SITE SELECTION OF MUNICIPAL SOLID WASTE LANDFILLS USING ANALYTICAL HIERARCHY PROCESS METHOD IN A GEOGRAPHICAL INFORMATION TECHNOLOGY ENVIRONMENT IN GIROFT

[1]H. Javaheri, *[2]T. Nasrabadi, [3]M. H. Jafarian, [1]G. R. Rowshan, [2]H. Khoshnam

[1]Faculty of Geography, University of Tehran, Tehran, Iran

[2]Faculty of Environment, University of Tehran, Tehran, Iran

[3]Department of Geography, University of disciplinary Sciences, Tehran, Iran

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ABSTRACT

Municipal solid waste generation is among the most significant sources which threaten the global environmental health. As an ideal selection depends on considering several independent factors concerning land use, socio economy and hydrogeology, the use of a multi criteria evaluation method seems inevitable. Taking benefit of geographic information system as a tool in combination with geographical information technology, equips the spatial decision support systems in appropriate site selection of sanitary landfills. The present study involves a kind of multi criteria evaluation method under the name of weighted linear combination by using geographical information technology as a practical instrument to evaluate the suitability of the vicinity of Giroft city in Kerman province of Iran for landfill. Water permeability, slope, distance from rivers, depth of underground watertable, distance from residential areas, distance from generation centers, general environmental criterion and distance from roads are the criteria which have been taken in to consideration in the process of analyzing. Superposing all of the raster type layers including geomorphologic, hydrologic, humanistic and land use criteria in land suitability, the final zoning of appropriate, fairly appropriate and inappropriate districts have been identified. Considering relative priority of all criteria in comparison with others, a specific weight is designated to each criterion according to their total influence on the whole process of decision making. The results from the application of the presented methodology are zones for landfill with varying zonal land suitability. Finally the zones will be ranked in descending order to indicate the priority of different options in front of the eyes of decision makers. The results achieved by this study may help policy makers of Giroft city by a variety of options for being considered as sanitary landfill locations.

Keywords: Analytical hierarchy process, geographical information technology, landfill, site selection

INTRODUCTION

As an outstanding sample of being contaminated with different kinds of anthropogenic manipulations, environment is successively encountered with ever increasing rate of manmade waste generation. Municipal solid waste generation is among the most significant sources that threaten the global environmental health. Accordingly, it is essential that integrated systems of waste management be considered within the path towards achieving sustainable development. Such systems generally emphasize on functional elements of waste minimization (reduction), reuse, recycle and finally placing the remained material in landfills (Leao *et al.*, 2004). As sanitary landfilling is an inevitable part of MSW (municipal solid waste) management system (Tchobanoglous *et al.*, 1993), appropriate site selection of landfills may play a key role in reducing the environment contamination. Landfill has become more difficult to implement, residents opposition and environmental contamination. Land is among invaluable and finite resources that must be used shrewdly. As an ideal selection depends on considering several independent factors

*Corresponding author-Email: *tnasrabadi@gmail.com*
Tel: +98 21 6111 3156, Fax: +98 21 6640 4647

concerning land use, socio economy, hydrogeology, etc. the use of a multi criteria evaluation (MCE) method seems inevitable. Taking benefit of Geographic Information System (GIS) as a tool in combination with geographical information technology (GIT) equips the spatial decision support systems (SDSS) in appropriate site selection of sanitary landfills. GIS supplied with information gained by fuzzy logic, simple additive weighting (SAW) and analytic hierarchy process (AHP) has been used in landfill site selection all around the world. (Hussey *et al.*,1996; Kao and Lin, 1996; Siddiqui *et al.*, 1996; Kao *et al.*, 1997;Charnpratheep *et al.*, 1997). The present study involves a kind of MCE method under the name of weighted linear combination (WLC) by using GIS as a practical instrument to evaluate the suitability of the vicinity of Giroft city in Kerman province of Iran for landfill.

Area of study

The study area locates approximately at 57º 44' east longitude and 28º 40' north latitude in central Iran. Fig. 1 shows the considered location in proportion with Iran and Kerman province. The main land cover types of the mentioned area are pastures, fallow lands, agriculture, water and residential areas. Economic growth in recent years has led to a remarkable increase in population and consequently in solid waste generation. Accordingly, appropriate site selection for regional solid waste land filling is a major need within the path towards sustainable development.

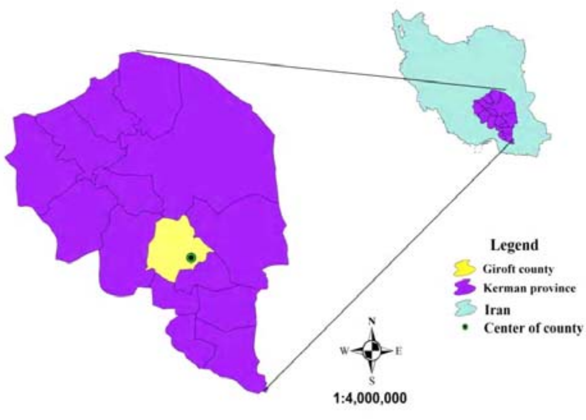

Fig. 1: Specification of Giroft location in Iran

MATERIALS AND METHODS

First step in the methodology consists of development of a digital GIS database in which spatial information is formed. Because of different scales upon which criteria are measured, it is necessary that factors be standardized before combination. Criteria used in this study are of two kinds; those whose increase wil result in prosperity augmentation and those whose increase will terminate in prosperity drop. In this research, a linear scaling method is applied using the minimum and maximum values as scaling points for standardization. Equations 1 and 2 are considered for two kinds of mentioned criteria respectively.

$$Yij = (Xij-Xj\ min)/(Xj\ max- Xj\ min) \quad (1)$$

$$Yij = (Xj\ max - Xij)/(Xj\ max- Xj\ min) \quad (2)$$

Where:

Yij = Standardized value for ith criterion and jth option

Xij = Raw score for ith criterion and jth option

Xj min = Minimum score for ith criterion and jth option

Xj max = Maximum score for ith criterion and jth option

Considered criteria classify the areas in to two classes: unsuitable(value 0) or suitable (1). With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map (Equation 3).

$$S = Wi\ Xi \quad (3)$$

Where:

S= suitability

Wi= weight of factor i

Xi= criterion score of factor i.

In the context of criterion weights, a wide variety of techniques exist for the development of weights. The technique used here and implemented in Idrisi software (Eastman, 2001) is that of pair wise comparisons developed by Saaty (1977) in the context of a decision making process known as the AHP. In the procedure of multi criteria evaluation using a weighted linear combination it is necessary that the weights sum to one. In Saaty’s technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pair wise comparisons between the criteria. The comparisons concern the relative importance of the two criteria involved in determining suitability for the stated objective. Ratings are provided on a 9-point continuous scale which is illustrated in Table 1. The procedure then requires that the principal eigenvector of the pair wise comparison matrix be computed to produce a best fit set of weights. These weights will sum to one as is required by the weighted linear combination procedure. Since the complete pair wise comparison matrix contains multiple paths by which the relative importance of criteria can be assessed, it is also possible to determine the degree of consistency that has been used in developing the ratings. Saaty indicates the procedure by which an index of consistency, known as a consistency ratio. The consistency ratio (CR) indicates the probability that the matrix ratings were randomly generated. Saaty indicates that matrices with CR ratings greater than 0.1 should be re evaluated (Mahini and Gholamalifard, 2006).

Table 1: Relationship between priorities and numbers in AHP Rating procedure

Number*	Priority
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred

* Even numbers indicate between category priorities

The results from the application of the presented methodology are zones for landfill with varying zonal land suitability. Finally the zones will be ranked in descending order to indicate the priority of different options in front of the eyes of decision makers. The major and minor sub criteria used in the present study are shown in Table 2.

Table 2: Major and minor criteria used in landfill site selection process

Major Criteria	Minor criteria
Geomorphologic	Water permeability Slope
Hydrologic	Distance from rivers Depth of underground watertable
Humanistic	Distance from residential areas Distance from generation centers
Land use	General environmental criterion Distance from roads

RESULTS

Geomorphologic criteria

Water permeability

According to the characteristics of geological texture of the region, this criterion categorizes the whole area in to three distinct classifications; soils having high rate of permeability (district cambisols, haplic and gleyic solonchalks, cambic podzols with karst formations,…) are considered unsuitable for being used as a landfill while soils with medium and relatively low rate of permeability (mollic gleysols, calcaric and eutric cambisols,…) and very low permeability (clayey soils, shale, calcaric fluvisols,…) are considered fairly suitable and optimal to site a landfill respectively. These three distinct zones are designated in Fig. 2.

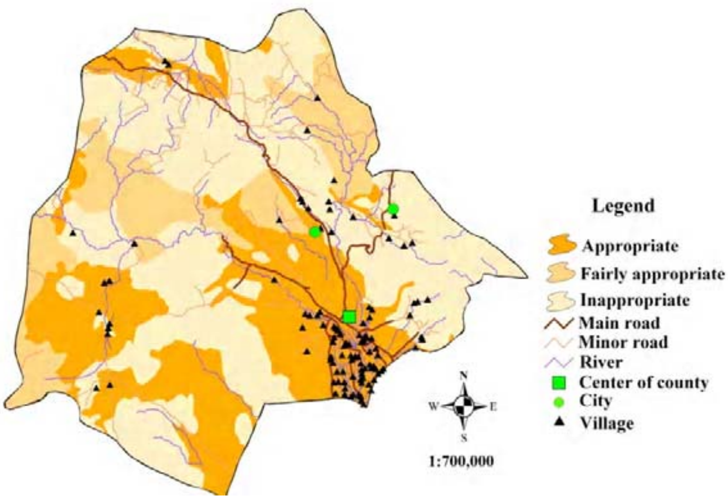

Fig. 2: Classification of water permeability

Slope

The topographical features of the study area are shown in Fig. 3. The slope layer is derived from DEM layer in GIS environment. Considering slope percent, five different classes are defined. The higher the value of the slope reaches, the lower the suitability of the land for landfilling drops.

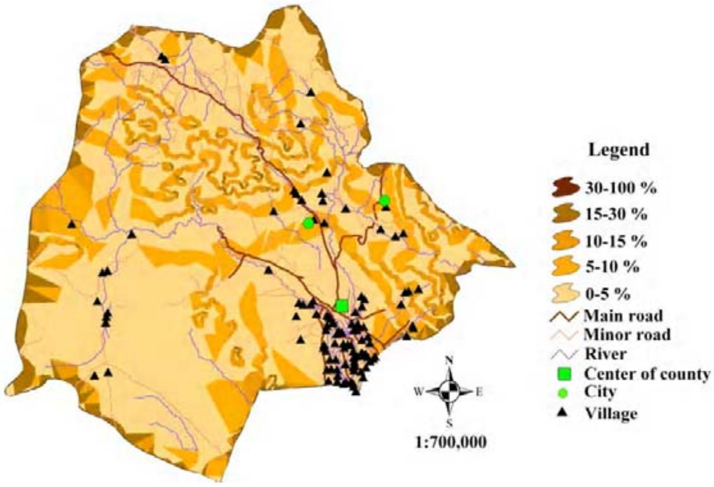

Fig.3: Classification of land slope

Hydrologic criteria

Distance from rivers

This criterion has a direct effect with land suitability for being used as landfill. In other words farther lands from streams and river banks will get more preferences for being selected. Accordingly, three different zones were specified considering relative distance from rivers. Zoning process is schematically shown in Fig. 4.

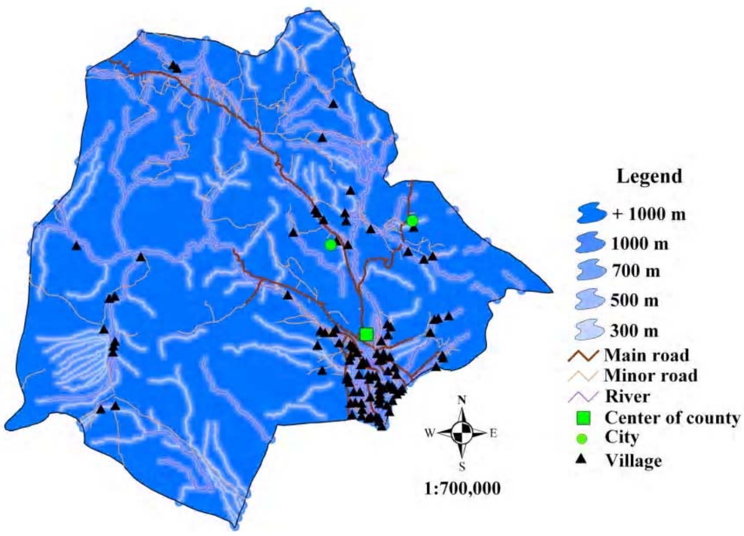

Fig. 4: Classification of distance from rivers

Depth of underground watertable

Considering underground water contamination, depth of watertable must be taken in to consideration as a highly effective factor. This criterion categorizes the whole area in to three zones; zones with deep enough watertable depth will be considered optimal while zones with relatively deep and shallow watertable are introduced as fairly suitable and unsuitable respectively (Fig. 5).

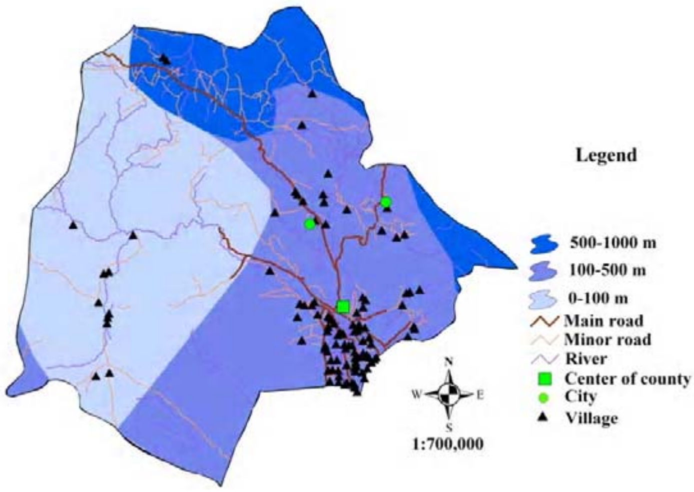

Fig. 5: Classification of underground water depth

Humanistic criteria

Distance from residential areas

Developed studies on different aspects of residents reaction in confrontation with landfilling show that public opposition decays exponentially while distance increases (Lober and Green, 1994; Lober, 1995). Furthermore, future residential and industrial growth must also be considered in allocating the place of landfill. Accordingly, separate zones are ranked with increasing priority directly related to distance from residential areas and illustrated in Fig. 6.

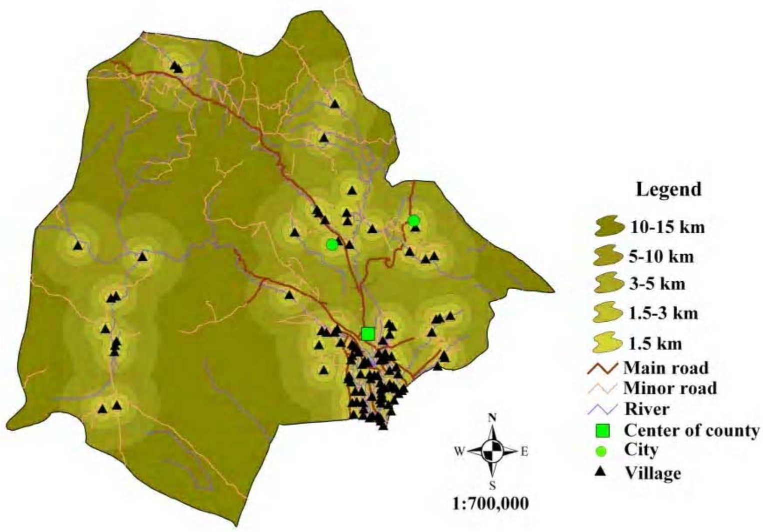

Fig. 6: Classification of distance from residential areas

Distance from generation centers

Considering all economic aspects specifically waste transport it is essential that the landfill be located in a place which has the minimum distance to waste generation centers. This criterion may seems to be in conflict with the one which deals with far distances between landfill site and residential areas. Here the role of weighted linear combination (WLC) in considering simultaneous conflicting criteria is more highlighted. According to the suitability achieved by this factor, five distinct zones have been considered (Fig. 7), which shows the distance has an indirect relationship with the land suitability for being selected as landfill.

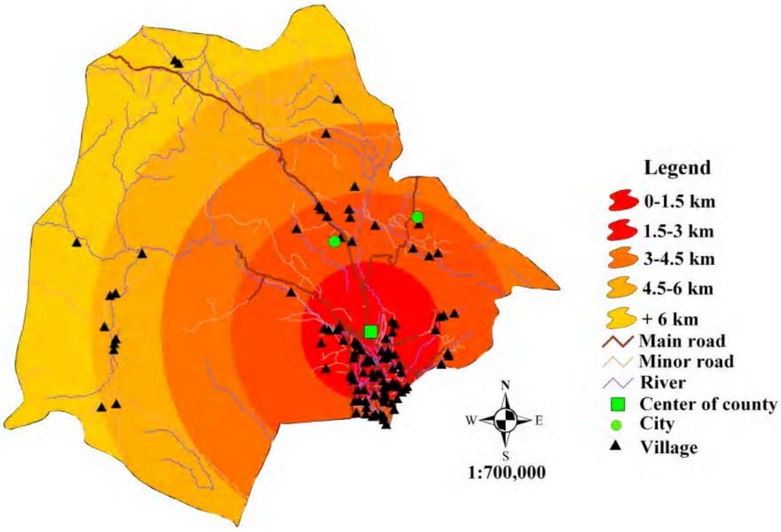

Fig. 7: Classification of distance from waste generation center

Land use criteria

General environmental criterion

This criterion concerns with natural features that may be exposed by the threats imposed because of landfill adjacency. Parameters like water, agricultural potential, pastures, fallow lands and built up areas have been taken in to consideration and consequently three designated zones are introduced indicating appropriate, fairly appropriate and inappropriate lands (Fig. 8).

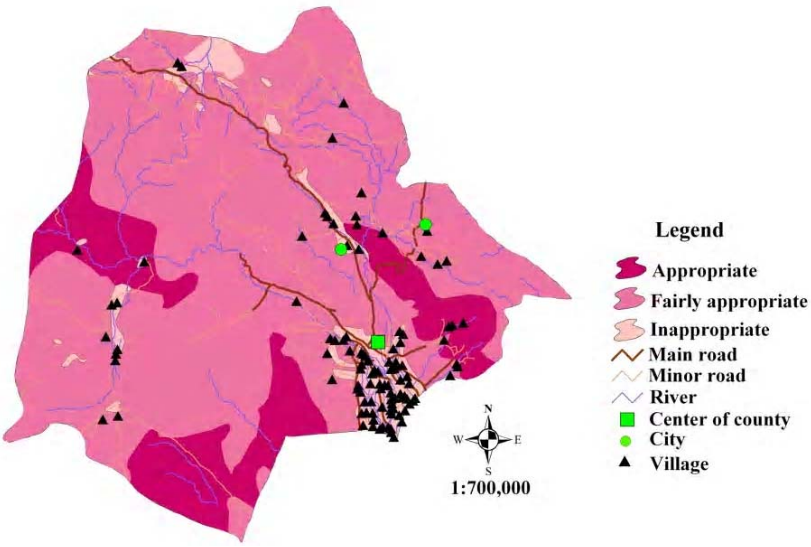

Fig. 8: Classification of general environmental impact

Distance from roads

Landfill location must be close to roads network in order to facilitate transportation and consequently to reduce relative costs. However, aesthetically and logically a buffer of 100 meter has been considered in this study. In other words, direct relationship between distance from roads and land suitability is started from the 100 meter distance of roads centerline. Accordingly, three zones with different levels of suitability are determined and considered in further analysis (Fig. 9).

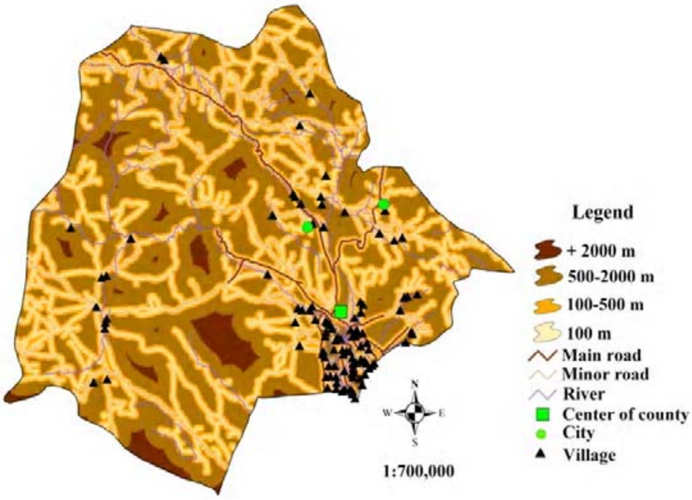

Fig. 9: Classification of distance from roads

DISCUSSION

Superposing all of the raster type layers including geomorphologic, hydrologic, humanistic and land use criteria in land suitability, the final zoning of appropriate, fairly appropriate and inappropriate districts have been identified (Fig. 10). Considering relative priority of all criteria in comparison with others, a specific weight is designated to each criterion according to their total influence on the whole process of decision making. The relative weight designation of different criteria in interaction with each others is shown in Table 3.

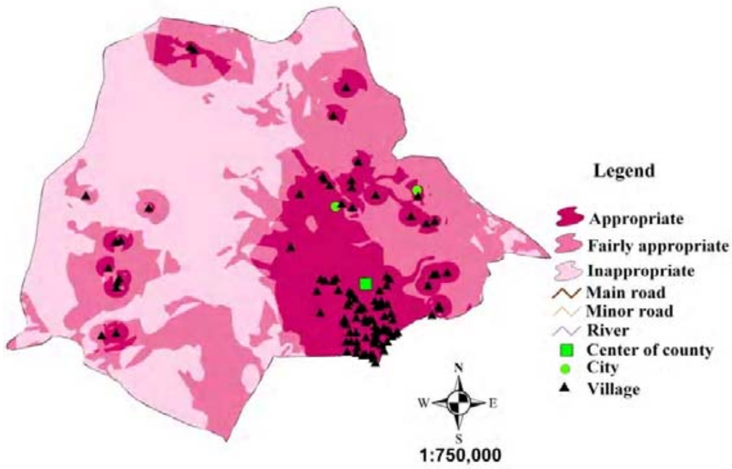

Fig. 10: Priority zoning of landfill location

Table 3: Pair wise comparisons and relative weights of major criteria

	Geomorphologic	Hydrologic	Humanistic	Land use	Weight
Geomorphologic	1	1.2	1.3	4	0.184
Hydrologic	2	1	1	5	0.353
Humanistic	3	1	1	5	0.399
Land use	1.4	1.5	1.5	1	0.064

Consistency ratio = .03, Consistency is acceptable

According to the final weight of each criterion in combination with different selected zones, sites are finally categorized in a final weight decreasing order, among which the first seven zones are shown in Fig. 11. A similar study has been done in Gorgan city by Mahini and Gholamalifard. In that study the Boolean approach is considered in WLC process and results are shown in a ranked table indicating appropriate sites for land filling in a way similar to that exposed here (Mahini and Gholamalifard, 2006). In another study in Regina, Canada, parameters like public, agriculture, hydrogeology, transport, land use, heritage, cost, political and wildlife are considered and the best potential landfill sites are ranked according to their total gained weight (Cheng *et al*., 2003).

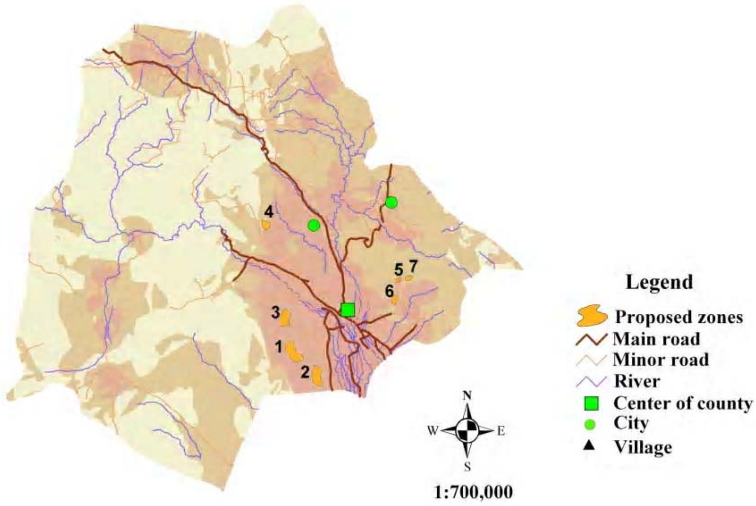

Fig. 11: Selected zones for landfill location ranked in a descending order

The results achieved by this study afford policy makers of Giroft city by a variety of options for being considered as sanitary landfill locations. It must be noted that a more complete study on current and future land uses and the price of the land as well as population growth and waste generation rate is recommended for future studies.

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