Journal of Research in Ecology

An International Scientific Research Journal

ISSN No: Print: 2319 –1546; Online: 2319– 1554

Short Communication

Land Suitability Analysis (LSA) based on fuzzy logic for prioritization of candidate sites for waste management

Authors:
Azizi Z[1] and
Salehi Y[2]

Institution:
1. Assistant Professor, Department of GIS-RS, Faculty of Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran.

2. MSc in Remote sensing and GIS, Science and Research Branch, Islamic Azad University, Tehran, Iran.

Corresponding author:
Azizi Z

ABSTRACT:

Waste management is a difficult and complex process since it requires considering a huge number of different criteria and regulations. Site selection for waste management is the most important stage in this procedure. Four important steps in Land Suitability Analysis (LSA) are identification and determination of weighting criteria, mapping and overlapping standardized layers. In this study, we used different GIS datasets including topography, geology, hydrology, climate, environment and fuzzification was applied using triangulation rule. Then, layers were combined using average weighting method and defuzzification was applied for the final fuzzy map of suitability. Our results showed that environmental consideration is the most weighted parameter. However, hydrological networks can play a significant role in determining a suitable location. Based on the final map, different locations were ranked based on the suitability for waste disposal. Our results should that using fuzzy logic in GIS environment not only can help to compile the spatial data in a manner that manager can face the uncertainties, it also promotes the possibility of sanitary waste disposal.

Keywords:

Landfill, Site Selection, GIS , Fuzzy, Ghorveh

Email ID:

zazizi@srbiau.ac.ir

Article Citation:
Azizi Z and Salehi Y
Land Suitability Analysis (LSA) based on fuzzy logic for prioritization of candidate sites for waste management
Journal of Research in Ecology (2017) 5(2): 838-848

Dates:
Received: 08 June 2017 **Accepted:** 20 July 2017 **Published:** 04 Aug 2017

Web Address:
http://ecologyresearch.info/documents/EC0445.pdf

Journal of Research in Ecology

INTRODUCTION

Solid-waste management consist of different steps including collection, transportation, processing, recycling and land filling. Among these steps, finding a site for suitable landfill is the most crucial one, because dumping wastes in unsuitable sites are a serious environment threat (Kumar and Hassan, 2013). There are various solid waste management methods such as landfilling, thermal treatment, biological treatment, and recycling (Kontos *et al*., 2005). Sanitary landfill is the most common method of solid waste management worldwide (Yesilnacar and Cetin, 2005). Likewise, of the various techniques of solid waste management, landfilling is the most popular and widely prevalent technique that used in Iran. Selecting the appropriate site for waste disposal is a very complex and difficult task that depends on a large number of different parameters and regulations. Since solid waste disposal sites are significant sources of soil, water and air contamination (Sener *et al*., 2010), they have been the focus of special attention. Undoubtedly, many cites in the world have unsuitable waste disposal system and Ghorveh is one of them.

The amount of solid waste generated in Ghorveh is 84 tons a day (Babajani and Samadian, 2014). The current location for the disposal waste is located in an unsuitable site where the level of ground water is high and the soil type is alluvial. Most of studies on site selection of disposal are based on GIS and Analytic Hierarchy Process (AHP) (Djokanovic *et al*., 2016; Kumar and Hassan, 2013; Sener *et al*., 2010). To manipulate, analyze a huge of data an appropriate technique is required. In this study, landfill site selection performed using GIS, remote sensing and fuzzy method for creation different parameters including topography, geology, hydrology, climate, environment and so on was used. Then, the generated layers reclassified and weighted and finally the final map using fuzzy method was created. At the end the final map was divided to five groups including very high, high, moderate, low and very low suitability areas. The results showed that the fuzzy method in the combination of GIS and remote sensing is an effective technique for site selection on the site of disposal of waste.

MATERIAL AND METHODS

For doing landfill site selection, data from both primary and secondary sources have been used that including:

- Freely available satellite image of Landsat 8 (OLI) of 23rd June 2016 was used for creating land use and vegetation cover (USGS, 2017).
- Digital Elevation Model (DEM) of SRTM obtained from USGS (United States Geological Survey) for mapping slope, aspect and drainage network (USGS, 2017).
- Geological map of the study area was used to creating the geologic units and faults (UWGB, 2012).
- Google earth data were used to drawing roads, power lines, extent of city, location of villages and wells (USGS, 2017).

For doing this, all the data was digitized and converted to raster format in Arc GIS 10.2.2 for analysis. All the data was reclassified and weighted. Then, the linear function was applied to weighted layers based on defined criteria. Finally, fuzzy model was applied for finding out the suitable location for the landfill

The study area

The extent of study with area about 2868 km^2 is located on the east south province of Kurdistan in longitude 47° 25' to 48° 11' east and longitude 34° 55' to 35° 34' north and shares its boundary with Bijar in north, Kermanshah in south, Hamedan in east and Sanandaj in west. Based of census report population of Ghorveh in November 2011 is 136961 people and including 38201 families (Babajani and Samadian, 2014). According to the meteorological organization of Iran, the examined area has a semi drought climate. January is the coldest month with the temperature of -20 to -30°C while July,

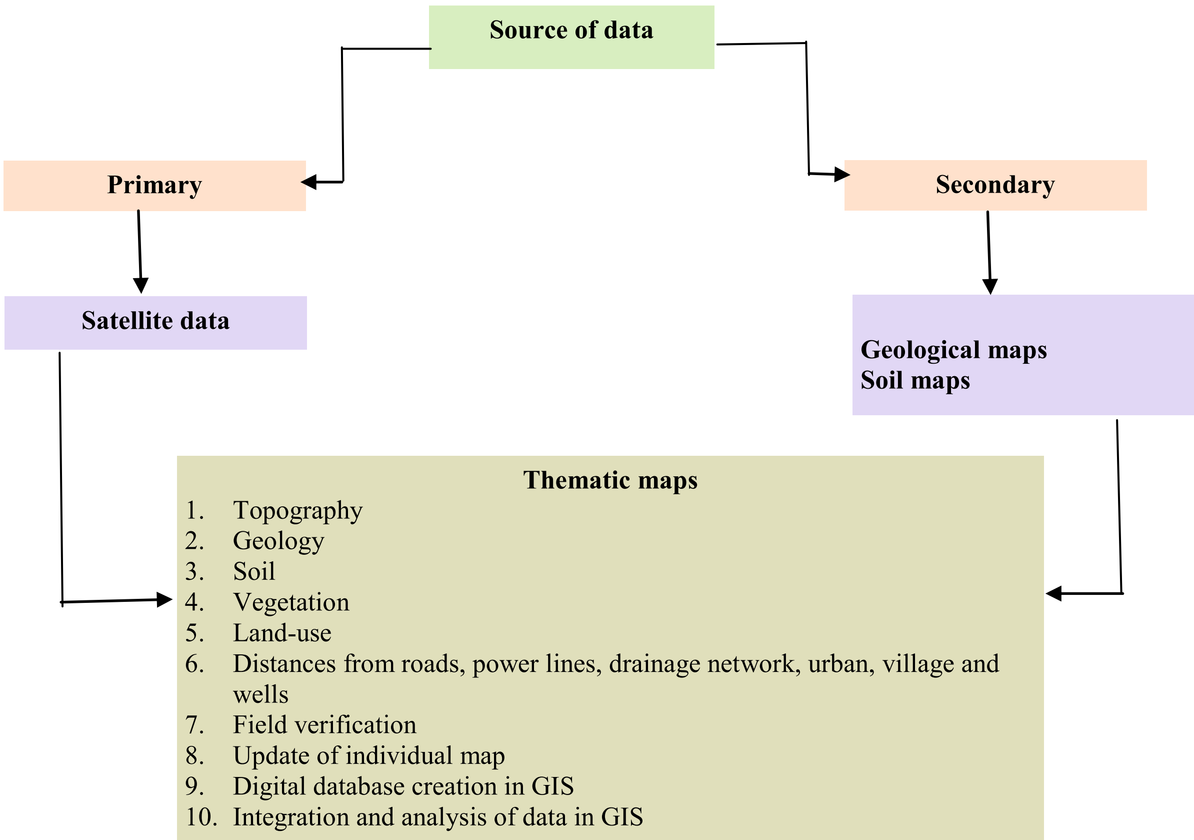

Figure 1. Flowchart of the methodology

is the warmest month with a temperature of 36°C. In this research, Kumar and Hassan (2013) approach were used for preparing the following layers (Figure 1 and 2).

The crated maps

Elevation

Elevation plays a key role in earth surface and atmospheric process and also extraction of many environmental features like slope and aspect (Bahrani *et al*., 2015). The best places for waste disposal are areas with medium altitude. The Digital Elevation Model (DEM) of the study area was created using data downloaded from SRTM. The Dem map was grouped to five classes and weighted in 1-5 groups (USGS, 2017) (Figure 3).

Slope

Slope is a basic parameter for choosing process site of land fill Because areas with high slope lead to leachate flooded and contaminated the lands. The slope map was prepared from Dem using Arc GIS software (Sener *et al.,* 2010) and was grouped to five classes for weighting (Figure 4).

Aspect

Landfill should not be exposed to wind or if this is not possible, it should be placed in the opposite direction to the most frequent wind (Djokanovic *et al*., 2016). For creation wind direction five years' data ranging 2010-2014 prepared and for creation wind direction map, WRPLOT software was used (WRPLOT, 2016) (Figure 5). Five classes were allocated in the study area, according to wind frequency. The most frequent wind is southwesterly and was given the low rating. The low frequent winds are northwesterly and northeasterly and they give the high rating. flat areas are exposed to winds from all sides thus they were given the lowest rating (Figure 6).

Geology

Choosing a site with a good impermeability protects the soil and aquifer against contamination from leachate (El-Maguiri *et al*., 2016). The geological map

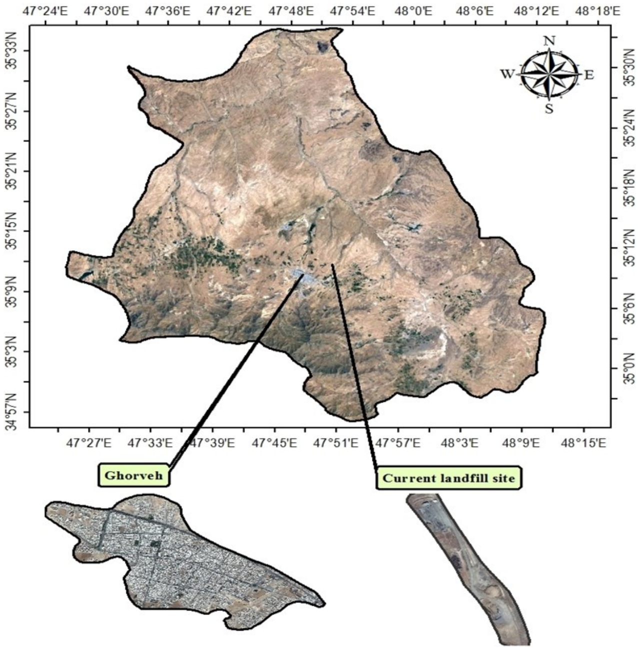

Figure 2. Map showing the study area

created in Arc GIS and was grouped to nine classes from low weight to high weight based on impermeability (Figure 7).

Distance from Faults

Lineaments like fault is one of the most important criterion for site selection. Areas with high fracture leads to leachate easily flooded and pollution the ground waters. For creation the map faults the geologic map 1:100000 was used and distances from faults grouped to five classes (Zaporoze, 2002) (Figure 8).

Distance from Roads

Access to landfill sites is one of the most important factor for landfill site selection

Distance from existing roads is always considered as an important economic factor in landfill site selection Landfills that are much closed to main roads are as an obstacle to economic development, since the site will be repellent of the tourists (Gbanie *et al*., 2013). For creating distance from road map, the Google earth software was used and in Arc GIS it is buffered. then distances were grouped to six classes (Figure 9).

Distance from power lines

Another criterion that must be considered is distance from power lines. Areas are suitable for landfills that are unsuitable distance from power lines to use from them. The Google earth software was used for creation power lines and buffered in arc GIS (Sener *et al.,* 2010). Then based on distance to power line divided to five classes (Figure 10).

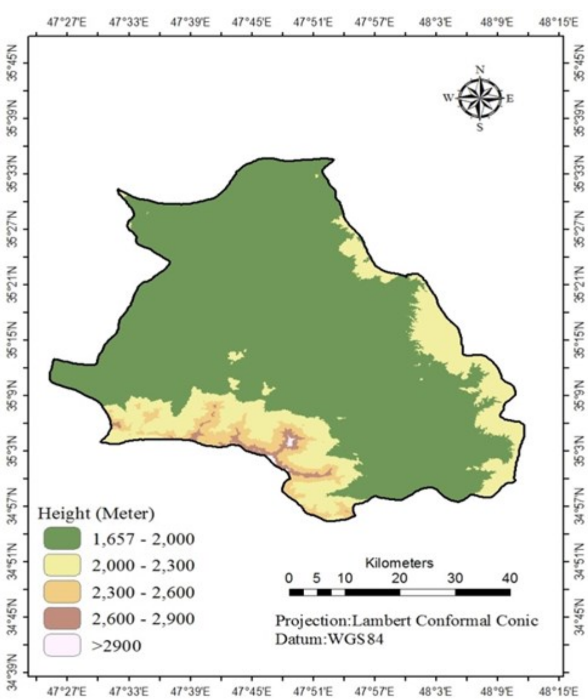

Figure 3. Elevation map

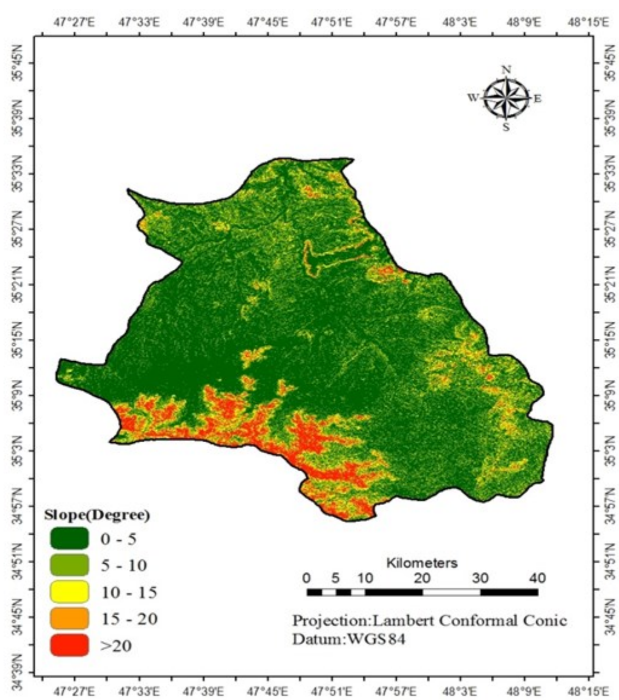

Figure 4. Slope map

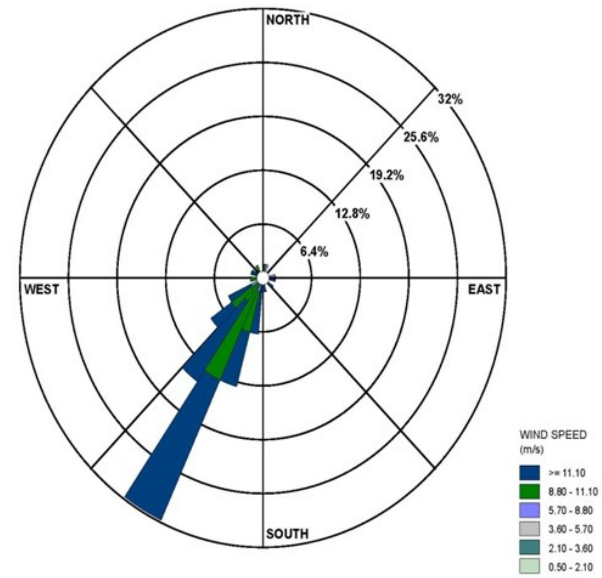

Figure 5. Wind map

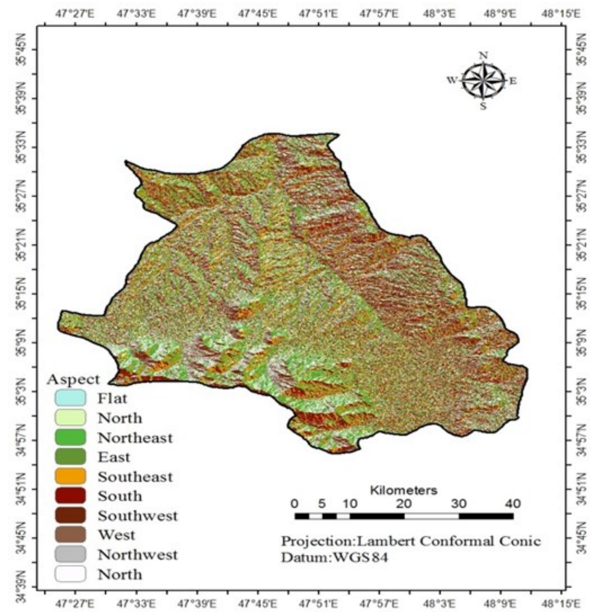

Figure 6. Aspect map

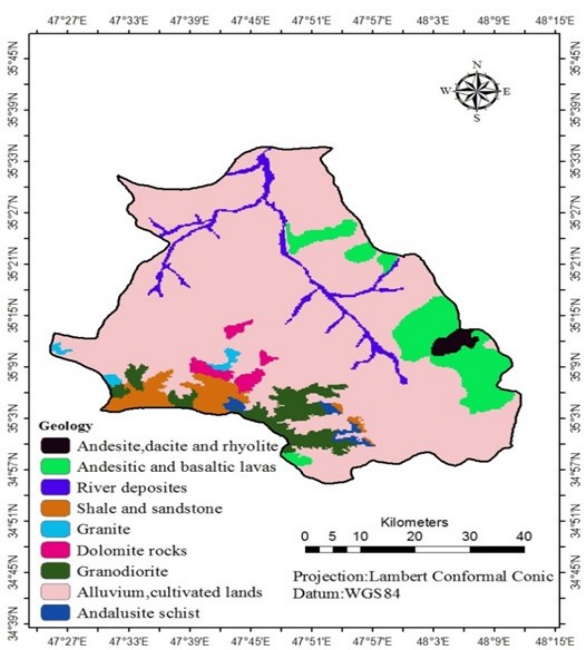

Figure 7. Geology map

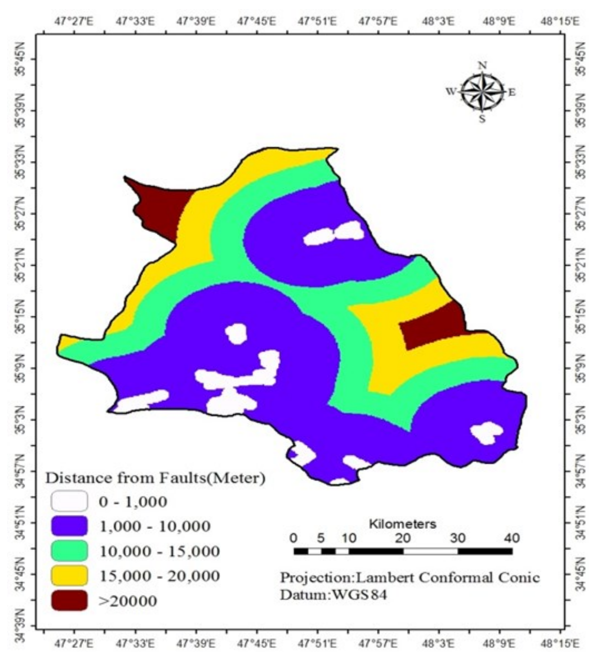

Figure 8. Distance from faults map

Distance from drainage network

Landfills should not be near or on rivers because leads to pollution water and thereat to life of aquatics. The drainage network map created by arc hydro tools using Dem in GIS and buffered in GIS (Sener *et al.,* 2010) then distances were divided to five classes (Figure 11).

Distance from city and villages

The location of the land fill should not be near city or villages. The landfills are closed to city are most obstacle for development landscapes or near villages leads to pollution air, water and agricultural lands near of the villages. Map of the extent city and villages created by Google earth due to updated images and buffered

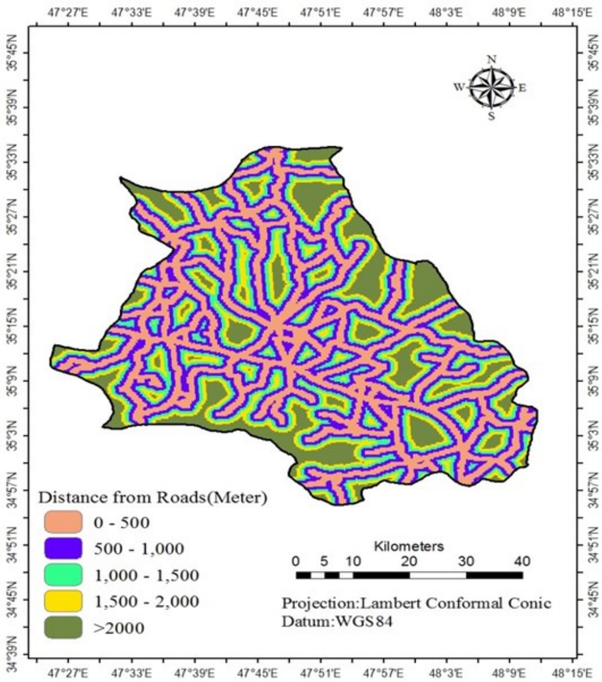

Figure 9. Distance from roads

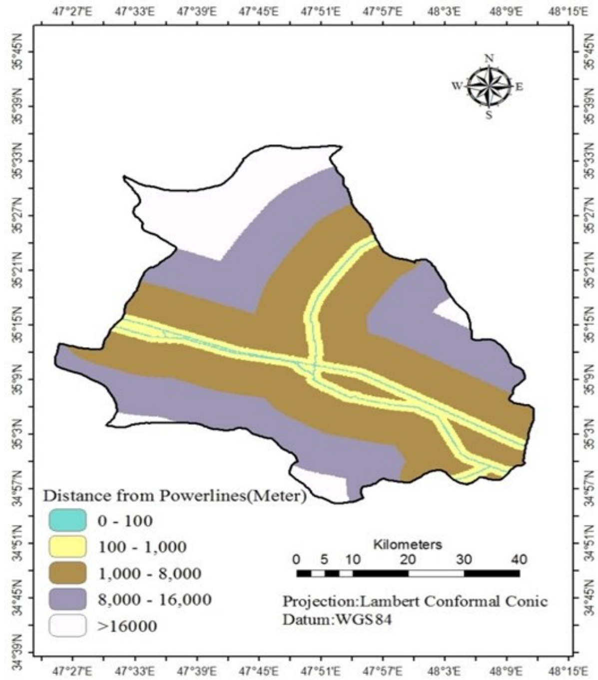

Figure 10. Distance from power lines

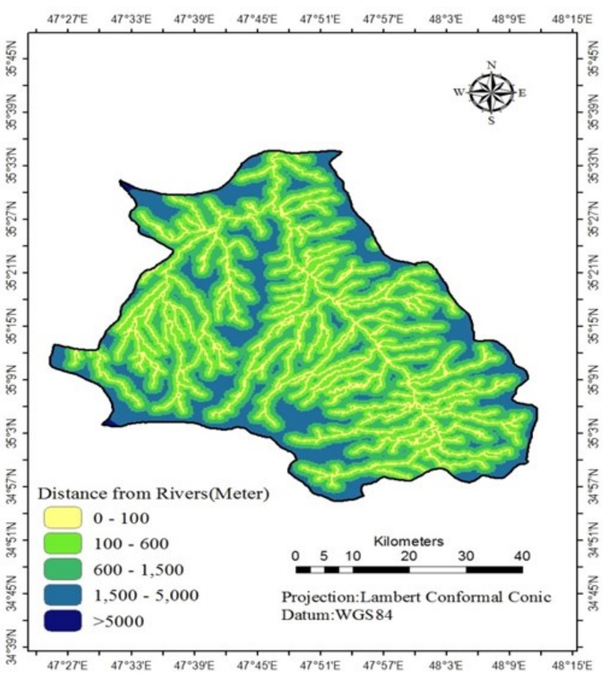

Figure 11. Distance from drainage network

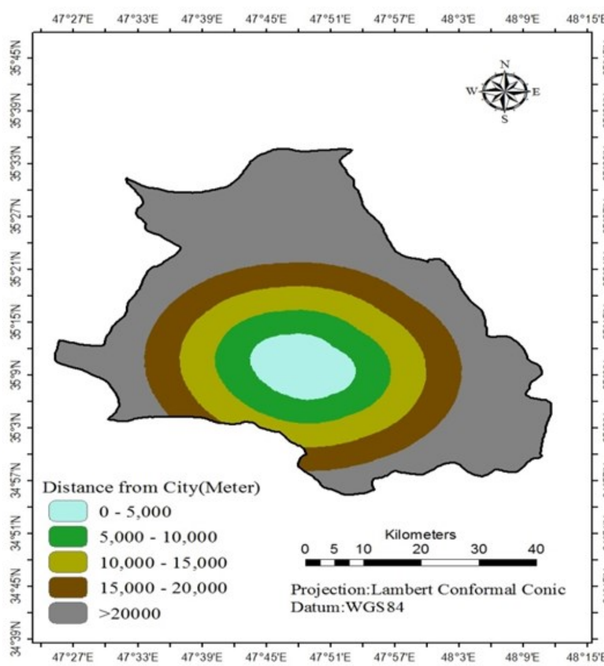

Figure 12. Distance from City

in GIS, then distances were divided to five classes based on close to city or villages (Figure 12 and 13).

Distance from wells

The sites that considered for disposal waste must be far from wells. It leads to contamination ground waters. The location of wells specified using regional water company reports and location wells created in GIS. Then the distance map was grouped to five classes (Figure 14).

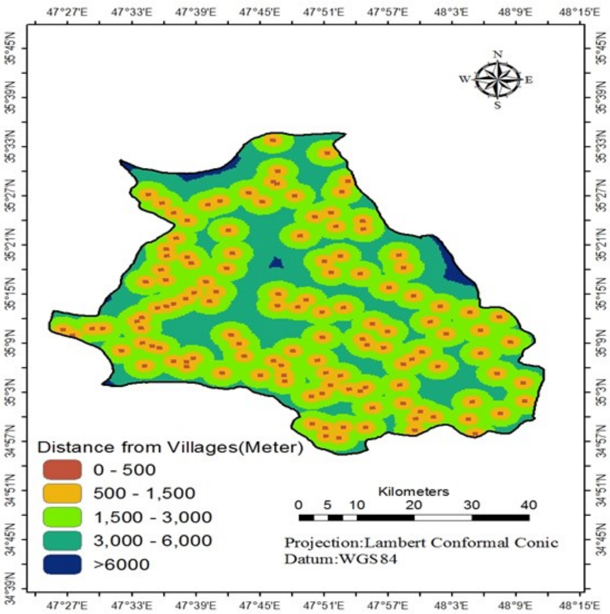

Figure 13. Distance from villages

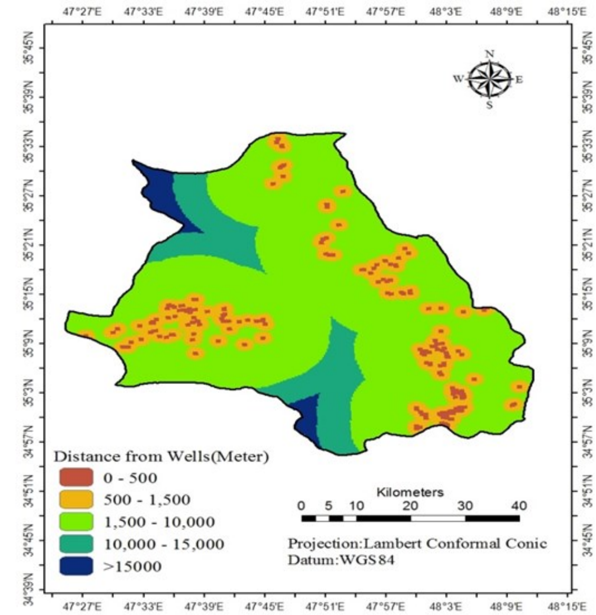

Figure 14. Distance from wells

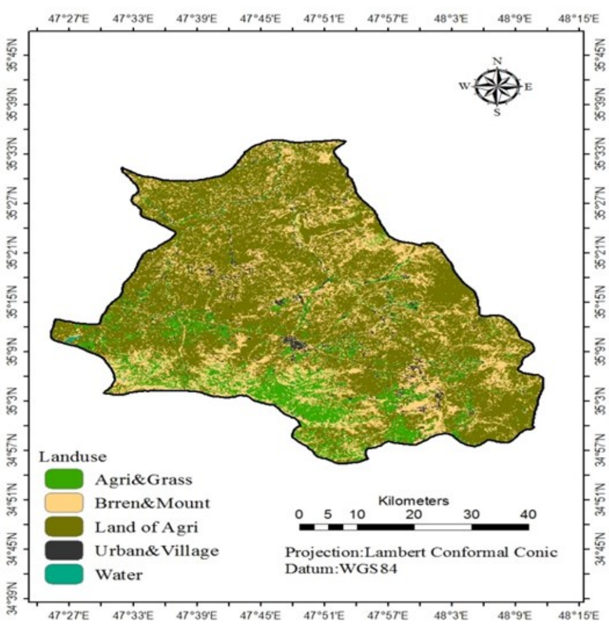

Figure 15. Land use

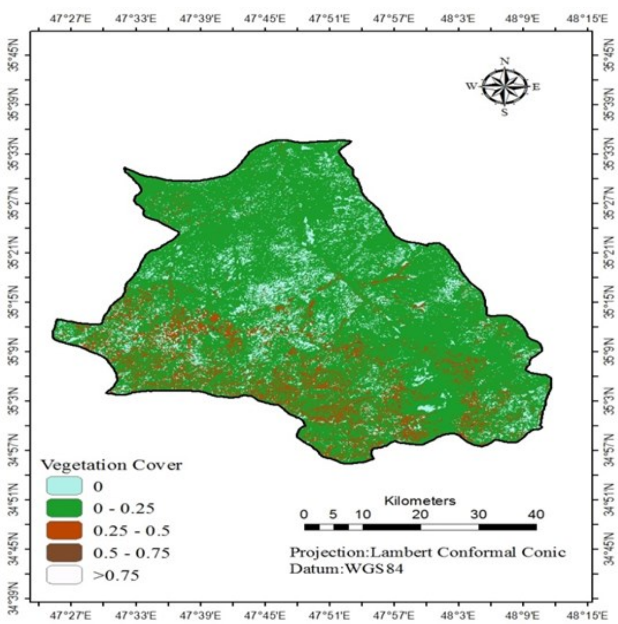

Figure 16. Vegetation cover

Land use

Land use refers to man's activities in land, various uses which are carried out on land (Thilagavathi *et al*., 2015). Land use is one of the most important factor for site selection. The land use map created using Landsat 8 images 23rd June 2016 by ENVI software and the final map was classified to five groups (Figure 15).

Vegetation of cover

Vegetation plays an important role for site of landfill. The sites have high vegetation cover shows that water level is high and may the leachate permeates to depth and pollution the ground water when is raining. The vegetation map created by Landsat 8 images 23rd, June 2016 (USGS, 2017) and the red and infrared bands were used for the vegetation map using NDVI

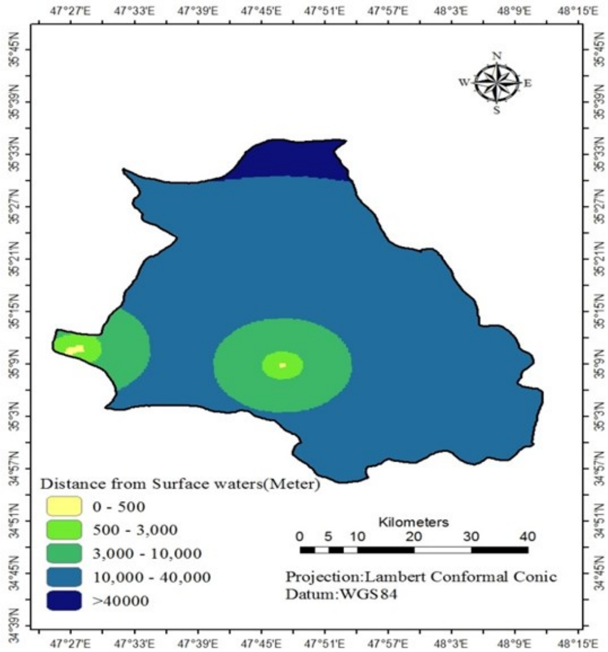

Figure 17. Distance from surface waters

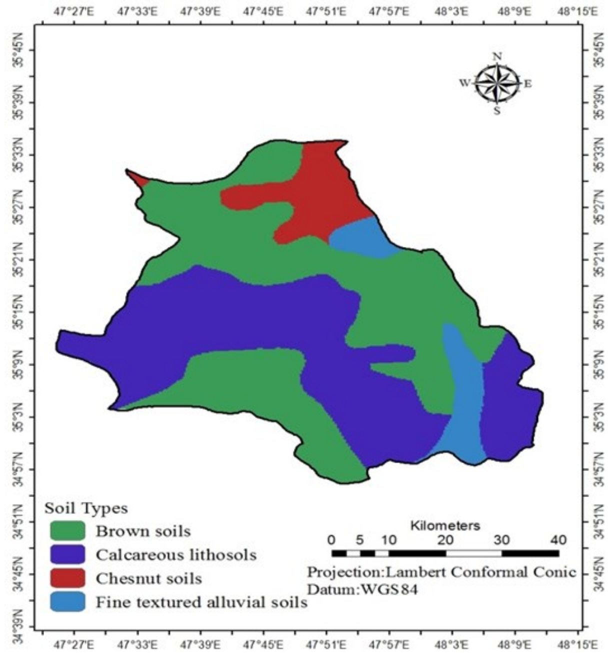

Figure 18. Soil types

(Normalized Difference Vegetation Index) and was grouped to eight classes (Figure 16).

Distance from surface waters

The landfill site should not be placed within surface water or water resources protection areas to protect surface water from contamination by leachate (El-Maguiri *et al*., 2016). According to China Solid Waste Management law, a 500 m buffer zone should be maintained around significant surface waterbodies. Therefore, the distance map created was grouped to five classes (Figure 17).

Soil types

Soil types is an important factor that should be considered in the landfill site selection. Soil properties such as texture, structure and so on are important (Kumar and Hassan, 2013). Because soils with low permeability (clay and clay loam soils) are suitable whiles soils with high permeability (sandy and sandy-loam soils) are unsuitable. The soil map was created by the soil profile of Iran. First the soil map of Iran digitized and glorified in GIS. Then the soil types created were grouped to four classes (Figure 18).

RESULTS

Analysis

After the thematic maps created, then it was weighted. All of the created maps reclassified and weighted that in following showed (Table. 1). So, criteria like elevation, slope, aspect, geology, distance from faults, distance from roads, distance from power lines, distance from drainage network, distance from city, distance from villages, distance from wells, land use, vegetation cover, distance from surface waters and soil types were done and their ranges were weighted from four until nine classes. Geology conditions had greatest classes.

The fuzzy method

Fuzzy logic theory, proposed in 1965 by Professor Lotfalizadeh, discusses against the classic logic that consider clear boundaries for different classes (Moeinaddini, 2010). After reclassifying and weighting the maps using fuzziness, the proposed landfill was created. Many phenomena have some inherent characteristics that make them uncertain to be addressed. Such uncertain concepts are said to be fuzzy. For these phenomena, due to uncertainty, it is not possible to make

Table 1. The summary of the input layers used in the analysis

S. No	Criteria	Ranges	Weights
1	Elevation	1657-2000	5
		2000-2300	4
		2300-2600	3
		2600-29000	2
		2900-3214	1
2	Slope	0-5	5
		5-10	4
		10-15	3
		15-20	2
		20-65/75263977	1
3	Aspect	-1	0
		0-22.5	4
		22.5-67.5	4
		67.5-112.5	3
		1125.5-157.5	4
		157.5-202.5	3
		202.5-247.5	1
		247.5-292.5	2
		292.5-337.5	3
		337.5-360	5
4	Geology	Granite	9
		Granodiorite	8
		Andesitic and basal-	7
		tic lavas	6
		Andesite, decide and	5
		rhyolite	4
		Dolomite rocks	3
		Andalusite schist	2
		Shale and sandstone	1
		River deposits	
		Alluvium, cultivated lands	
5	Distance from Faults	0-1000	1
		1000-10000	2
		10000-150000	3
		150000-200000	4
		>200000	5
6	Distance from Roads	0-500	5
		500-1000	4
		1000-1500	3
		1500-2000	2
		>2000	1
7	Distance from power lines	0-100	1
		100-1000	2
		1000-8000	3
		8000-16000	4
		> 16000	5
8	Distance from drainage network	0-100	1
		100-600	2
		600-1500	3
		1500-5000	4
		>5000	5

Continued………..

…..Continued

9	Distance from City	0-5000	5
		5000-10000	4
		10000-15000	3
		15000-20000	2
		>20000	1
10	Distance from villages	0-500	1
		500-1500	2
		1500-3000	3
		3000-6000	4
		6000-8458/325195	5
11	Distance from wells	0-500	1
		500-1500	2
		1500-10000	3
		10000-15000	4
		15000-21613/63086	5
12	Land use	Barren and mount	5
		Agri and grass	4
		Land of agri	3
		Urban and village	2
		Water	1
13	vegetation cover	0	5
		0-0.25	4
		0.25-0.50	3
		0.50-0.75	2
		0.75-0.871673882	1
14	Distance from surface waters	0-500	1
		500-3000	2
		3000-10000	3
		10000-40000	4
		40000-48391/73047	5
15	Soil types	Brown soils Fine tex-	1
		tured	2
		alluvial soils Chesnutt	3
		soils	4
		Calcareous lithosols	

sharp classes and draw the boundaries clearly. This way, it is better to classify them using fuzzy logic rather than binary yes/no classification (Kainz.2010). There are different functions for ranking the layers. In this study, we used linear function to fuzzify the membership. This function, linearly transforms the values between the user-specified minimum and maximum. For values lower than minimum and higher than maximum, zero (definitely not a member) and one (definitely a member) will be considered, respectively (Bahrani *et al.* 2015). After applying the fuzzy function to the layers, using different types of operators, the layers were overlapped. Amongst different operators, the Gama operator was selected for this study. If the impacts of some criteria increase or decrease use from this operator as an overlay method. Finally, the resulting map produced using the fuzzy method and grouped to five classes including very good, good, average, weak and very weak (Figure 19). After the analysis of using all thematic layer total area in our study included 2868 Km^2 . The results show that 1.5% of areas are highly suitable (very good), 2.7% of areas is moderately suitable and 91.7% of area is less suitable. Suitable area obtained is shown in Figure 19.

Results from this research using the GIS and remote sensing method confirm earlier findings by Eskandari *et al*. (2015), Ouma *et al*. (2011) and Alrukaibi and Alsulaili (2017) in their research about land suitability analysis for prioritization of candidate sites for waste management. The final decision in this research for a landfill site is as much a political decision as a scientific one and strongly depends on complex of maps (Ismail, 2017)

CONCLUSION

Finding a site for waste disposal always have been a major problem in waste management. In recent years, integration remote sensing and GIS have been an effective method for site selection process. In the present study, combination remote sensing, GIS and fuzzy method was used. GIS as a database management system enable us manage a large number of spatial and non -spatial data. In this study, 15 criteria were included: elevation, slope, aspect, geology, distance from faults, distance from roads, distance from power lines, distance from drainage network, distance from city, distance from villages, distance from wells, land use, vegetation cover, distance from surface water and soil types used for site selection the landfill. At the end, the final map was grouped to five classes. The results showed that integration remote sensing, GIS with the fuzzy method can be a useful tool on site selection issues.

REFERENCES

Alrukaibi DS and Alsulaili AD. (2017). GIS-based modeling for appropriate selection of landfill sites, *Journal of Engineering Research,* 5(2): 87-109.

Babajani K and Samadian N. (2014). Detailed results of the general census of population and housing county of Ghorveh. Statistical Center of Iran.

Bahrani S, Ebadi T, Ehsani H, Yousefi H and Maknoon R. (2016). Modeling landfill site selection by multi-criteria decision making and fuzzy functions in GIS, case study: Shabestar, Iran. *Environmental Earth Sciences,* 75(4): 1-14.

Chabuk AJ, Al Ansari N, Hussain HM, Knutsson S and Pusch R. (2016). Landfill siting using GIS and AHP (Analytical Hierarchy Process): a case study Al-Qasim Qadhaa, Babylon, Iraq, *Journal of Civil Engineering and Architecture*, 10: 530-543

Djokanovic´ S, Abolmasov B and Jevremovic´ D. (2016). GIS application for landfill site selection: a case study in Pancˇevo, Serbia. *Bulletin of Engineering Geology and the Environment,* 75(3): 1273–1299.

El-Maguiri A, Kissi B, Idrissi L and Souabi S. (2016). Landfill site selection using GIS, remote sensing and multicriteria decision analysis: case of the city of Mohammedia, Morocco. *Bulletin of Engineering Geology and the Environment* 75(3): 1301–1309.

Eskandari M, Homaee M, Mahmoodi S, Pazira E and Van Genuchten MT. (2015). Optimizing landfill site selection by using land classification maps. *Environment Science Pollution Research,* 22(10): 7754-7765.

Gbanie SP, Tengbe PB, Momoh JS, Medo J and

Simbay Kabba VT. (2013). Modelling landfill location using Geographic Information Systems (GIS) and Multi -criteria Decision Analysis (MCDA): case study Bo, Southern Sierra Leone. *Applied Geography,* 36:3–12.

Kainz W. (2010). The mathematics of GIS. University of Vienna, Austria. 170 p.

Kontos TD, Komilis DP and Halvadakis CP. (2005). Siting MSW landfills with a spatial multiple criteria analysis methodology. *Waste Management*, 25(8): 818–832.

Kumar S and Hasan MI. (2013). Selection of a landfill site for solid waste management: an application of AHP and spatial analyst tool. *Journal of the Indian Society of Remote Sensing*, 41(1): 45–56.

Moeinaddini M, Khorasani N, Danehkar A and Darvishsefat A. (2011). Siting MSW landfill using hierarchical fuzzy TOPSIS methodology (case study: karaj). *Journal of Natural Environment, (Iranian Journal of Natural Resources)*, 64(2): 155-167(In Persian).

Sener S, Sener E, Nas B and Karaguzel R. (2010). Combining AHP with GIS for landfill site selection: a case study in the Lake Beysehir catchment area (Konya, Turkey). *Waste Management,* 30(11): 2037-2046.

Thilagavathi N, Subramani T, Suresh M and Karunanidhi D. (2015). Mapping of groundwater potential zones in Salem Chalk hills, Tamil Nadu, India, using remote sensing and GIS techniques. *Environmental Monitoring and Assessment,* 187(4): 1–17.

Yesilnacar MI and Cetin H. (2005). Site selection for hazardous wastes: A case study from the GAP area, Turkey. *Engineering Geology,* 81(4):371–388

USGS (2017). Science for a changing world. Available from: https://earthexplorer.usgs.gov.

UWGB. University of Wisconsin - Green Ba. (2012). [Cited 2012 January 31]. Available from: https://www.uwgb.edu/dutchs/STRUCTGE/SL48InterpMap.HTM

WRPLOT (2016). Freeware wind rose plots for meteorological data 20.4 MB - 14 Nov 2016.

Zaporozec A. (2002). Groundwater contamination inventory. International Hydrological Programme within Project 3.1 (IHP-V). Series on groundwater No. 2. 160p.