifespan, a final covering of soil will be laid down, and the land will again be opened to agricultural and recreational purposes. When planned and managed according to the pertinent regulations, the secure landfill is an environmentally friendly and economic method that causes minimal or no harm to the ecosystem.

*Active fault and earthquake condition*

The area is under the effects of the Southeast Anatolian Thrust, which delimits the GAP region in the north, and the East Anatolian Fault (EAF), which goes through the western part of the region southeastwards. The Karacadag Fissure, resulting from the collision of the Arabian Plate and the Anatolian Plate, is a typical example of tension fissure in the region. Furthermore, the Bozova Fault, passing by the main body of the Ataturk dam towards Bozova, is a major active fault, as are the Tut Fault, passing through southwest of Adiyaman, and the Sürgü Fault, in the north (Fig. 7). Under the influence of this neotectonic system, Sirnak, Batman, Diyarbakir, and northern Adiyaman in the east and Gaziantep and northwestern Kilis are located in a first-degree earthquake zone. According to the report of the new earthquake zoning map (Fig. 8), five zones are differentiated in degrees in consideration with the expected maximum acceleration calculations. The report shows that 33% of the region is located in a first-degree

earthquake zone (Table 2). Despite its historical seismicity, the EAF has not been investigated as much as the North Anatolian Fault (NAF) since there has been no major earthquakes on it during the 20th century. Because there are numerous important engineering structures, including 22 dams and 19 hydroelectric power plants, the assessment of seismic parameters in landfill design and construction is of the utmost importance. In site selection in this study, first-degree earthquake zones were avoided and, as far as possible, third- and fourth-degree zones were focused on.

*Transportation*

As of 2005, there is a 34,465 km road network comprising 103 km of highways, 5,942 km of state and provincial roads and 28,420 km of village roads. The Gaziantep–Sanliurfa highway where the physical realization is 73% is still under construction (GAP 2006). There is a total of 805 km of railway, which includes the Gaziantep–Nusaybin and the Diyarbakir–Batman–Kurtalan lines. Within the region, there are seven functioning airports, in the provinces of Gaziantep, Diyarbakir, Sanliurfa, Batman, Siirt, Adiyaman, and Mardin. Also, the largest cargo airport in Turkey is now under construction in Sanliurfa. The “GAP International Airport” is expected to be completed at the end of 2007. Site(s) to be selected must have sufficient road networks for transportation without difficulty. Ninety-eight percentage of the village settlements in the region are connected to main roads (Fig. 9).

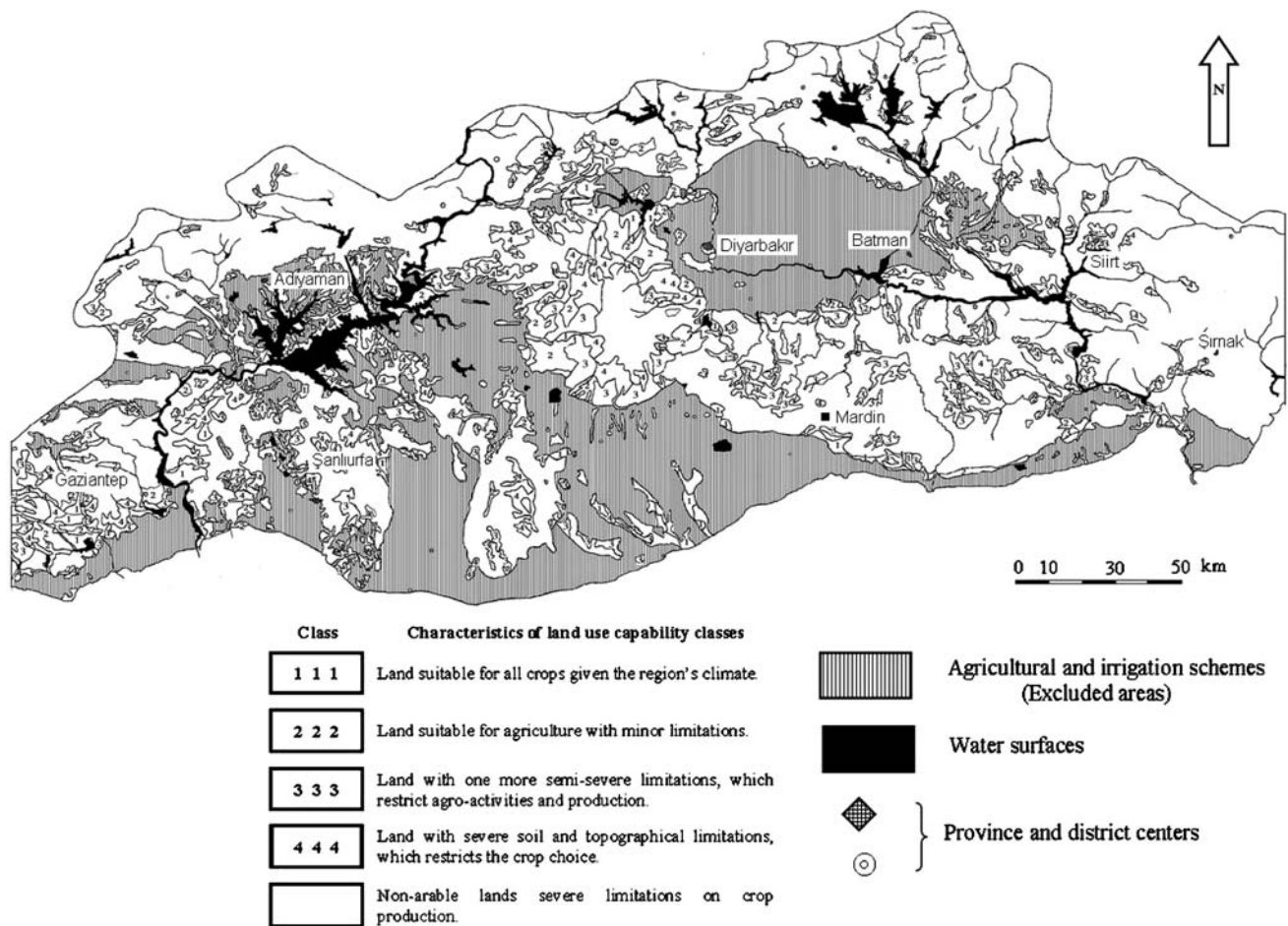
**Results**

For final site selection, these maps, were overlaid, each was rated on a scale ranging from very good (1) to very poor (5), and a composite map was obtained (Fig. 10). During assessment of the criteria for site selection, priority was given to geomorphological structure, relief matters such as excessive sloping and heights such as mountains and hills, tectonic matters such as active faults and first-

**Table 1** Land use capability classes of the GAP area (Gümrukçüoğlu et al. 2000)

Land types	1	2	3	4	5	6	7	8
Area (ha)	946,061	816,191	706,344	692,058	1,291	835,855	3,014,497	267,889
Percentage (%)	13	11	10	10	0	11	41	4
Inventory								
Land use			Area (ha)	Percentage (%)				
Agricultural lands (1–4)			3,160,654	43.5				
Suitable for pasture and forests (5–7)			3,851,643	53				
Lands not suitable for agriculture (8)			267,889	3.5				
Total			7,280,186	100				





**Fig. 6** Map of land use the capability classes of the GAP area (Adapted from GAP 1992)

degree earthquake zone condition, and protected areas under the water pollution control regulations. Five classes of areas were determined according to relative degree of suitability: (1) very good (2) good (3) moderate (4) poor and (5) very poor. Because suitable and unsuitable areas were not clustered in any particular area, i.e., they were scattered, general site selection characteristics were discussed for each classification.

#### Fifth-degree (very poor) areas

These sections were classified as “very poor” for site selection because of the southeast Taurus mountains, EAF in the northwest, the Karacadag volcanic mass and the Mardin threshold; because in terms of slope they comprise wide high-sharp crested forms; because of the Southeast Anatolian thrust and the fact that it is a first-degree earthquake zone, the frequency of streams in the drainage area of the Tigris river and, in connection with this, the irregularity in the relief, and hence, the fact that denudation is very marked and land use capability (LUC) is

very low. The high negativity in terms of these criteria restricted lithological examination. Nonetheless, in terms of lithology influencing the landforms, these areas have a very complex lithology such as ophiolite, serpentine, schist and gneiss.

#### Fourth-degree (poor) areas

When areas outside of fifth-degree (very poor) areas are assessed, basic factors such as, in general, the effect of relief high-sharp crested areas, second-degree earthquake zone, severe denudation, negative LUC in terms of site selection, and proximity to a water basin necessitated the classification of these areas as fourth degree. Most of the areas classified as fourth degree in terms of lithology influencing the landforms, and parts in the east of the region comprise Eocene aged limestone series. Parts between Sanliurfa and Ceylanpinar are on Neogene aged limestone and a very small part is on volcanics. None of the general lithological features of these deposits takes precedence over the others.



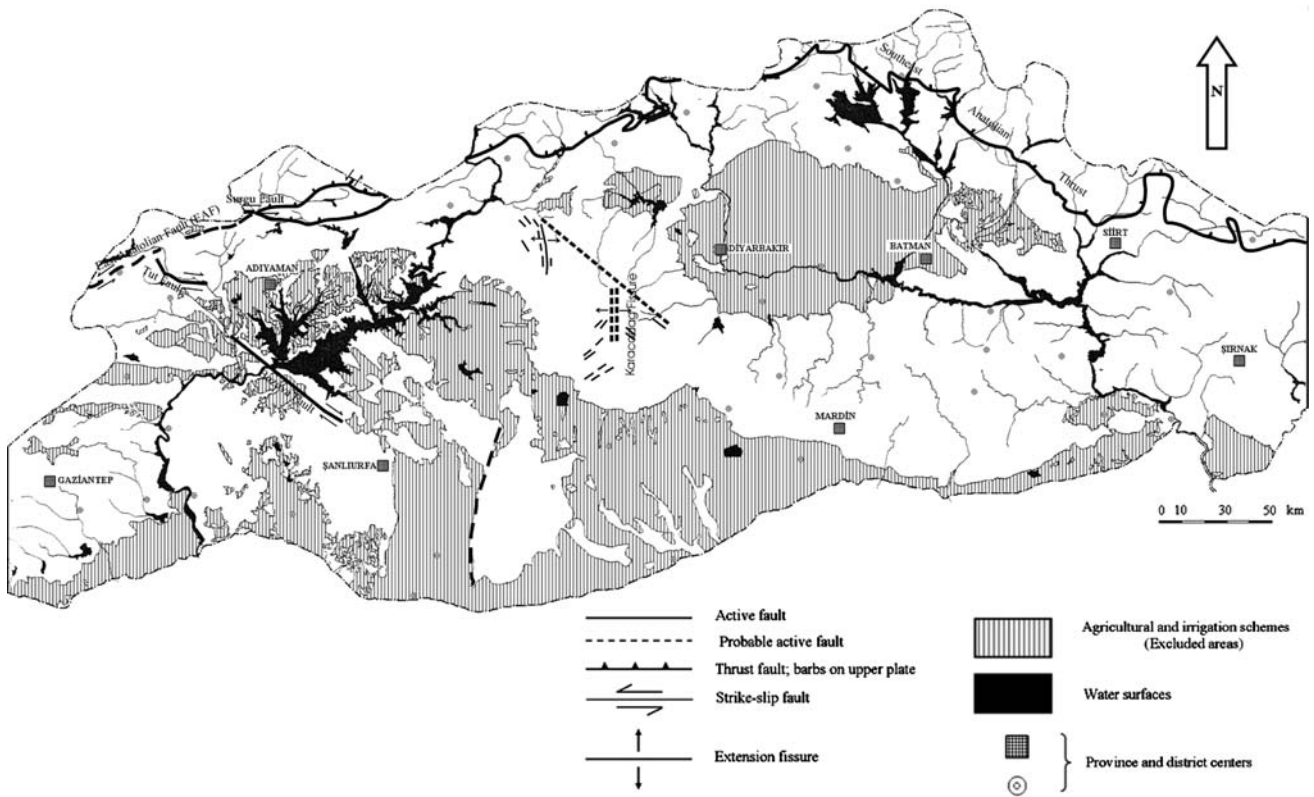


Fig. 7 Active fault map of the GAP area (Adapted from MTA 1992)

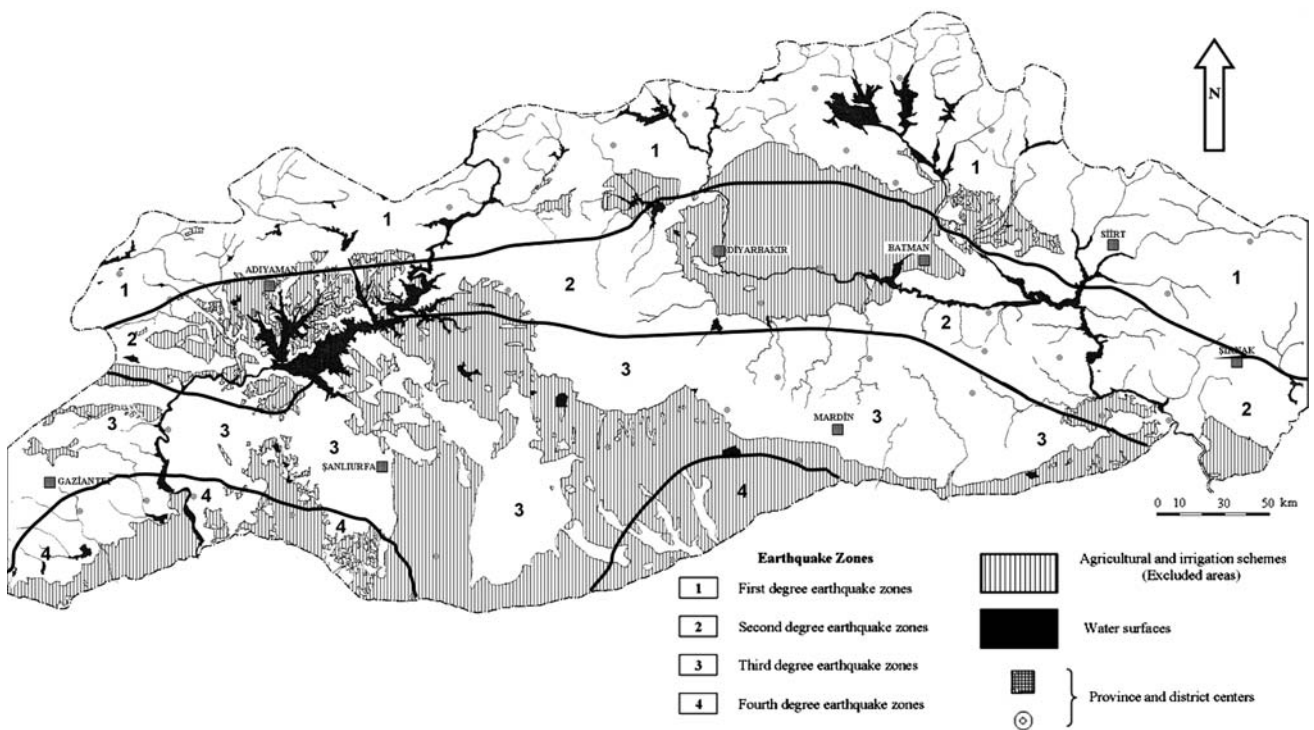
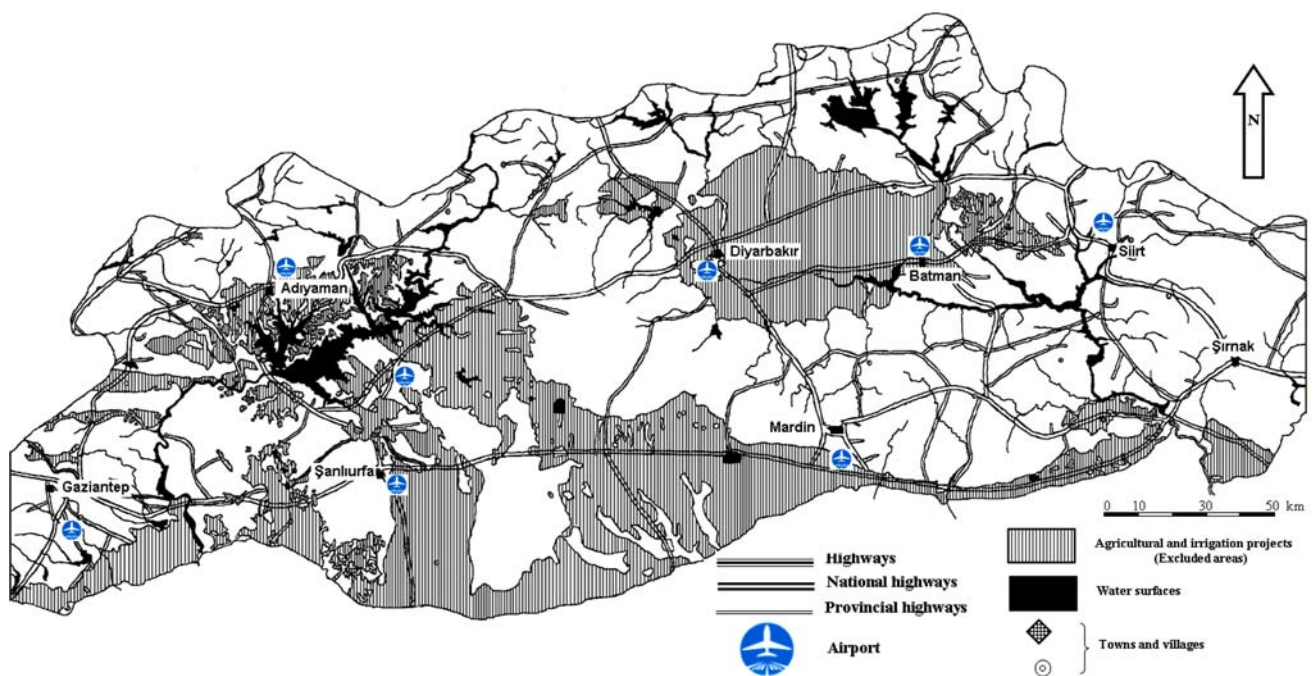


Fig. 8 Earthquake zoning map of the GAP area

**Table 2** The areas of provinces in the GAP region according to the earthquake zoning map of Turkey (Özmen et al. 1997)

Provinces	Earthquake zone	Area (km <sup>2</sup> )								
		I Degree		II Degree		III Degree		IV Degree		Total
			%		%		%		%	
Diyarbakır	2	8,764	57	5,879	38	628	4	–	–	15,271
G.Antep	3	1,188	18	1,598	24	2,609	39	1,373	20	6,769
Ş.Urfa	3	368	2	2,628	14	13,787	71	2,665	14	19,449
Adıyaman	2	4,146	54	3,456	45	39	1	–	–	7,641
Batman	2	2,205	47	2,416	52	58	1	–	–	4,680
Kilis	3	–	–	200	13	759	51	542	36	1,502
Siirt	1	5,050	92	449	8	–	–	–	–	5,499
Şırnak	2	3,131	44	3,243	45	815	11	–	–	7,190
Mardin	3	–	–	940	11	6,817	77	1,098	12	8,855
GAP	–	24,852	33	20,809	27	25,512	33	5,678	7	76,856



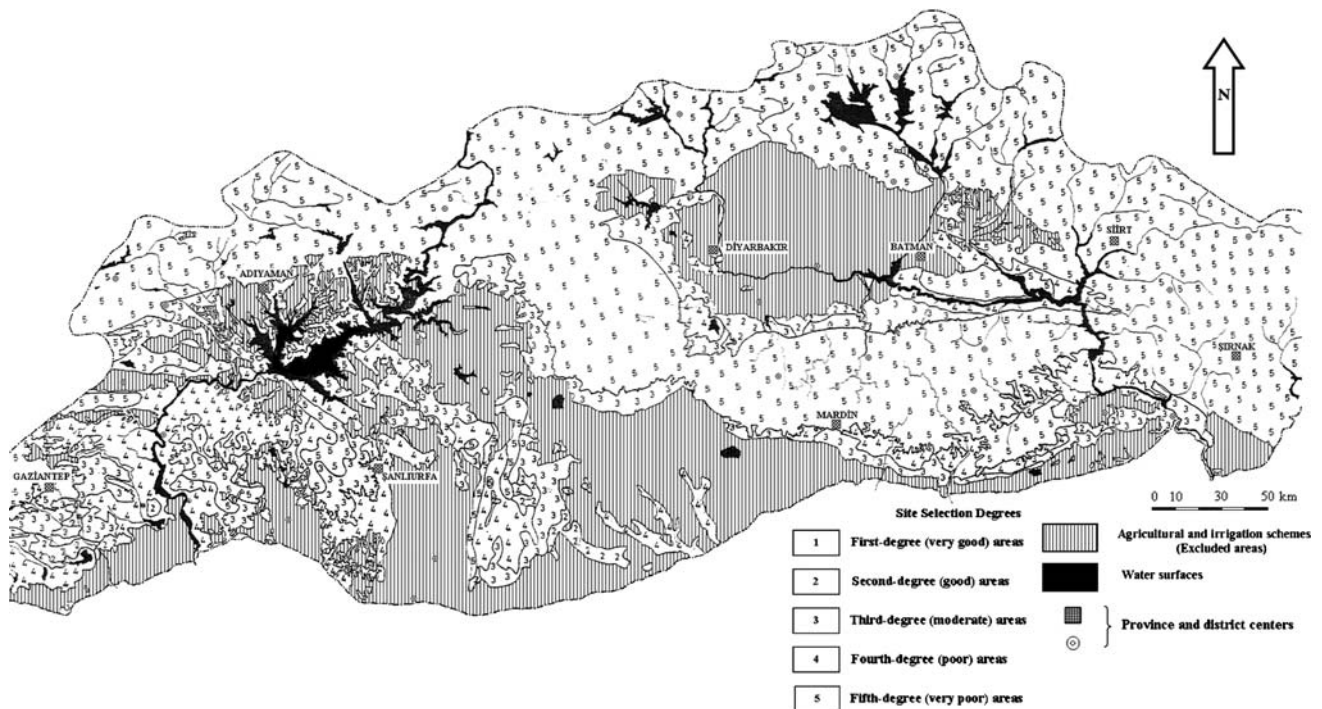
**Fig. 9** Transportation access network map of the GAP area (Adapted from KGM 1996)

### Third-degree (moderate) areas

Areas of third-degree suitability are concentrated on the edges of regions used for irrigation and agriculture which were excluded from the assessment. These areas, which, geomorphologically, are outside of heights such as mountains and hills, are moderately sloped. However, there is a significant slope problem. Thus the denudation resulting from severe erosion is significant. Tectonically, these areas are remote from known active faults. In terms of LUC, the third-degree areas consist of agriculturally medium-quality soils. The possibility of a negative reaction from the public in the event of waste storage in these areas should not be ignored. If storage is to be done in these areas, the problems mentioned above need to be addressed. The cost of

any solution here would be greater than in first- and second-degree areas.

With regard to lithology influencing the landforms, this area is shown to be limestone and partially basalt. If land over basalt is chosen, the problem of materials for covering and impermeability may be solved to a significant extent because the clays found in this area tend to be smectites derived from these basalts. However, the shrink–swell problem of smectites should not be forgotten. Furthermore, in non-altered basalts, permeability is at a level that may create problems. In fact, there was a water leakage problem in the foundation of Hacıhidir dam, which was built on a basalt base on a tributary of the Euphrates near Siverek. The hardness and permeability of limestone varies from region to region. In some sections, limestones are soft, or



**Fig. 10** Final site selection map of the GAP area

they are alternated with marls. The difficulty of excavation in hard, compact and massive limestones is a major disadvantage. Cover soil, if it meets the pertinent criteria, may be supplied from nearby agricultural areas.

**Second-degree (good) areas**

The second degree areas consist of a narrow area near the Dicle Basin irrigation fields in the east of the GAP region, in the middle sections in the west of Ceylanpinar plain, in the north in the south sections of Diyarbakir plain, and in the south of Gaziantep. The Gaziantep municipal solid waste storage facility is located in this area. The general feature of these areas is that, although they are at a level that may be assessed as plains, there are problems in some sections. In terms of slope, it is moderately crested. In terms of LUC, it is on fourth-degree lands that may be considered separate from agriculture. In areas identified as second degree in the north and northwest sections, there is a partial erosion problem. Water basins and protected areas are far enough not to be affected. Tectonically, on a regional scale, there is no active fault problem. Seismically, most of these areas are in a third-degree earthquake zone. As for lithology influencing the landforms, the second-degree areas are on Eocene aged limestone and basalts in the east around İdil, on Eocene aged limestone in the south of Diyarbakir, on Neogene limestone in the environs of Ceylanpinar, and on Eocene limestone and recent

alluvium in the south of Gaziantep. It should be kept in mind that the hardness of limestone may cause problems for excavation, and that the fact that it is karstic, fractured, and cracked may cause seepage problems. Also, the alteration condition and depth on basalts must also be considered. If clays deriving from basalts are to be used, their mineralogical compositions and geotechnical characteristics must be investigated by laboratory tests. Furthermore, it is crucial that impermeability be achieved in the field that is chosen. In particular, the landfill base must meet requirements. Although alluviums do not present problems for excavation, leakage is a major problem.

**First-degree (very good) areas**

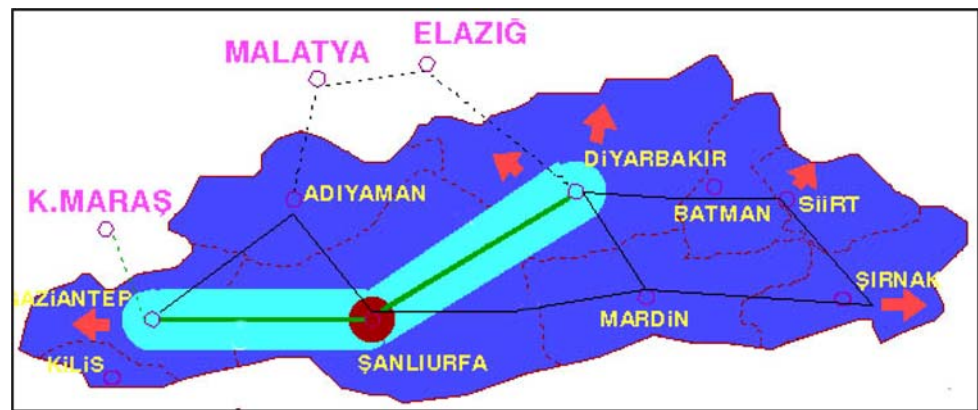
Great care was taken in determining areas outside of fifth-, fourth-, third-, and second-degree areas. They were assessed separately. The first area is 5 km north of Sanliurfa, the second and its neighbor the third are in the vicinity of Halfeti district to the north of the Sanliurfa–Gaziantep highway.

*North of Sanliurfa*

This area is in the direction of the Sanliurfa–Diyarbakir highway and is 5 km from Sanliurfa. It comprises flat and nearly flat plains. In terms of slope, it belongs to the



**Fig. 11** Development axes and attraction centers in the GAP (Ünver 1993)



moderately crested class, and is suitable. It has a mild slope. Its erosion condition is mild degradation. Tectonically, there is no active fault problem. Seismically, it is in a third-degree earthquake zone, where damage is not considered. Lithologically, the area comprises Upper Cretaceous and Eocene aged formations, and basalts from volcanites. Upper Cretaceous units are in the form of marly limestone, and have a thickness of 300–350 m. Eocene aged units are of chalky and marly structure. The apparent thickness is 200 m, and decreases gradually towards the west. Basalts from volcanites are the product of Karacadag volcanism. Basalts have altered to a significant degree; they are permeable when fractured and cracked, and thus impermeability must be achieved in the field. In particular, the landfill base material must meet the pertinent criteria in the Hazardous Wastes' Control Regulations. The disadvantage of this area, in which dry agriculture is carried out, is that it is first-degree agricultural land in terms of LUC. If cover material is to be supplied from this soil, mineralogical analysis and detailed geotechnical investigations must be carried out. When attraction centers in the industrialization process of GAP are taken into consideration, while industrial hazardous wastes are disposed of, the fact that they are near these centers or routes, especially the most suitable areas are in the vicinity of Şanlıurfa, will minimize problems with access and transport problems (Fig. 11). Another disadvantage of this area is that, if storage is carried out here in a 25-year process, the development of roads and utilities may come close to the region. If the facilities are managed in accordance with the regulations in force, there will be no problems in this regard.

#### *East of Halfeti*

This area is north of the Şanlıurfa–Gaziantep highway in the environs of Halfeti. It is divided into two parts, east and west, by flat and nearly flat plains. In terms of slope, it is in the moderately crested class, and is suitable. Because of its

mild slope, erosion is in the form of light degradation. Tectonically, there appears to be no active fault problem on a regional scale. Seismically, it is in a third-degree earthquake zone, where damage is not considered. In terms of lithology influencing the landforms, this region is an Eocene aged chalky and marly unit (MTA 1975), the most typical characteristic of which is the fact that it outcrops in wide areas and is recognizable from a distance by its white color. The disadvantage of this area is that, in terms of LUC, it comprises first- and second-degree agricultural land. A positive feature is the fact that it is in a suitable position for the GAP development axis. The proximity of the western part of this area to the Birecik Dam Lake area is a disadvantage (if this area is chosen), but this can be minimized by operation of storage starting from the eastern part.

The results of this study clearly indicate that it is always possible to obtain adequate information from a geomorphological map which is detailed, precise and accurate, and to use such a map rather than separate maps for geological features, climatic features (temperature, precipitation, speed and direction of the prevailing wind), slope and erosion.

#### **Conclusion**

The determination of suitable site location and conditions for hazardous wastes to be landfilled is one of the major awaiting problems particularly for developing countries where arguably, the industrial development is harmfully affecting the environment. It is concluded that their resolution of environmental management aspects underpinning the centralized planning leads to the requirement for an accurate preparation and application of the environmental master plan using the environmental geomorphological approach that is explained in this paper.

The principal factors affecting the determination of landfilling location for hazardous wastes are identified in



the paper, these are geomorphology, land use, seismicity (active fault and earthquake condition) and transportation and their degrees of impact are also detailed.

The validity of the adopted site screening method for locating suitable landfilling sites for hazardous waste, is explained. This method comprises the use of a single geomorphological map instead of separate maps for geological features, climatic features (temperature, precipitation, speed and direction of the prevailing wind), slope and erosion. Furthermore, the present study is compared with a previous study carried out in the GAP region, where the use of land resources is crucial for agricultural and water management purposes. The application of the described selection process and the verified method in this region shows that the adopted method and detailed criteria are valid.

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