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SELECTING SOLID WASTE SITES USING INTEGRATED FUZZY LOGIC MODEL AND MULTI CRITERIA APPROACH IN SHASHEMENE TOWN: OROMIA REGIONAL STATE, ETHIOPIA

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Abstract

Solid waste is unwanted material generated from combined residential, industrial, and commercial activities in a given area. Since landfills are permanent sites, they need special attention in selecting the location by applying an efficient method. This study employed the Fuzzy logic in combination with Weighted Linear Combination (WLC) methods for the selection of solid waste landfill site in Shashemene town. Moreover, the study used multi-criteria decision-making integrated with Geographic Information System (GIS) to evaluate solid waste site. The results show that the most considerable factors in site selection are the distance from road, river, residential areas, and commercial areas with weights of 0.242, 0.194, 0.134, and 0.119 respectively. However, slope and height are not significant criteria. Overall, the final capability map generated by the weighted linear combination method represents 41.5% of the study area is not suitable for landfill setting, whereas low, moderate, high, and the most suitable classes cover 30.7%, 16.4%, 7.5 and 3.9% of Shashemene town, respectively. The study also identified three best (3) sites of 25.9ha, 205.19ha, and 268.75ha for the landfill in the town.

Keywords: Analytical Hierarchy Process (AHP), Fuzzy logic, landfill site selection, multi-criteria, solid waste, Weighted Linear Combination (WLC)

1 Introduction

Solid waste is unwanted material that is generated from combined residential, industrial, and commercial activities in a given area. Most urban areas in the country plagued by acute problems related to solid waste due to the continuous migration of people from rural and semi-urban areas to towns and cities (Shukla, 2000). It is also a global environmental problem in today's world both in developing, and developed countries. Increasing population growth, rapid economic growth and the rise in the community's living standard accelerated solid waste generation in the world (Elmira *et al*., 2010).

Many of urban local bodies dispose of solid waste in open land, vacant areas and by roadsides which creates unhygienic condition and in many seasons those wastes degraded and emits CO^2, methane, other toxic gases which in turn toxicants water bodies which cause Jaundice, nausea, asthma (Nishanth *et al*., 2010). Solid waste dumping site selection is difficult because of its requirement to consider environmental and other factors that can be easily and significantly affected (Sumathi *et al*., 2008).

Recently, there is an increasing and complexity of solid waste production in the world mainly because of growing developments, urbanization, and improving living standards in cities, which intern at expense of the environmental cost (Smit *et al*., 1996). To solve all problems of solid waste disposal, having a properly planned waste dumping site is one of the most important management activities, which need to be carefully planned (Regassa *et al*., 2011). The disposal sites must consider all the socio-economic, environmental, land use factors and peoples" safety within the cities/towns. The study area is no exception from these problems like many towns and cities in Ethiopia. Recently, to investigate the capability of the land and public acceptance, economic development and environmental impact assessment of landfill, GIS has a greater ability in data analysis, effective database establishment, and flexibility of applying models such as WLC, Fuzzy and Boolean logic and Multi-criteria decision method (Sordoud *et al*., 2017). Moeinaddini *et al*. (2010) applied Weight Linear Combination (WLC) and Analytical Heirarchy Process (AHP) focused on hydrology, wind orientation, slope, distance from the road and residential areas as significant parameters to carry out landfill site selection in the two Iranian metropolitan areas of Gorgan and Karaj respectively. Seners *et al*. (2010) applied AHP and GIS were combined for landfill site selection in Konya, Turkey. The distance from transport routes and rail, the distance from archaeological sites, urban areas, land use/land cover, and slope were taken as factors in the investigation. Considering the relative priority of all criteria in comparison with others, a specific weight was designated to each criterion according to their total influence overall process of decision making. Furthermore, Zeinhom *et al*. (2009) used integration of GIS and Multi-Criteria Decision Making (MCDM) to locate landfill sites in Mansoura city, Egypt. In their research, eight criteria were used. They used both Weighted Linear Combination (WLC) and Analytical Hierarchy Process (AHP) in a GIS environment. The study was intended to assess the existing site and identify a suitable site for solid waste disposal of Shashemene town with implemented WLC in a GIS-Fuzzy Logic environment to locate the site for a landfill.

2 Materials and Methods

2.1 Description of the study area

Shashemene is located in West Arsi Zone of the Oromia National Regional State, with a distance of about 251 kilometers to the south of the capital city of Ethiopia Addis Ababa. Geographically, the town located is at 7^{o}12'00"N – 7^{o}13'57"N latitude and 38^{o}36'00"E – 42^{o}00'16"E longitude in the Ethiopian rift valley region (Figure 1). The 2007 national census reported a total population of the town 100,454, of whom 50,654 were men and 49,800 were women.

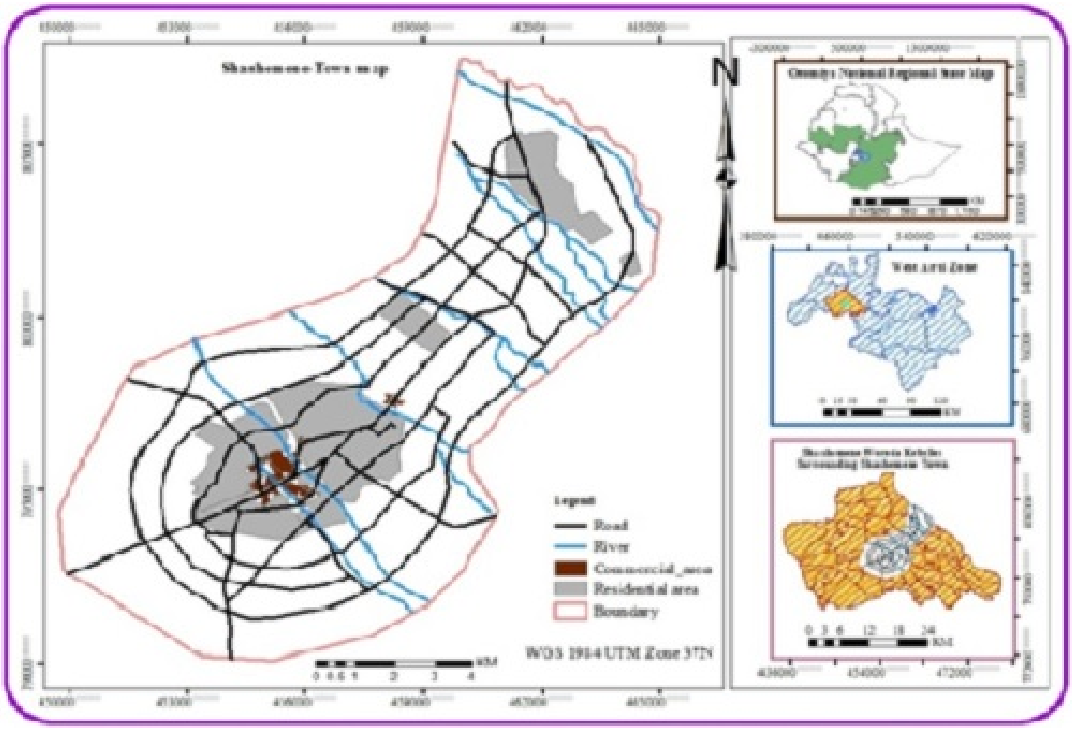


Fig. 1 Map of the study area

2.2 Materials

Several datasets, both vector and raster at different scales were used.

Table 1 Input data sources and description.

Input data	Entity	Sources
Spot 5	Tiff	Ethiopia Geospatial Agency
SRTM (ShuttleRadarTopographicMission)	Digital Elevation Model (DEM)	http://srtm.csi.cgiar.org/.
Topographic map sheet	Tiff	Ethiopia Geospatial Agency
Structural plan	Vector	Office of Land Development Agency, Shashemene town
Soil map	Vector/shape file	http://www.fao.org
GPS readings	Point data	Field surveyed

2.3 Methods

Digitization: to convert base map to digital maps, thirteen (13'n) criteria features such as roads, environmentally sensitive areas, cemetery areas, residential and mixed-use, planned social services, and Land Use have been obtained through digitized structural plan of the town. River, commercial area, military area and existing social services were digitized from a topographic map and the soil type was digitized from soil map that was downloaded.

Fuzzy logic: It was introduced by Zadeh in 1965 and permits the notion of nuance. Apart from true, a proposition may also be anything from almost true to hardly true. The fuzzy theory, which is a generalization of classic set theory, allows a membership function to operate over the range of real numbers (0, 1). To convert criteria maps to fuzzy layers, equation 1 is used.

$$X_i = \frac{R_i - R_{min}}{R_{max} - R_{min}} * Standardized\ range \qquad (1)$$

Where, the **standardized range** represents the range of changes in standardization, X = the cell's value following standardization, R_i = the cell's value before standardization, R_{min} = the minimum value in the factor, and R_{max} = the maximum value in the factor.

Boolean logic: It was used to standardized constraint maps to fuzzy layers. In standardizing constraints, Boolean logic based on the value of 0, 1 was used, where constrains take zero and other parts take 1 (Aliani *et al*,. 2016; Gemitzia *et al*., 2007) so, land use/cover and soil type were standardized using Boolean logic for a solid waste suitable site.

Analytical Hierarchy Process (AHP): The AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales, which will then measure intangibles in relative terms. It assists to establish priorities among the elements within each stratum of the hierarchy. After that, a consistency Index (CI) computed using the following formula.

$$CI = \frac{\lambda_{maxn}}{n} \qquad (2)$$

Where, n is the number of criteria and λ_{max} is the biggest eigenvalue (Malczewski, 1999).

To determine if the comparisons are consistent or not, the Consistency Ratio (CR) calculated using the formula:

$$CR = \frac{CI}{RI} \qquad (3)$$

Where, RI is the Random Inconsistency index that is dependent on the sample size, a reasonable level of consistency in the pairwise comparisons is assumed if $CR < 0.10$, while $CR \geq 0.10$ indicates inconsistent judgments (Saaty, 2008).

The consistency ratio of this study indicated that 0.08 which was acceptable as given in table 3.

Table 2 Determined relative criterion weights

Criteria/parameters	EIGENVECTOR	Percentage
River	0.194	19.4
Commercial area	0.119	11.9
Residential area	0.138	13.8
Social service	0.080	8.0
Water well/Reservoir	0.064	6.4
Environmentally sensitive area	0.044	4.4
Cemetery	0.028	2.8
DEM	0.013	1.3
Slope	0.012	1.2
Military area	0.015	1.5
Road	0.242	24.2
Land use land cover	0.029	2.9
Soil type	0.024	2.4
Total	1	100

2.4 Evaluation criteria

River: Since major rivers have a higher discharge and greater downstream influence, no solid waste disposal should be sited within the floodplains of major rivers. Based on Soroudi *et al*. (2017), 2000 and 4000 meters were decided 'a' and 'b' control points for rivers with linear and monotonically increasing fuzzy membership function used.

Cemetery sites: According to Nas *et al*. (2010), cemetery areas were standardized using control points (1500m) and b(4500m) with linear and monotonically increasing fuzzy membership type and shapes respectively because it causes problems and complaints about the residents. Environmentally sensitive areas: The environmentally sensitive area in this study is faults that cause limitation for setting a landfill. Environmental sensitive areas were standardized using control points 'a' 1000(m) and 'b' 5000(m) with linear and monotonically increasing fuzzy membership types and shapes respectively.

Commercial area: Commercial areas include highly building areas, business centers, and area developed by many infrastructures. Based on Foomani *et al*. (2017) control points of 3000, 4000, 5000 and 6000 meter was chosen considering the commercial area as one source of hazardous waste with sigmoidal fuzzy function type and symmetric membership shape was chosen due to it causes bad odors and depreciation of land in the surrounding area. The sufficient landfill capacity for the city's long-term requirements should be considered and the landfill site should not be affected by the development plans of the city.

Residential area: Landfill sites should be located away and far from populated areas. Otherwise, it causes bad odors and depreciation of land in the surrounding area (MET *et al*., 2008). Based on the methodology described in Babalola and Basu (2011), 500(m) and 3000(m) of 'a' and 'b' control points and linear and moronically increasing fuzzy function was considered for this factor.

Slope: Slope is an important factor in the suitability site selection because it determines the amount of surface runoff produced by the precipitation rate and displacement velocity of water to the potential site in addition to the construction cost (Tsegaye, 2006). According to the study of Foomani *et al*. (2017), 5% and 15% were chosen as 'c' and had control points with monotonically decreasing shape and linear fuzzy membership function type was considered.

Water well/reservoir area: Nas *et al*. (2010) have recommended a minimum distance of 2000m off from wells and reservoirs for locating a dumping site due to pollution-related problems. Therefore, 2000m and 6000m control points of 'a' and 'b' with linear fuzzy function type and monotonically increasing fuzzy function shape was considered.

Military area: According to Alfy *et al*. (2010), solid waste disposal must be 3000m far from the military area. For this study, fuzzy standardized using 3000m and 6000m control points of 'a' and 'b' with sigmoidal fuzzy function type and monotonically increasing fuzzy function shape was considered because of areas used for the testing of military equipment or training of military personnel are not open for public usage.

Social service area: Social service places, where people gather and do their day-to-day activities are also among the sensitive sites that need careful planning in waste disposal process. Social services in this article are two types of existing places and future planned areas. Existing places area (schools, mosques, hospitals, and church and market areas) and future planned areas according to the structural plan of the town were identified. As described in the methodology Semaw (2018), 1000m and 4000m control points of 'a' and 'b' with linear and monotonically increasing fuzzy membership function was used.

Road: Road is one of the criteria that should be considered in solid waste dumping site suitability analysis. Based on Demesoukad *et al*. (2013), control points of 500, 1000, 1500, and 2000 meters with J-shape type and symmetrical fuzzy membership function shape was considered.

DEM: Hilly landscapes not only increase construction costs but also become a burden to vehicles transporting waste to landfill locations since a number of highlands will be difficult to negotiate if proper leveling is not done (Foomani *et al*., 2017). Based on the study of Soroud *et al*.(2017), 1600 - 2000m equal to between 0 - 1, more than 2000m equal to 0 with user-specified fuzzy membership function was considered.

Land Use/land cover: Land use/Land cover map of the study area is one of the criteria used to select potential sites for solid waste disposal in Shashemene town. Forest areas are not suitable for landfills, but agriculture areas are suitable because they are suitable for landfill facilities (Guler and Yomraholu 2017). According to the study of Ebistu and Minale (2013), land use/land cover of Open space equal to 1, Agriculture equal to 0.6 and Forest area equal to 0 was considered with User specified fuzzy membership function type as shown on figure 4A.

Soil type: Soil characteristics promote safe and economic feasible impletion and operation of a dumpsite for site selection. Based on the study of Soroud *et al*. (2017), nitosols equal to 1 and xerosols equal to 0.8 with discrete fuzzy membership function were concerned as shown in figure 3K.

Weighted Linear Combination (WLC): This method is used to combine and generate a single map, showing areas of different suitability levels for setting a landfill within the study area. It is simple and most widely applied method (Rafiee *et al*., 2011). Using WLC method, the Suitability Index was calculated by summing the product of each weight of each criterion with its standard score and it is the method of evaluation that represented cell suitability by weighting and combining factor map layers using equation 4 as follows:

$$S_f = \sum_{i}^{N} = 1W_iX_i \tag{4}$$

Where, S_f stands for total suitability index value (0-1) of factor maps, W_i = Weight, X_i indicate criterion score factor i and N = Total number of factor criterion. In considering constraints based Boolean logic, constraints with the value of 0 should multiplied by suitability as calculated from the factor using equation 5 as follows.

$$S_c = \sum_{i}^{K} =_i b_j \tag{5}$$

Where S_c totals suitability index value, (0), k, and b_j show total number of constraints and suitability index value for each constraint (0) respectively. Final suitability index

The final suitability index (S_t) was computed by integrating total factor suitability (S_f) and the total constraints suitability (S_c) index using equation 6 as follows.

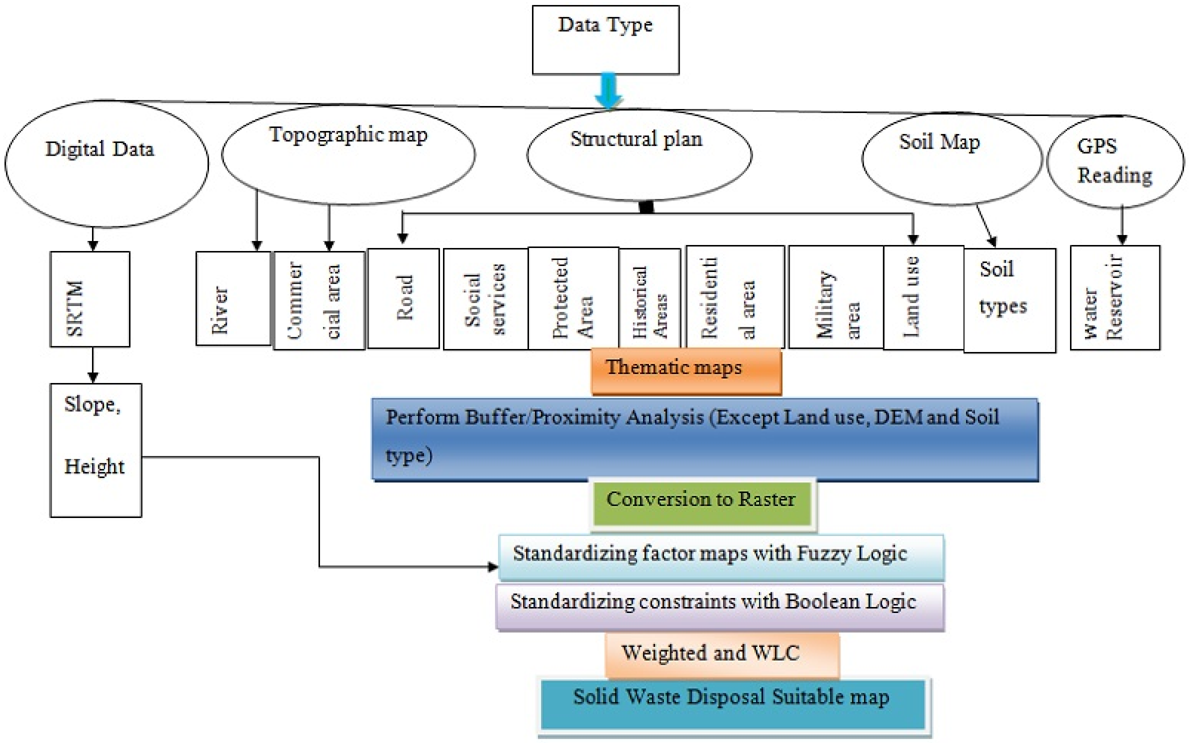
$$S_t = S_f{}^* S_c \tag{6}$$

Where S_f = Integrated total factor, S_c = Total constraint suitability. Based on Soroud *et al.* (2017), the final suitability of each criterion suitability and combined WLC results of solid waste dumping site was reclassified as described in Table 2 below.

Table 3 Classification for Solid Waste disposal sitting of final WLC

Class number	Land capability	Final value of each pixel
1	Not suitable	0 – 0.2
2	Low suitable	0.2 – 0.4
3	Moderate suitable	0.4 – 0.6
4	Highly suitable	0.6 – 0.8
5	Extremely suitable	0.8 - 1

Methodological Flow Chart of the Study



3 Results and Discussions

3.1 Results

River suitability map: The result of fuzzy standardized map of figure 2A showed that within 2000m distance from the river, the area was unsuitable and it was showed by red color or (0) value on the map. The green and yellow colors showed suitable area above 2000m distance from river and far distance from river respectively and the suitability level increases by (1) value. The result of river suitability map in figure 2B showed that out of the total area, 10861.74ha (84.25%) was unsuitable for solid waste disposal site and area which is 311.4ha (2.42%) was evaluated as highly suitable and the rest area 1039.77ha (8.06%) was evaluated as the most suitable for solid waste disposal site for river criteria.

Cemetery sites suitability map: According to Nas, *et al*. (2010) distance from Cultural Heritage Sites should not be within 1500m because it causes problems and complaints of the residents. The result of fuzzy standardized map of figure 2C showed that within 1500m distance from cemetery, the area was unsuitable and it was showed by red color or (0) value on the map. The blue color or (1) value showed suitable area, which was above 4500m far away from cemetery area. When the distance of solid waste disposal site increases from cemetery, the suitability level increases by (1) value.

Environmentally sensitive areas suitability map: Value 0 indicated that unsuitable area within 1000m distance and value 1 showed suitable area near 5000m distance from the site as showed in figure 2E. The results of figure 2F showed that out of the total area, 2437.83 ha (18.91%) was unsuitable for solid waste disposal site, which was found in the area of 1000m.

Commercial area: The areas of town nearer to the site had less distance, which were 3000m far and less standardized fuzzy value near to 0. Medium distance, which was 4500m, has high value near to

1 and it was highly suitable for solid waste disposal site. Selection and high distance more than 6000m has fuzzy standardized value near 0 as showed on figure 2G. The suitability level of commercial area in figure 2H showed that out of the total area, 9949.86 ha (77.17%) was unsuitable for solid waste disposal site because it was found in the 3000m and 6000m distance from commercial areas.

Residential areas suitability map: The fuzzy standardized map of residential area in figure 2I showed that near distance, which was 500m, has fuzzy value near 0 of red color on map and it was unsuitable area. On the other hand, areas that were 3000m faraway have 1 fuzzy value and indicated in green color on the map showed suitable area. The results of suitability map on figure 2J showed that out of the total area, 7473.4ha (57.96%), which was found in 500m was unsuitable area for solid waste disposal site.

Slope suitability map: The slopes greater than 15% and less than 5% have 0 value and they were unsuitable area for solid waste site selection and value 1 of slopes between 5% and 15% were considered highly suitable area as showed in figure 2K. The result on figure 2L showed that majority of the study area falls of the slope class that covered 75% of the area (slope between 5% and 15%), which was extremely suitable for solid waste dumping.

Water well/reservoir areas suitability map: The fuzzy standardized map in figure 3A showed that value 1indicated suitable areas, which were about 6000m far from the water well and 0 value showed unsuitable area, which was about 2000m distance from water well/reservoir area. The results of suitability map in figure 3B showed that out of the total area, 3152.34 ha (24.45%), was found about 2000m far from the water well and it was unsuitable for solid waste disposal site.

Military area: The fuzzy standardized map on figure 3C showed that about 3000m distance had fuzzy value 0, which indicated unsuitable area in red color on the map and far distance about 6000m had fuzzy 1 value, which indicated suitable area of green color on the map. The suitability results on figure 3D showed that out of the total area, 5426.55 ha (42.09%) was unsuitable for solid waste disposal site.

Social service area: Fuzzy standardized map in figure 3E indicated that about 1000m had a fuzzy value 0 and red color on map, which showed unsuitable area and near 4000m have fuzzy value 1 and green color on map, which indicated suitable area. The suitability map results in figure 3F showed that out of the total area, 8856.7 ha cover highest area about 68.69% was found near 1000m from social service, and it was unsuitable for solid waste disposal site.

Road suitability map: The fuzzy standardized map in figure 3G showed that the area near 500m to the road and 2000m far from the road had a fuzzy value near 0 that indicated the area was unsuitable. The area near 1000m to the road had a high pixel value of 1 and it was a suitable area indicated in figure 3G. The suitability map results of figure 3H showed that out of the total area, the highest area of about 85% (10949.49 ha) was found near 500m to the road was unsuitable. Only 5.6% of this area was suitable for the solid waste disposal site. Generally, the road was the most determining criteria for the solid waste disposal among the thirteen criteria since 85% of the area was unsuitable under this factor.

DEM: The result of the fuzzy standardized map in figure 3I showed that height of 2000m had fuzzy value 0, which indicated an unsuitable area with red color on the map, and height of between 1800m of the town DEM had fuzzy value 1 that was indicated suitable area as shown by green color on the map in figure 3I. In this criterion, the suitability map showed three suitability levels of unsuitable, high suitable and the most suitable. The area under this factor did not fulfill less suitable of fuzzy value 0.2-0.4 and moderate suitable of fuzzy value 0.4-0.6 as shown on figure 3J. The suitability map results in figure 3J showed that out of the total area, about 29.19% (3762.99ha) were found at 2000m height and they were unsuitable for solid waste disposal site

Land Use Land Cover: The result showed that agricultural area had moderate suitable (value 0.6), open space area had the most suitable (value 1), and forest area had unsuitable (value 0) as shown in figure 4A. In this criteria, the suitability map in figure 4B has three suitability level of unsuitable, less suitable and high suitable because of the area under the factor did not fulfill the most suitable, and moderate suitable that means no fuzzy standardized value of between 0.4 - 0.6 (moderate suitable) and 0.8 – 1 (extremely high suitable). The suitability map results in figure 4B showed that, out of the total area, about 2164.14ha (65.19%) was unsuitable for solid waste disposal site. Generally, only 205.02ha and 950.40ha, which were 6.18% and 28.63%, were evaluated as less and highly suitable for the solid waste disposal site respectively as showed in figure 4B.

Soil type suitability map: The study area has soil type showed in figure 3L and largely dominated by Eutric Nitosols, which covered 49.52% and found in the north-east, east and east- south part of the study areas. The second type of soil is Haplic xerosols, which constitutes 31.6% dominated the western and northern parts of the study area.

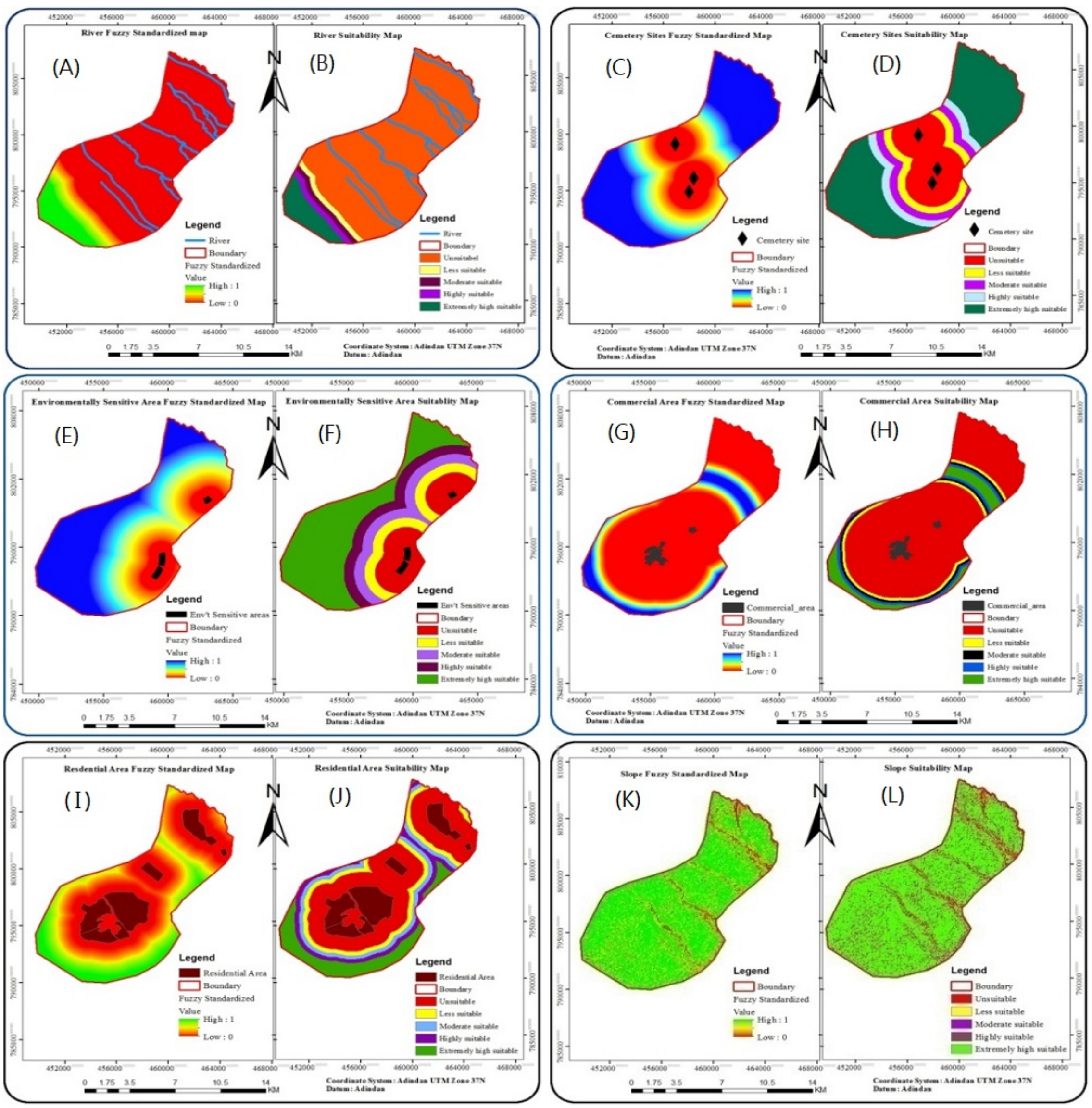
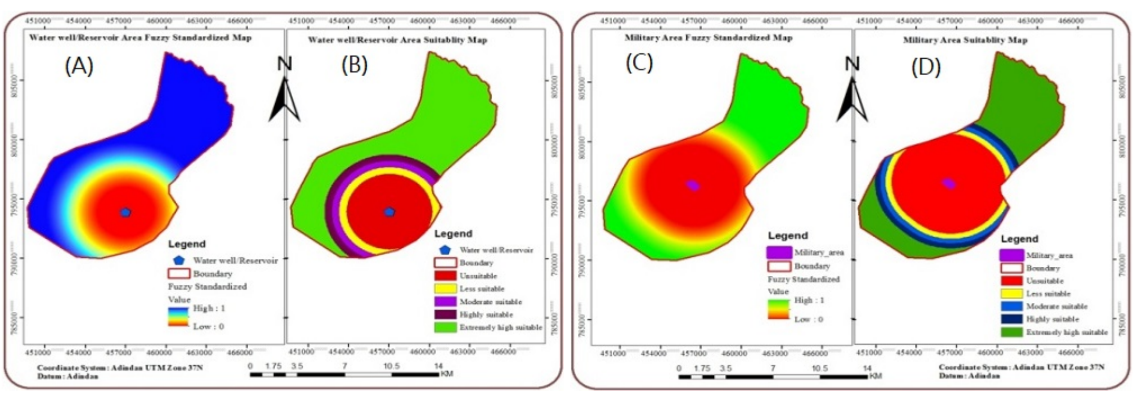


Fig. 2 (A) Land use/Cover fuzzy standardized map (B) Land use/land Cover suitability map.

3.2 Discussion

The present study represents an important step in addressing a critical gap in the selection of solid waste disposal site and enhances environmental acceptability. Solid waste dumpsite should be located at a suitable distance from roads to reduce the relative cost for transportation. According to Demesoukal *et al*. (2013), a minimum distance of 500m buffer should be maintained for road suitability location. The river was also a factor due to pollution problems and contamination by leach so, no solid waste disposal should be sited within the floodplain of the rivers and a minimum distance of 2000m should be maintained (Gemitzi *et al*., 2007; Soroudi *et al*., 2017). The cemetery area is cultural heritage sites and distance of 1500m used with linear and monotonically increasing fuzzy type and shape due to problems and complaints about the residents (Nas *et al*., 2010). Areas found within 1000-meter buffer distance from environmentally sensitive areas were considered unsuitable for solid waste disposal sites due to the high permeability of soil near the fault and keep groundwater contamination (Rafiee *et al*., 2011; Foomani *et al*., 2017). Water well is an important environmental criterion for the landfill site selections process and according to Nas *et al*. (2010), a minimum distance of 300m off from wells and reservoirs for locating a dumping site should be used. and areas located within this distance are unsuitable, and the more the long distance a landfill moves the more the suitability is due to less exposure to pollution and contamination.

Commercial areas include building areas such as business centers, areas developed by many infrastructures, and it is a source of hazardous wastes. Therefore, during site selection, minimum distances of 3000 meters need to be considered since it causes bad odors and depreciation of land in the surrounding areas (Foomani *et al*., 2017). Solid waste disposal must be 3000m far away from the military area since areas used for testing military equipment's or training military personnel are not open for public usage (Alfy *et al*., 2010). Social service sites should consider landfill planning to avoid possible interventions and risk against human health; we need to consider a minimum distance of 500 meters (Hasan *et al*., 2009; Semaw, 2018). The interpretation of the final WLC suitable shows there are five categories of suitability levels. The final WLC map generated showed in figure 5 and table 4 indicated that unsuitable, less suitable, moderately suitable, highly suitable, and extremely highly suitable areas respectively for solid waste dumping sites.



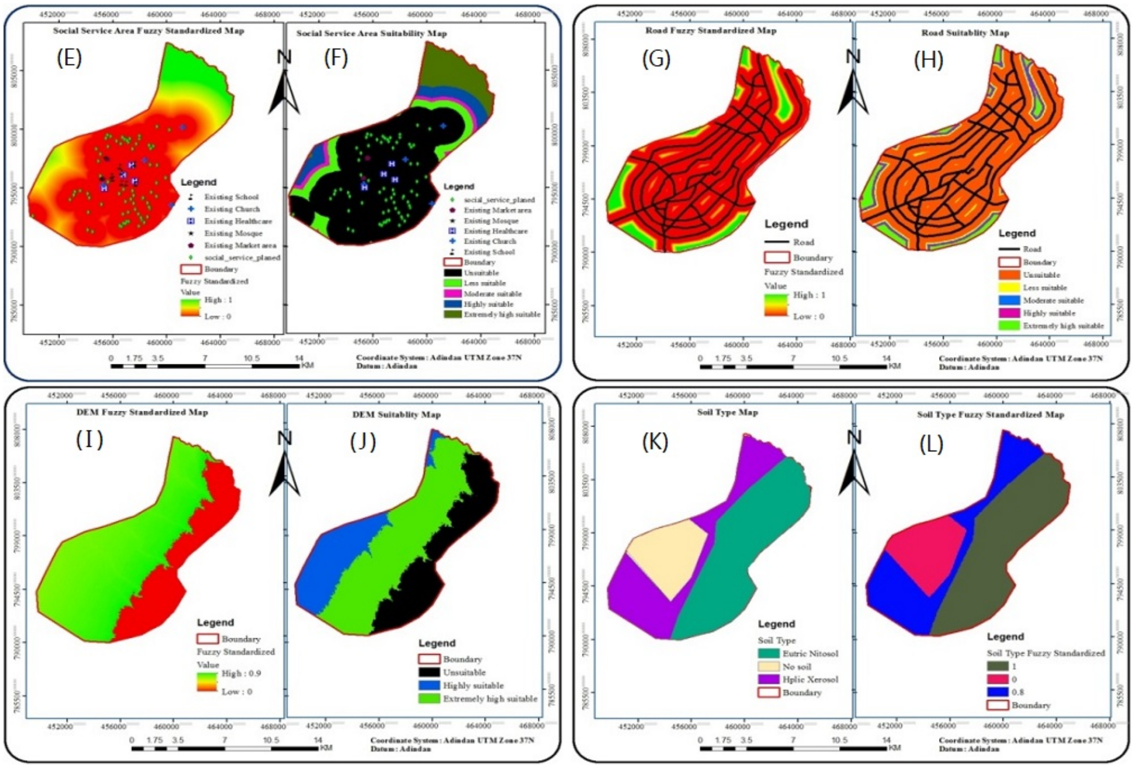


Fig. 3 Map showing Fuzzy Standardized and Suitability of each criterion (A & B: River, C & D: Cemetery area, E & F: Environmental sensitive area, G & H: Commercial area, I & J: Residential area, K & L: Slope in percent).

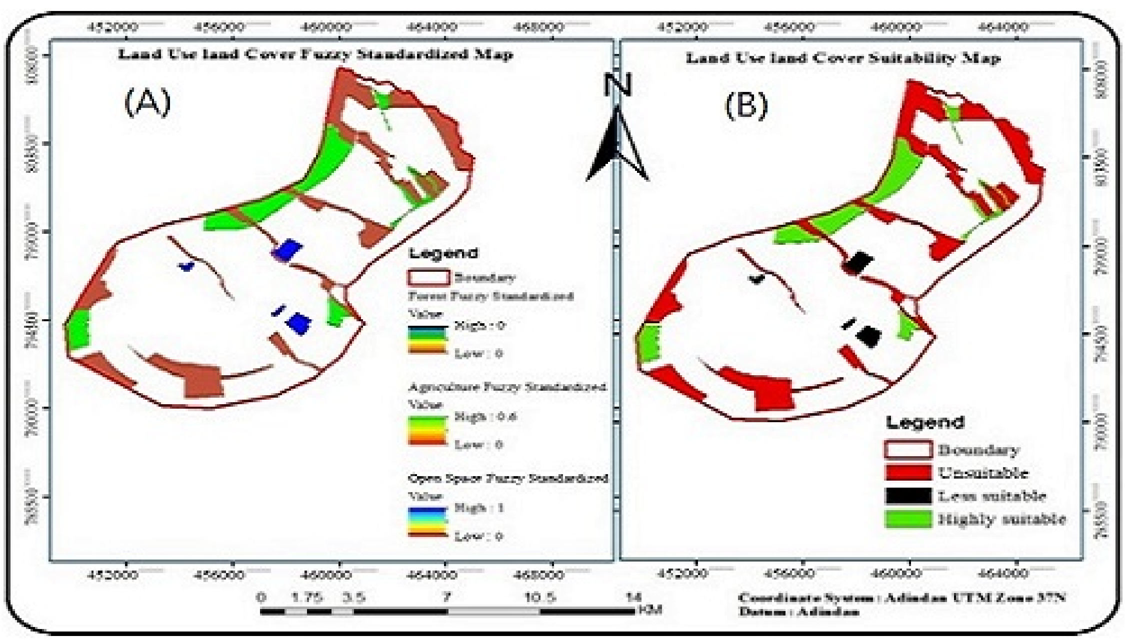


Fig. 4 Map showing Fuzzy Standardized and Suitability of each criterion (A & B: Water well/reservoir, C & D: Military area, E & F: Social services, G & H: Road, I & J: DEM in meter, K & L: Soil type).

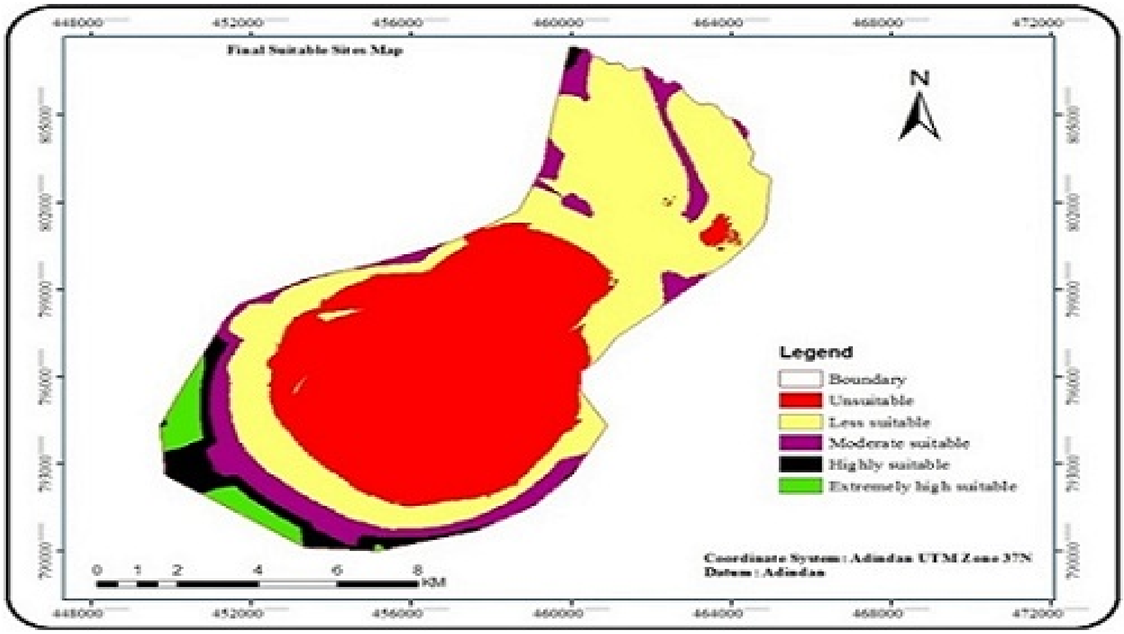


Fig. 5 Final WLC suitable sites.

Table 4 Weighted linear combination of Solid waste disposal Site Suitability Area.

Suitability Level	Value	Area (ha)	Percent
Unsuitable	1	5356.5	41.5
Less suitable	2	3959.0	30.7
Moderate suitable	3	2110.1	16.4
High suitable	4	966.8	7.5
Extremely suitable	5	500.8	3.9
Total		12893.2	100.0

By using the stated criteria, suitable areas for solid waste dumping sites potential were on the southwestern parts of the town. To evaluate the solid waste disposal sites, criteria such as distance from the road, the river, the residential areas, and the commercial areas were used. Finally, as showed in figure 6A, class site 3 (rank 1) is selected as the most suitable site for municipal solid waste disposal. This is because it is (0.9km) far away from the road, (2.653km) far away from the river, (3.17km) far away from residences, and (4.132km) far away from commercial areas. The other sites are site 1 (rank 2) and site 2 (rank 3) respectively. Generally, six final evaluated candidates of the solid waste disposal sites for Shashemene town were put in table 5, and presented with their area and geographical location and in figure 6B.

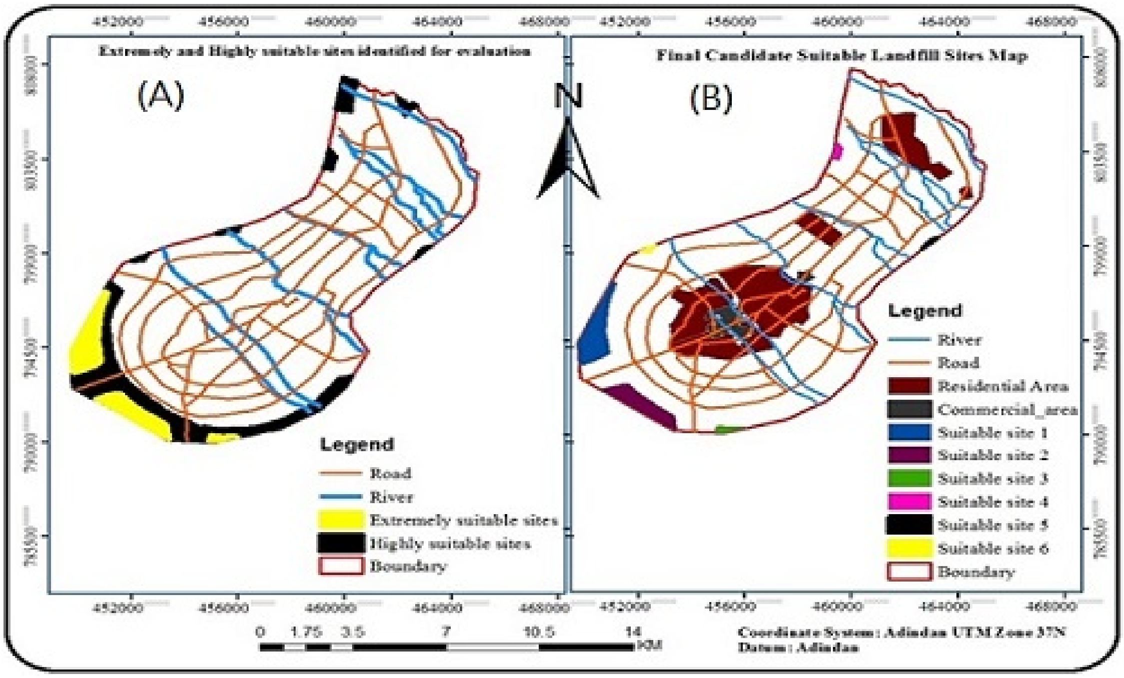


Fig. 6 (A) Extremely and Highly suitable sites identified for evaluation map (B) Final evaluated suitable landfill candidate sites map

Table 5 Final candidates of suitable sites.

Final class of suitability	Geographical location		Area (ha)
	Latitude	Longitude	
Suitable 1	38^{o}35'38.59"N	7^{o}08'58.30"E	25.9
Suitable 2	38^{o}32'58.77"N	7^{o}11'13.57"E	205.2
Suitable 3	38^{o}33'59.44"N	7^{o}09'37.50"E	268.8
Suitable 4	38^{o}37'56.98"N	7^{o}16'06.82"E	24.4
Suitable 5	38^{o}34'07.01"N	7^{o}13'35.95"E	7.6
Suitable 6	38^{o}39'50.79"N	7^{o}13'49.00"E	6.8

4 Conclusions

Since the landfill is a fundamental step in waste management strategy, the landfill site selection demands in-depth consideration. Setting of the landfill sites is a multidisciplinary and a very complex process, therefore, careful consideration of all factors ranging from environmental to economic is required. In the present study, the flexibility to apply such models as WLC, the combination of GIS, fuzzy logic (for standardization of factor maps), Boolean logic (for standardization of constrain maps), and multi-criteria assessment methods (MCDM) was used for MSW landfill sitting. Although a weighted value was assigned to factors in fuzzy theory by applying the Analytical Hierarchy Process (AHP) method according to their importance for the suitability and consistency ration indicated 0.08.

The four sub criteria of road, river, residential area and commercial area are the most determinant sub main criteria used to evaluate the potential of solid waste disposal site so as to choose the final best suitable site. Finally as shown on figure 6A, the most suitable site suggested in this study was about 25.9 hector with geographical coordinate of the selected site is 07^{o}8'58.304"N and 38^{o}35'38.59"E. In addition, the distance from nearest road, river, residences and commercial area is (0.9km), (2.653km), (3.17km) and (4.132km) respectively. Overall, the final capability map generated by the weighted linear combination method represents that 41.5% of the study area is not suitable for landfill sitting, while low, moderate, high and extremely high suitable classes cover 30.7%, 16.4%, 7.5% and 3.9% respectively of Shashemenetown. Finally, six most highly suitable solid waste disposal sites were identified for Shashemene town but the final decision may be influenced by political opinion, public opinion, economic studies, land ownership, and other field studies should be considered for final decision.

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Conflict of interest

The author declare that no conflict of interest.

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