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Implementation of Overlap Index Model for Locating the Optimum Areas for Establishing the Landfill Areas using GIS- Case Study of Semnan City

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ABSTRACT

A Geographic Information System (GIS) is a computer system for managing the spatial (position) data. The main factor which distinguishes this system from other saving and recovering systems is its attitude towards the geographical positions. Having this characteristic, GIS as a novel technology has turned into a dynamic industry in analyzing qualitative and quantitative data and plotting geographical images. The final goal in most of the Geographic Information System projects is combining the different data from different sources in order to describe, analyze the phenomenon, and create new maps which can be used in decision makings. Preparation of maps with prioritization for selecting the appropriate place for constructing a structure or carrying out projects such as power plants, dams, landfills, pipeline, power transmission, urban development and evaluation of potential minerals are examples of cases which show the need to combine different informative layers in order to have a final map. Modeling in GIS is done in different forms. The models which are used for selecting the place for carrying out the projects or establishing the structure, are usually of the prescribed type, i.e. there is a series of specific criteria (such as appropriate engineering conditions) for the considered geographical place which may be a result of engineering, technical, economic or social principles and are used for achieving the desired goal. Finally, by using the integrated models, the desired specifications and criteria in the area are generalizes and the desired map is obtained.Proper and Scientific selection of the landfill is very important from the environmental, economic, and logistic aspects. The goal of the current research is to locate the best place for landfill in the Semnan city. In the current study, the appropriate location for a landfill area near the vicinity of Semnan city was determined using GIS and MCDA (Multi-criteria decision analysis). In order to do this, eight layers of given maps consisting of topography, residential, roads, faults, streams, slopes, geology and groundwater were prepared and two different methods of combination MCDA and GIS were used. Desert investigations lead to interesting results which were the good accordance of the candidate locations to the selected criteria. Another interesting result was that it became necessary to consider a number of additional parameters in the model which could not be predicted before desert investigations.
KEYWORDS: Landfill, Locating, GIS, Expert Choice 11, Semnan, Overlap index

1. INTRODUCTION

Waste materials are inherent parts of urban life. The development of urban areas, increase of using materials with non-degradable waste, and other achievements of machine life have made the way of waste disposal one of the main concerns of urban environmental management. Managing these wastes in different qualities and quantities is one of the main environmental problems. Decreasing the waste from the sources, recycling and transforming the wastes are some methods which are widely used in waste materials management. The efficient management of solid wastes starts from the proper management of urban solid wastes. Therefore in order to achieve successful management of urban solid wastes, the best selection and evaluation is necessary for management methods.

Evaluation of management methods of urban solid wastes usually requires a qualitative and objectivity judgment. Specially, choosing the management methods of urban solid wastes is a strategic subject which is limited by the source needs, real support, time requirements, accordance to expected results, etc. Decision making based on Multi-criteria decision analysis is used for overcoming the problems which need decision making over a huge volume of complicated information. This method is based on the principle that the problem can be divided into smaller understandable parts, then each part is analyzed separately and at the end the parts are combined using a modification reasonable method (Malczewski, 1997). The main goal of this study is developing a methodology using GIS and MCDA and then applying this methodology to Semnancity which is located at the northern west side of Mashhad.

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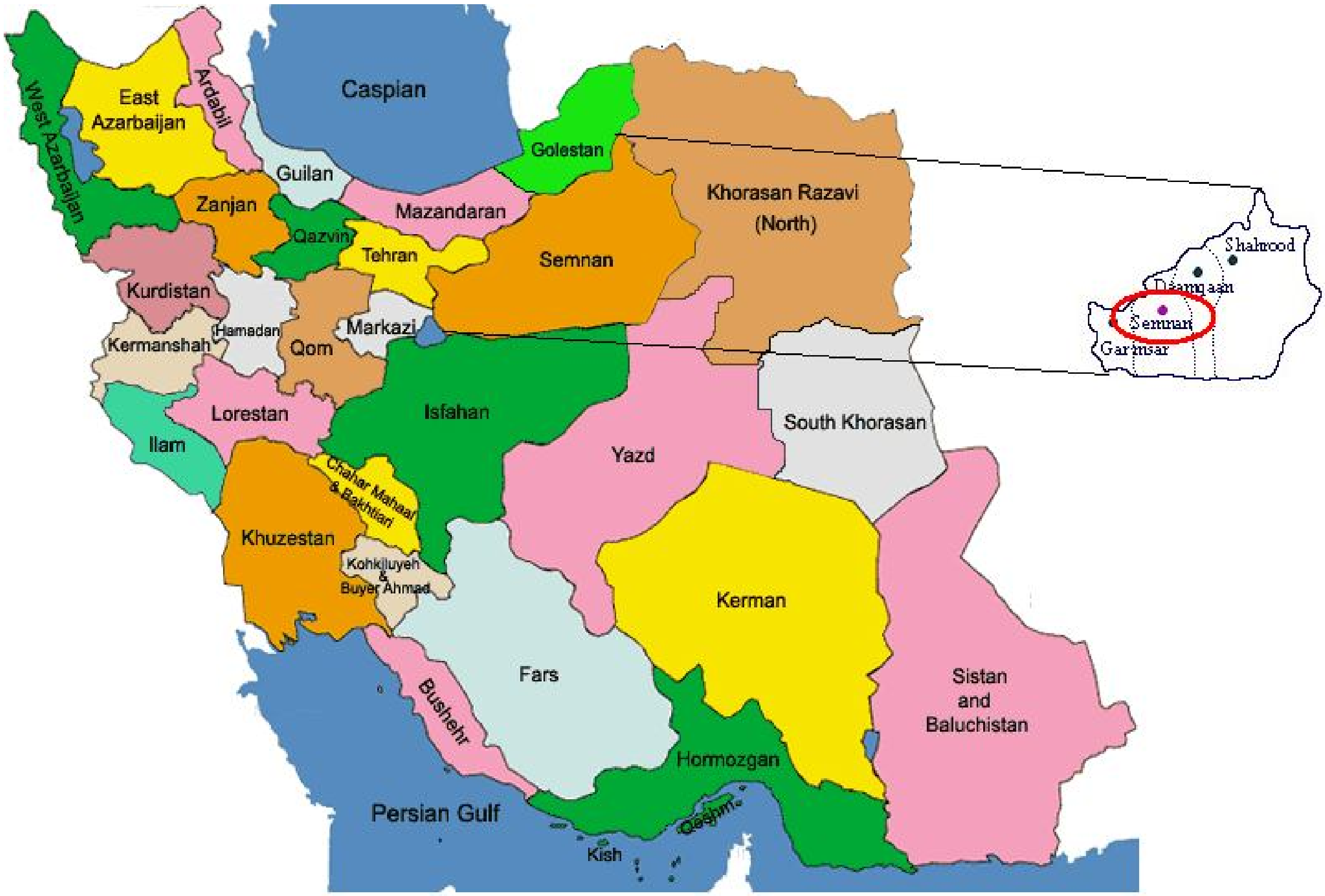
Semnan is a city having a population over 103346 and an area about 8.44 km^2. From the geological view, most parts of the studied area consist of Mozduran, Shurijeh and Quaternary sediments formations. The amount of waste production is different at different seasons in such a way the highest amount of waste production is at the spring and summer seasons. The amount of waste produced is 10 ton per day and 700 gram per capita per day. It must be stated that the population growth of this city is 0.6 %.



2. General information
2-1 The studied area

Fig. 1 The situation of the studied area

The studied area in the Semnan province has the coordinates 58º 30′ East longitude and 37º 17’ North latitude. The total area of the zone is about 3810 km^2 (Fig. 1) which consists of 1300 km^2 of plain areas and the remaining parts of it are elevations. The most elevated point of the domain is 3032 m above sea level, and the lowest point which is located at the Semnan plain output is about 1000 m above sea level. The Semnan city is located at a region with semi-humid and mountainous cold climate and therefore possesses relatively large surface and ground water resources. The average rainfall of this city is 276 mm based on the 10-years statistics. The map extent is the middle part of PahneKapeDagh. These stone units with a life time from Jurassic age till now outcrop in the zone. In the studied area, there are sedimentary, igneous and volcanic rocks which consist of sandstone, marl, tuff, limestone, basalt and andesite.

3 METHOD

3-1 METHODOLOGY

In order to achieve the goal of locating the landfill area of urban wastes disposal of Semnan city, the informative layers such as geological maps, land use, area slope, topography, rural locations, urban space, surface water, roads, and faults were gathered and then prepared in the GIS 9.3 and then weighted in the software Expert Choice 11.

The GIS system is an accurate, quick and user-friendly software which can handle many layers and has a high ability in combining and composition of different informative layers. These characteristics make it a proper tool. Geographic Information System (GIS) is a computer system for managing the spatial (position) data.

Analytic hierarchy process (AHP) is a flexible, strong and simple method which is used for making decisions in conditions that decision criteria make it hard to select between the choices. AHP is one of the most developed tools for multi-criteria decision making (Omkarprasad, 2004). This software is able to convert the very complex problems into simpler problems (Erkut and Moran, 1991). In the studied area it was attempted to use a tree diagram for simplifying locating of the landfill place (Fig. 2). At the first level, a Hierarchical matrix is created which has the capability of couple-couple comparison (Guiqin, 2009). The AHP method is executable in the software Expert Choice 11. In the Expert Choice 11 software, first the criteria and sub-criteria are specified and then weighting is done using pairwise comparison method. The error must be lower than 0.1 in weighting (Tzeng, 2002).

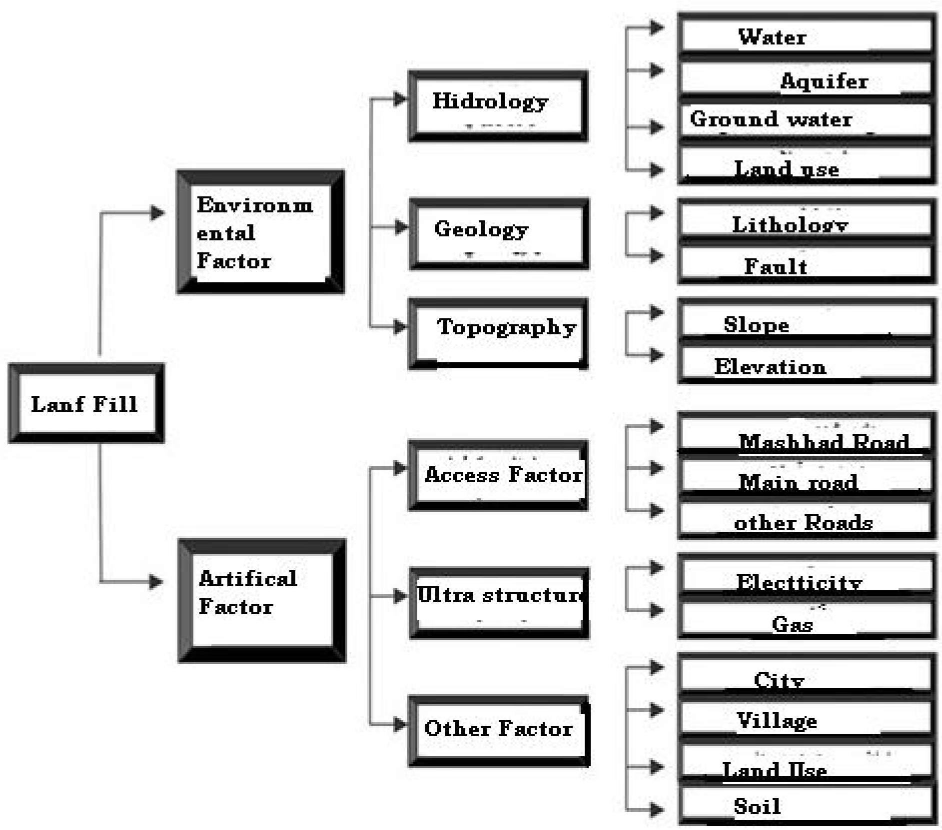


Fig. 2 The tree diagram for simplifying the locating of landfill location in the studied zone

3-2 Ranking and layer composition

The desired criteria in locating the waste disposal for the studied zone are listed in Table 1 according to the regulations, standards and the zone geographical conditions. A summary of the layers, base maps, buffer zones, and ranking used in this study are given in Table 1.

First each of the informative layers are given scores and then the obtained weight is added to the layers in the software Expert Choice 11. This weighting is based on the scores. The scores are in the range of 1-9 in such a way that 1 is the lowest and 9 is the highest score. After weighting the layers, it is necessary to obtain a total weight for the layers which can be done in the software Expert Choice 11. The informative layers which have been rastered previously are overlapped based on the obtained total weight, and therefore the final landfill map can be achieved.

after entering all the layers, the two methods of AHP and SAW were chosen for analyzing the data for selecting the landfill zone using GIS. The output maps which were obtained by the two methods including the layers weight multiplication and also the limitations are shown in Fig. 3.Desert investigations lead to interesting results which were the good accordance of the candidate locations to the selected criteria. Another interesting result was that it became necessary to consider a number of additional parameters in the model which could not be predicted before desert investigations.

Table 1 The considered rules and regulations

	Name of criterion	Regulation and the way it affects
1	Downtowns	The minimum distance is 1000 m
2	Road	The minimum distance is 1000 m
3	Surface water resources	The minimum distance of 300 m from the main rivers and 200 m from the rills
4	Geology	It must have bed rocks and the rocks should be impermeable if possible
5	Land use	It should not have valuable uses such as agriculture, forest, wetland and grassland as much as possible
6	Fault	The minimum distance is 500 m
7	Slope	The slope must be lower than 10 degrees
8	Village	The minimum distance is 500 m

Table 2: A summary of the layers, base maps, buffer zones and rankings used in this study

NAME OF LAYER	BASE MAP	BUFFER ZONE	RANKING		AREA (%)
			LOCAL	GLOBAL	
Used Lands	Land use map	Pasture with vegetation cover of 5-25 %	9	6	15
		Pasture with vegetation cover of 25-50 %	7		10
		Tope	5		3
		Irrigated and rainfed arable lands	3		67
		Town and industrial town	1		5
Geology Units	Geology Organization and Mineral Exploration	Basaltic, andesitic, and tuff rocks	9	7	15
		Neogene sediments and Shurijeh and Sarcheshmeh formations	7		5
		Sandstone and marl	5		2
		Tirgan formation with limestone interlayers	3		67
		Quaternary sediments	1		11
Slope	Topography map	0-10	9	10	10
		10-20	7		6
		20-40	5		8
		40-60	3		12
		60-100	1		64
Road	Topography map	1000	1	3	
		2000	5		
		>2000	9		
Elevation	Topography map	<1600	9	5	8
		1600-1900	7		20
		1900-2300	3		32
		>2300	1		40
Surface waters	Topography map	>1000	9	4	
		500-1000	5		
		<500	1		
Distance from city	Topography map	0-3000	1	6	15
		3000-7000	9		30
		7000-15000	5		55
Distance from fault	Topography map	>3000	9	5	

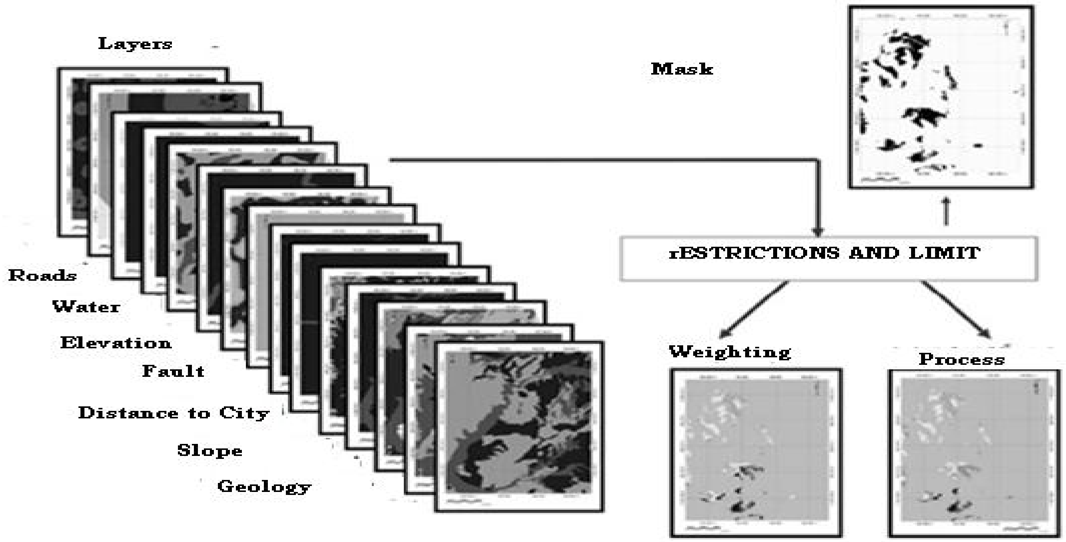


Fig. 3 Layers weight multiplication and the limitations in data analysis for selecting the landfill location in the studied region

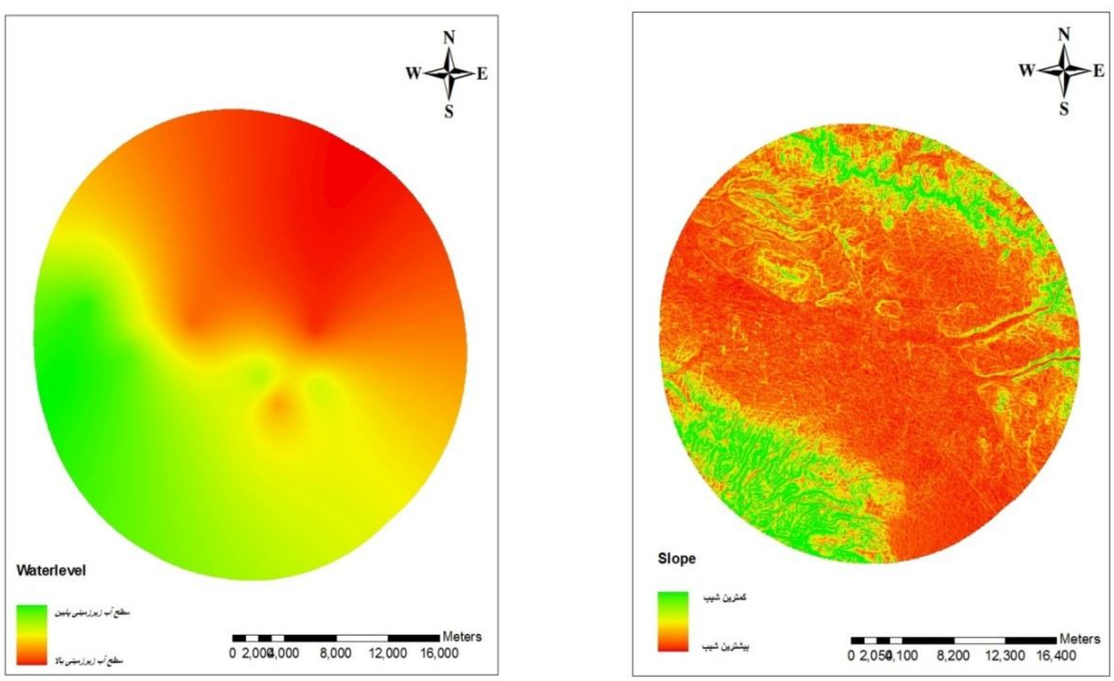
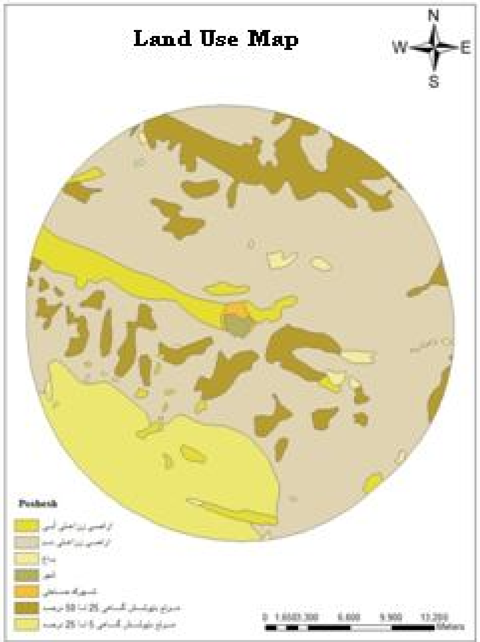


Fig 4. (a) Slope maps, (b) underground waters (c) lands use (d) geology



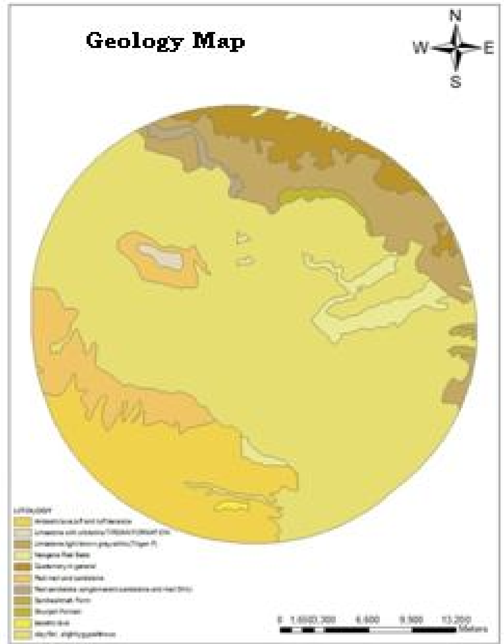
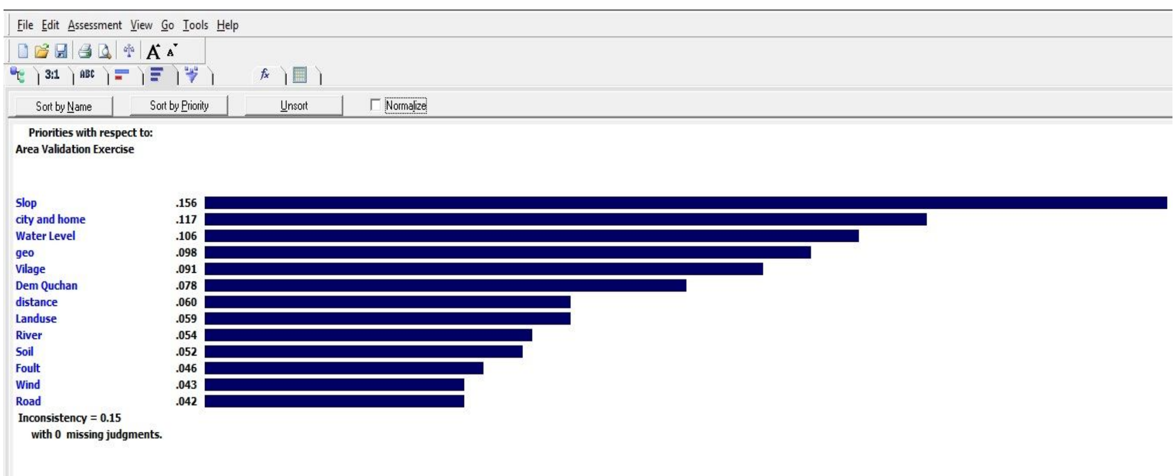


Fig. 5 The final weight of the layers



Compare the relative importance with respect to: Area Validation Exercise

	Wind (L: 1.	Landuse	geo	Road	Soil	distance	City and Vi	Water Lev	City Clip	Slop	Foult	River	Dem Qucha
Wind (L: 1.128)		3.0	5.0	3.0	3.0	5.0	3.0	5.0	3.0	5.0	5.0	5.0	3.0
Landuse			2.0	1.0	1.0	2.0	1.0	2.0	7.0	2.0	2.0	2.0	7.0
geo				2.0	2.0	1.0	2.0	1.0	7.0	1.0	1.0	1.0	7.0
Road					1.0	2.0	1.0	2.0	5.0	2.0	2.0	2.0	5.0
Soil						2.0	1.0	2.0	5.0	2.0	2.0	2.0	5.0
distance							2.0	1.0	7.0	1.0	1.0	1.0	7.0
City and Vilage								2.0	5.0	2.0	2.0	2.0	5.0
Water Level									7.0	1.0	1.0	1.0	7.0
City Clip										7.0	7.0	7.0	1.0
Slop											1.0	1.0	7.0
Foult												1.0	7.0
River													7.0
Dem Quchan	Incon: 0.01												

Fig. 6 Layers matrixing

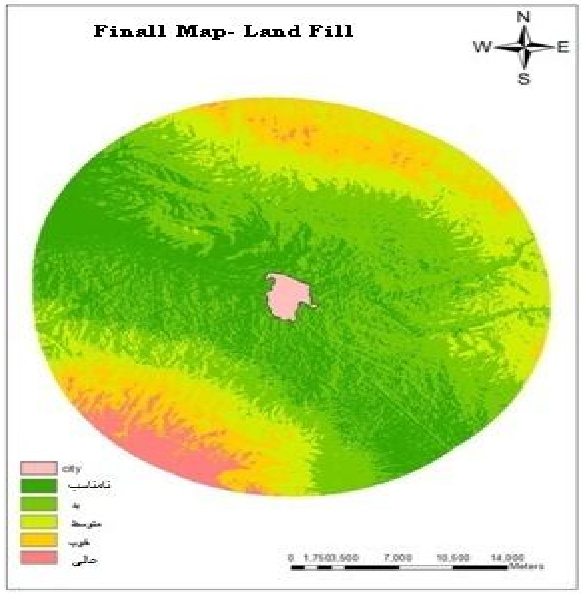


Fig. 7 Zoning of the landfill

4 .Conclusions

This study showed that combining GIS, SAW, and MCDA is a strong tool for the problem of selecting the landfill location. It is due to the fact that GIS provides the use and data presentation efficiently, while MCDA provides the consistent ranking of the potential areas suitable for landfill based on a number of criteria. It also makes it possible to determine the best possible choice in the studied zone according to the importance of each of the parameters in the layers weighting.

In the final zoning map of landfill, the locations were separated from the best to the worst locations and the very proper locations were selected according to the distance to city, slope, elevation, surface water resources, and the direction of the surface and underground waters. In the locating procedure, five locations were specified when two of them were appropriate and very appropriate which are located at the southern west and north sides. In these zones, the level of underground water is low and the lithology of the region is of the Andesite type.

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