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Case Study

Application of hierarchy-fuzzy analysis models and artificial neural networks in locating urban waste burial (case study: Lali city)

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A B S T R A C T

Background and objective: Today, waste burial is the most common method in many countries due to its lower cost and acceptance of a wider range of waste. In locating the waste landfill, various parameters such as the needs of urban communities, government, and environmental laws, and a large number of quantitative and qualitative criteria are evaluated. For this purpose, several multi-criteria decision-making methods are used in prioritizing suitable places.
Materials and methods: This study aims to investigate the suitable places to bury urban wastes in Lali city using a hierarchical-fuzzy analysis process (FAHP) along with a spatial information system and artificial neural network. For this purpose, data such as slope, slope direction, geology, land use, fault, precipitation, soil science, topography, vegetation, communication lines, hydrographic networks, wind, underground water level, and population centers as Information layers were used to locate the waste burial. After standardizing and preparing the maps, the steps related to the weighting of the desired layers were carried out to achieve the weight and importance of each in the positioning process. Then, pairwise comparisons were made between the indicators based on fuzzy numbers and using the FAHP technique.
Results and conclusion: Considering all the effective factors in locating and weighting each of the criteria and sub-criteria and combining the data with GIS and artificial neural networks, the proposed areas for landfilling according to the direction of the prevailing winds in the region, in the southeast part of the range Studies were considered that the city has the least development in this direction. Whereas, the location of the current waste burial site is located in an inappropriate place in the north of the city and a tourist area.

1. Introduction

One of the environmental consequences caused by the increase in population in urban areas is the change in consumption patterns and food habits and the increase in packaged materials, which

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results in an exponential increase in the amount of urban solid waste. So that now disposal of the waste caused by this consumption is one of the major and costly problems for most city managers (He et al., 2021).

Landfilling of waste is the most common disposal method in many countries due to its lower cost and acceptance of a wider range of waste (Ghane Ezabadi et al., 2021). Choosing a waste landfill is one of the important steps in urban solid waste management, which is done carefully and through a practical process due to the harmful environmental, economic, and ecological effects of the waste landfill (Chang et al., 2008). Among the criteria and criteria for choosing suitable places for the sanitary burial of waste, we can mention the geological characteristics, access roads, slope, faults, land use, distance from urban and rural centers, the geology of the region, hydrography, and underground water of a region (Yousefi et al., 2011). It seems necessary to use new tools and technologies, including GIS spatial information systems, to find a suitable burial place widely used in environmental planning to reduce the negative consequences of waste (Abdoli, & Samiei Zafarqandi 2018). This research identifies the best waste burial place in Lali City using a hierarchical-fuzzy analysis process, GIS, and an artificial neural network.

1.1. Analysis Hierarchy Process (AHP)

The AHP method, based on the human brain's analysis for complex problems, was proposed by a researcher named Thomas L. Saati in the 1980s. This technique is based on paired comparisons and allows researchers to examine different scenarios (Masoumi et al., 2014). The process of rank order analysis is a flexible, strong, and simple method, and it works best in situations where the criteria for choosing options are conflicting. This process involves different options in decision-making and allows for sensitivity analysis of criteria and sub-criteria. This process has five key steps: 1- Forming a hierarchical structure 2- Forming a pairwise comparison matrix 3- Calculation of eigenvector and eigenvalue 4- Carrying out consistency test and weight calculation 5- Consistency test checks whether the answers of the questionnaires are consistent or not.

1.2. Fuzzy hierarchical analysis process (FAHP)

The fuzzy hierarchical analysis method was presented by Chang in 1996 under the title of developmental analysis method (Chang 1996). In short, the FAHP model has steps including drawing a hierarchical diagram and defining fuzzy numbers to perform pairwise comparisons. To make comparisons, it is necessary to define fuzzy numbers and fuzzy scales, which are given in Table (1).

Table 1- Linguistic and fuzzy variables and their scales to prioritize criteria

definite number	Definition	Triangular fuzzy scale
1	exactly equal	(1,1,1)
2	Equal importance	(3.2,1,1.2)
3	Weak significance	(2,3.2,1)
4	Strong significance	(5.2,2,3.2)
5	Very strong importance	(3,5.2,2)
6	Absolute importance	(7.2,3,5.2)

The normal hierarchical analysis method does not correctly reflect the way of human thinking, because exact numbers are used in the pairwise comparisons of this method. On the other hand, fuzzy logic can mathematically formulate many concepts and systems that are imprecise and ambiguous and provide the basis for reasoning and decision-making in conditions of uncertainty (Saaty 1988). The fuzzy membership function model helps to overcome the uncertainty and make the fuzzification of a method compatible with human language. The steps of the fuzzy hierarchical analysis method according to Chang et al. are as follows (Chang, 2008):

Step 1: Draw a hierarchy diagram. Step 2: Define fuzzy numbers to perform pairwise comparisons. Step 3: Form the pairwise comparison matrix (A) by using fuzzy numbers. Step 4: Calculate the weights of the layers. Step 5: De-fuzzification. In the end, de-fuzzification of the weights is done for each layer and the weight of each layer is calculated using the method of the center of the region.

1.3. Fuzzy logic model operators

These operators include fuzzy union, fuzzy sharing, fuzzy algebraic multiplication, fuzzy algebraic addition, and fuzzy gamma operator.

1.3.1. Fuzzy gamma operator

According to equation (1), this operator is created by combining the product of fuzzy algebra and the sum of fuzzy algebra:

$$\mu_{combination} = (FuzzySum)^{\gamma} \times (Fuzzy\,\mathrm{Pr}\,oduct)^{1-\gamma} \quad (1)$$

In this regard, the value of γ can be determined between 0 and 1. If its value is selected as 1, the relation will be converted into a fuzzy addition operator, and if its value is selected as 0, the relation will be converted into a fuzzy multiplication operator. The gamma operator is more useful than other fuzzy operators and is used when some parameters' effect decreases and some increase. For this reason, in this research, the gamma operator has been used in locating the landfill site.

Much research has been done in the field of waste burial. In 1997, among others, Charnpratheep et al. conducted research on the application of the AHP method in the location of the waste disposal site, in which they used the combination of this method and the fuzzy method in the GIS environment for the initial screening of the burial sites in Thailand (Charnpratheep et al., 1997). In 2008, Chang et al. researched the selection of solid waste landfills in Harlingen, located in the south of Texas (He et al., 2020). In his master's thesis, Shahabi investigated the role of geomorphic factors in locating the landfill site of urban waste in Saqqez using GIS models and remote sensing technology (Shahabi, 2018). In 2015, Shah Ali also located Zanjan's urban waste landfills using the fuzzy method. He has done his analysis by considering parameters such as slope, geological conditions, surface water, and distance from roads (Shah Ali, 2015).

2. Materials and methods

2.1. Study area

Lali City with an area of 1418 square kilometers is located in the north of the capital of Khuzestan province and 175 kilometers from Ahvaz City. It borders Andika city from the east and northeast, Masjid Suleiman city from the south and southwest, the Sardasht section of Dezful city from the north and northwest, and Gotvand city from the west Fig. 1 and has a population of 37,486 people.

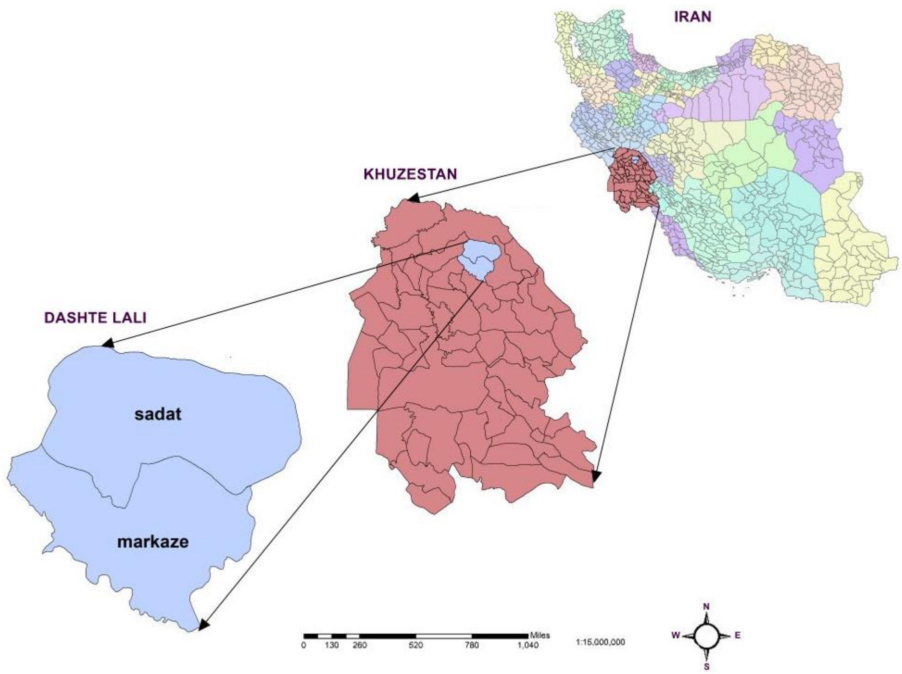

Fig. 1 - Location of the studied area

2.2. Methods

Preparation of a conceptual model of waste burial location

The conceptual model of waste disposal placement is a framework for guiding the placement steps, which is important in the selection, preparation of layers, and combination of factors. This model is important to clarify the expert's mind regarding different factors and how they affect the selection of suitable waste burial places. Fig. 2 shows the conceptual model of waste disposal location in Lali City.

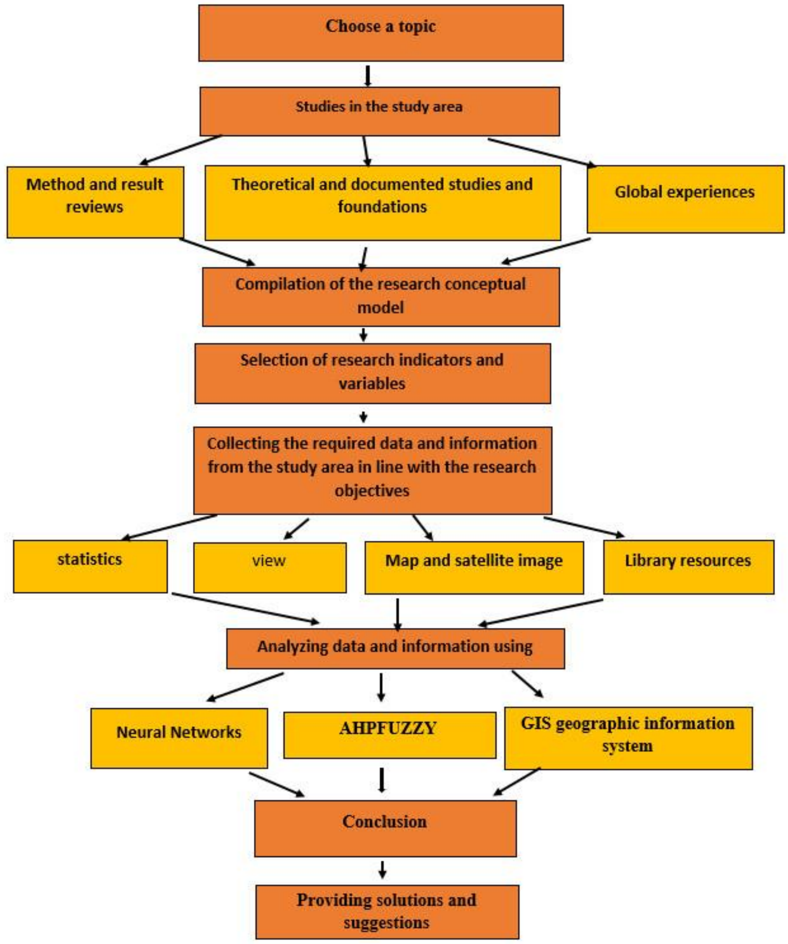

Fig. 2- Conceptual model of waste disposal location in Lali city

The method of conducting this research was field and analytical-descriptive. Based on the Qanbari and Jamali; and Parsasyrat research (2015), information layers including slope, slope direction, geology, land use, fault, precipitation, soil science, topography, vegetation, communication lines, hydrographic networks, wind, underground water level, and Population centers were used as information layers in five indicators of technical factors, social and economic factors and environmental factors for waste burial location. Then, experts made pairwise comparisons between indicators and components based on the fuzzy numbers in Table (2) and using the FAHP technique.

Table 2 - Trigonometric fuzzy numbers

priorities		equivalent of prioritiesThe fuzzy		
		lower limit(L)	Average(M)	upper line(U)
Equal importance	1	1	1	1
Equal to relatively more important	2	1	2	3
Relatively important	3	2	3	4
Relatively important to very important	4	3	4	5
great importance	5	4	5	6
High to very high importance	6	5	6	7
Very important	7	6	7	8
Very much to absolutely more important	8	7	8	9
importantMore	9	8	9	10

Also, some data were standardized and their fuzzy maps were prepared.Next, the maps were put together with the gamma method to carry out location operations and identify suitable areas for waste disposal by overlapping information layers in the GIS environment and applying the weights of indicators and components. Finally, three-dimensional modeling of this area was done in the Voxler software environment using artificial neural networks after determining the appropriate area for waste burial. Meanwhile, ArcGIS, ENVI, Arc Hydro Tools, MicroStation, Google Earth, Voxler Mapsource, IDRISI, and Office software were used in the research.

2.3. Data collection and preparation

At this stage, it is necessary to examine the collected information and prepare it for the required analysis. In this way, the scale and image system of the layers should be the same. The steps of preparing the layers in the GIS environment are presented in Fig. 3.

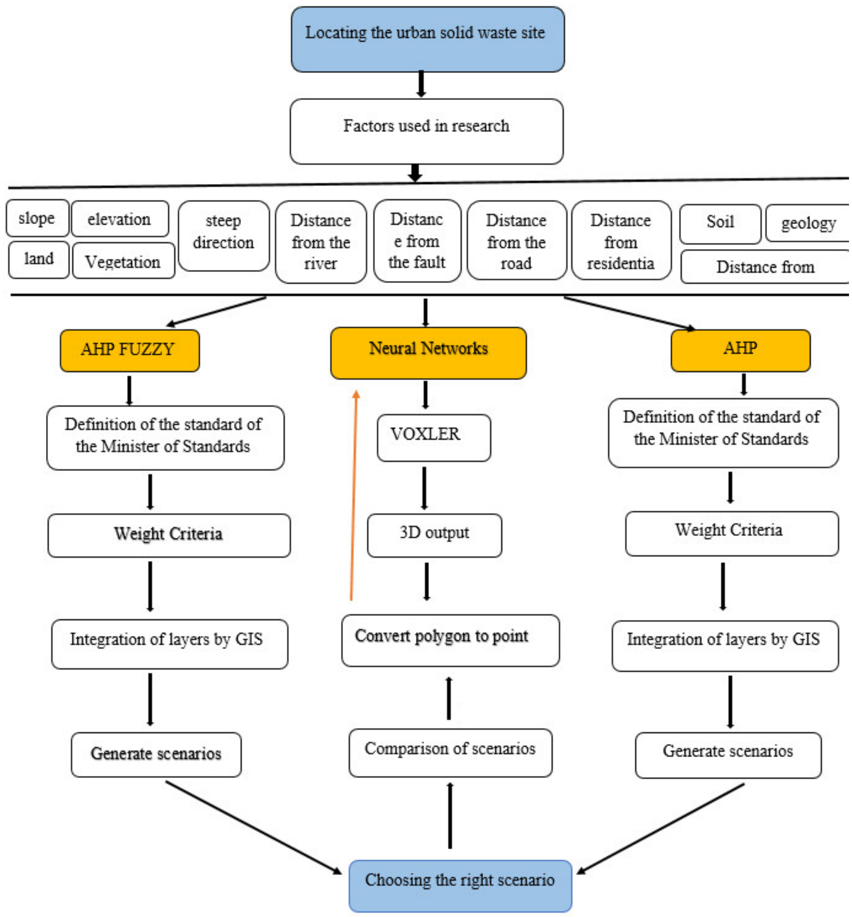

Fig. 3- Steps of preparing layers in the GIS environment

2.3.1. Process effective criteria in locating waste landfills

The layers were compared two by two using fuzzy numbers, by the opinion of experts, and entered in the corresponding tables as fuzzy numbers. In Fig. 4. , fuzzy numbers are used and their triangular fuzzy scale is given. After forming the pairwise comparison matrix and completing it, using the developmental analysis method, the weight of each criterion was determined. To do this, the program written in Excel and MATLAB software environment was used. By entering the data of the comparison tables in the form of fuzzy numbers, the weight of each criterion was determined as shown in Fig. 5 . After applying the proportional membership function, each layer was multiplied by the corresponding weight and finally, a standardized map of each criterion was created.

	slope			elevation			steep direction			Distance from the river			Distance from the fault			Distance from the road		
slope	1	1	1	0/594200819	0/659753955	0/734849907	1/64375183	2/047672511	2/511886432	0/436648417	0/5	0/581810759	0/560977573	0/630957344	0/708536772	0/308133914	0/367097772	0/448903884
elevation	1/360822108	1/515716567	1/682932718	1	1	1	0/511462278	0/624830384	0/757858283	0/742055697	0/850283	0/964192504	0/717741634	0/839378327	0/969640266	0/380124525	0/440930103	0/513533044
steep direction	0/398107171	0/488359342	0/608364342	1/319507911	1/600434334	1/955178402	1	1	1	1/274288769	1/507200766	1/782602458	0/724779664	0/821875915	0/950979393	0/362389832	0/417589805	0/482096252
Distance from the river	1/718771928	2	2/290172049	1/037137289	1/176079023	1/347607739	0/560977573	0/663481616	0/784751482	1	1	1	1/045639553	1/319507911	1/600434334	0/821875915	1/027066087	1/201124434
Distance from the fault	1/411359352	1/584893192	1/782602458	1/031310306	1/191357898	1/393259011	1/051547497	1/216728684	1/379729661	0/624830384	0/757858283	0/9563525	1	1	1	0/870550563	1	1/148698355
Distance from the road	2/227648357	2/724069927	3/245342223	1/947294361	2/267933155	2/630716865	2/074274579	2/394694477	2/759459323	0/832553207	0/973647181	1/216728684	0/870550563	1	1/148698355	1	1	1
Distance from residential areas	1/173160676	1/401131032	1/772587203	1	1	1	1/189460822	1/551845574	2/082846253	0/750499042	0/870550563	1/069610376	1/148698355	1/319507911	1/484111394	1/069610376	1/461442552	1/933182045
Soil type	0/513533044	0/608364342	0/717741634	1/059223841	1/284735157	1/64375183	0/636129818	0/702775546	0/781587058	0/346572422	0/412234317	0/488359342	0/265641327	0/334162531	0/427543583	0/941744833	1/061858759	1/201124434
geology	1/64375183	1/903653939	2/168943542	0/630957344	0/802741562	0/973647181	1/393259011	1/741101127	2/208166722	0/268246152	0/374915371	0/542235886	0/876905622	1	1/140373576	0/950979393	1/228659679	1/504731955
land use	1/113824179	1/393259011	1/717241407	2/382715796	2/983145	3/641128406	3/743324423	4/982923758	6/108504014	0/285738091	0/370107172	0/506495684	1/092388464	1/368510858	1/682932718	1/092388464	1/379729661	1/728483122
Vegetation	0/773997397	0/882646179	1	0/693144843	0/839378327	1	0/870550563	1/059223841	1/29199401	0/388838712	0/444544768	0/513533044	0/973647181	1/13754383	1/350960039	0/927317892	1/078378847	1/261914689
Distance from groundwater	0/894112961	1/045639553	1/228659679	1/741101127	2/290172049	2/861938162	1/621226166	1/974350486	2/352158045	0/677610913	0/802741562	1	0/870550563	1/013894214	1/184664453	1/515716567	1/838416287	2/168943542

	Distance from residential areas			Soil type			geology			land use			Vegetation			Distance from groundwater		
slope	0/564147139	0/713709123	0/852398158	1/393259011	1/64375183	1/947294361	0/461053956	0/525305561	0/608364342	0/582329308	0/717741634	0/897807768	1	1/132956811	1/29199401	0/813895025	0/9563525	1/118426915
elevation	1	1	1	0/608364342	0/778370542	0/944087511	1/027066087	1/24573094	1/584893192	0/274640136	0/335216692	0/419689164	1	1/191357898	1/442699906	0/349413559	0/436648417	0/574349177
steep direction	0/480112249	0/644394015	0/840717056	1/279448002	1/42292942	1/572006171	0/452864356	0/574349177	0/717741634	0/163706203	0/20068539	0/267142221	0/773997397	0/944087511	1/148698355	0/4251415	0/506495684	0/616817086
Distance from the river	0/934919876	1/148698355	1/332446738	2/047672511	2/425804834	2/885399812	1/844215823	2/667268608	3/727919273	1/974350486	2/701920077	3/499708406	1/947294361	2/249492226	2/571760398	1	1/24573094	1/475773162
Distance from the fault	0/67380387	0/757858283	0/870550563	2/338942837	2/992555739	3/764474495	0/876905622	1	1/140373576	0/594200819	0/730721276	0/915425266	0/740214345	0/879087006	1/027066087	0/84412088	0/98629619	1/148698355
Distance from the road	0/517281858	0/684255429	0/934919876	0/832553207	0/941744833	1/061858759	0/664570189	0/813895025	1/051547497	0/578541952	0/724779664	0/915425266	0/792446596	0/927317892	1/078378847	0/461053956	0/543946443	0/659753955
Distance from residential areas	1	1	1	1/73131904	1/974350486	2/220643035	1/13754383	1/401131032	1/695218203	1/718771928	2/019611595	2/338942837	1/065208538	1/343369895	1/665106415	0/392026341	0/44705648	0/513533044
Soil type	0/450320013	0/506495684	0/577594295	1	1	1	0/875469241	1/031310306	1/216728684	0/778370542	0/889089536	1/009805798	0/308133914	0/403638557	0/560977573	1/515716567	1/820564203	2/123717518
geology	0/589894562	0/713709123	0/879087006	0/821875915	0/969640266	1/142244585	1	1	1	0/543946443	0/659753955	0/802741562	0/49111861	0/608364342	0/724779664	0/644394015	0/705679676	0/778370542
land use	0/427543583	0/495144711	0/581810759	0/990289422	1/124746113	1/284735157	1/24573094	1/515716567	1/838416287	1	1	1	0/847609102	0/98223722	1/133966578	0/627412416	0/767703899	0/957204865
Vegetation	0/600562217	0/744396613	0/938783313	1/782602458	2/477464016	3/245342223	1/379729661	1/64375183	2/036168005	0/881860206	1/018084002	1/179789125	1	1	1	0/84412088	1/107566343	1/368510858
Distance from groundwater	1/947294361	2/236853829	2/550849001	0/470872417	0/549280272	0/659753955	1/284735157	1/417073545	1/551845574	1/044708438	1/302585542	1/593847961	0/730721276	0/902880451	1/184664453	1	1	1

Fig. 4- AHP fuzzy criteria matrix

	Fuzzy sum of each row			Fuzzy composite expansion			The degree of preference of Si over Sk											degree of preferenc	Normalizatior	Weight criteria
slope	9/358397	10/895299	12/702273	0/0476155	0/0657435	0/0910816	1	1	0/1597548	0/6061098	0/5119874	0/4380484	1	0/8929988	0/2563046	0/6927281	0/3870412	0/159754823	0/029164137	0/029164137
elevation	8/9716904	10/258463	11/853876	0/045648	0/0619007	0/0849982	0/9067871	1	0/0650421	0/5051682	0/4101395	0/3366543	1	0/7993685	0/1618921	0/5975209	0/2861318	0/065042071	0/011873794	0/011873794
steep direction	8/6543431	10/128401	11/942343	0/0440333	0/0611159	0/0856326	0/8914857	0/9807501	0/0738032	0/5034565	0/4111879	0/3396809	1	0/7882609	0/1686614	0/5931624	0/2904302	0/073803197	0/013473187	0/013473187
Distance from the river	15/932855	19/62505	23/717098	0/0810663	0/1184198	0/1700634	1	1	1	1	1	1	1	1	1	1	1	1	0/182555599	0/182555599
Distance from the fault	12/057786	14/097357	16/52723	0/06135	0/0850651	0/1185085	1	1	1	0/5288671	0/9077709	0/8316353	1	1	0/6253043	1	0/778573	0/5288671	0/09654765	0/09654765
Distance from the road	12/798769	14/996284	17/70283	0/0651201	0/0904893	0/1269381	1	1	1	0/6215495	1	0/9247771	1	1	0/716658	1	0/8721985	0/621549548	0/11346735	0/11346735
Distance from residentia	13/376299	15/789997	18/775781	0/0680586	0/0952787	0/1346317	1	1	1	0/6983157	1	1	1	1	0/7918818	1	0/9481472	0/698315737	0/127481447	0/127481447
Soil type	8/6908556	10/055229	11/748932	0/0442191	0/0606744	0/0842457	0/8784372	0/9692062	0/9891393	0/0521849	0/4841924	0/3907927	0/1361978	0/7737022	0/147796	0/5759755	0/2691076	0/052184895	0/009526645	0/009526645
geology	9/8553289	11/708219	13/865322	0/0501439	0/0706487	0/0994213	1	1	1	0/2775751	0/7253384	0/6335439	0/2528205	1	0/3728087	0/8046241	0/5092438	0/252820483	0/046153795	0/046153795
land use	14/848965	18/363224	22/180919	0/0755515	0/1108058	0/1590483	1	1	1	0/9110471	1	1	1	1	1	1	1	0/911047132	0/166316755	0/166316755
Vegetation	11/116372	13/432979	16/186995	0/0565601	0/0810561	0/1160688	1	1	1	0/4836858	0/931737	0/8437749	0/3684837	1	1	0/5766195	0/7210094	0/368483683	0/067268759	0/067268759
Distance from groundwa	13/79865	16/373888	19/337325	0/0702075	0/0988019	0/1386583	1	1	1	0/7459146	1	1	1	1	1	0/840184	1	0/745914581	0/136170883	0/136170883

Fig. 5- The final weight of the effective criteria in locating the waste landfill with the FAHP method

2.4. Calculation of the area of the areas

After determining the final map, each generated zone’s area was calculated in the ArcGIS environment. In the end, polygon outputs were converted into points for 3D rendering and use in Voxler software.

2.5. Performing the FAHP process

In the fuzzy method for combining layers, the assigned fuzzy score changes after reclassifying each layer according to the importance of the layers. After preparing the fuzzy maps, using the fuzzy gamma operator and ArcGIS software, the areas with different fuzzy numbers are divided. The reason for choosing the fuzzy gamma operator is that it is more comprehensive than other operators. The higher this number is, the more favorable the area will be (Charnpratheep & Garner 1997).

3. Results and discussion

3.1. Fuzzy maps of each of the effective parameters in locating the residual

The maps resulting from the fuzzification of the parameters effective in locating waste landfills are shown in Fig. 6.

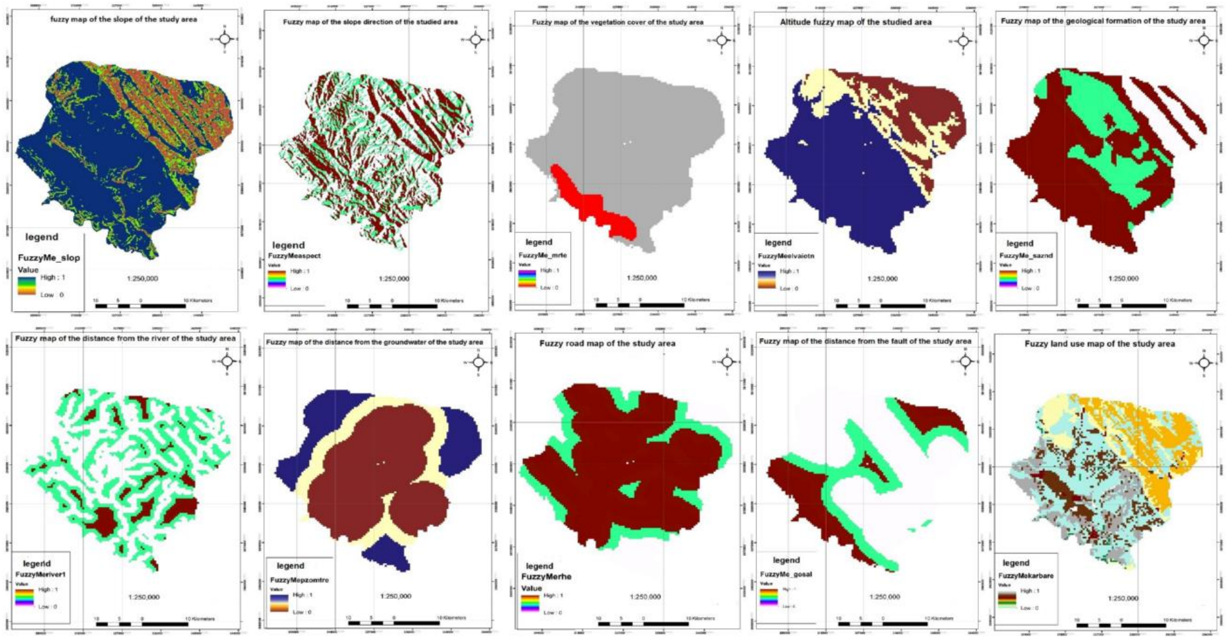

Fig. 6- Fuzzy maps of slope criteria, slope direction, vegetation cover, elevation, geology, underground water, distance from the river, road, distance from the fault, and land use

3.2. Consolidation, the weighting of data, overlapping of maps, and waste disposal site zoning

In this research, various gamma fuzzy functions such as 0.0-6.0-7.0-8.0-9.0 were used. The final map resulting from the combination of maps is shown in Fig. 7.

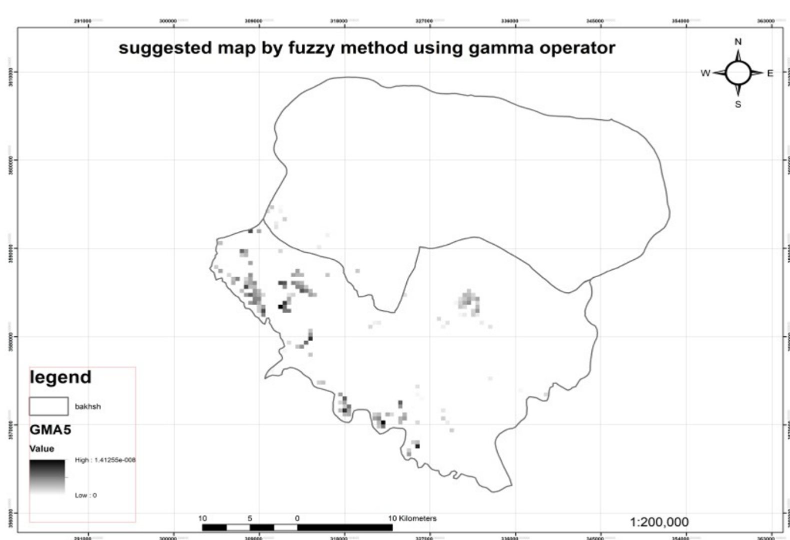

Fig. 7- The final map of the zoning of suitable areas for waste disposal with the FAHP method and the use of fuzzy gamma cloud

3.3. Artificial neural network analysis

After determining the appropriate area for waste burial, using an artificial neural network, 3D modeling of this area was done in the Voxler software environment Fig. 8. According to the standards, the burial depth should be at least 3 meters. Therefore, the suitable area for burying waste was classified from 20 cm to 3 meters deep and the volume of this area was calculated, which was estimated to be 21952000 square meters.

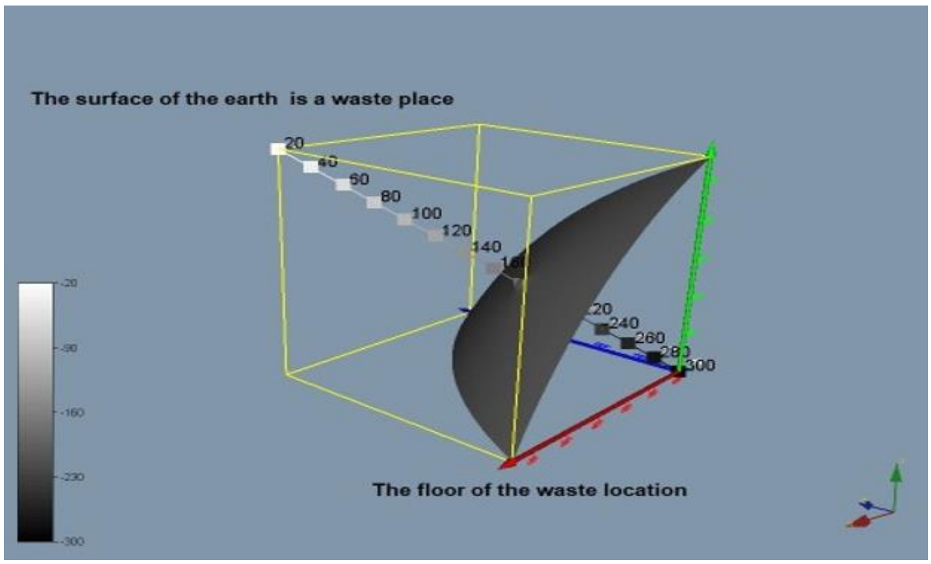

Fig. 8- 3D rendering of the proposed area for waste burial

According to the conducted investigations and field visits in the region, the best place has been suggested at a distance of 11 kilometers from Lali city Fig. 9.

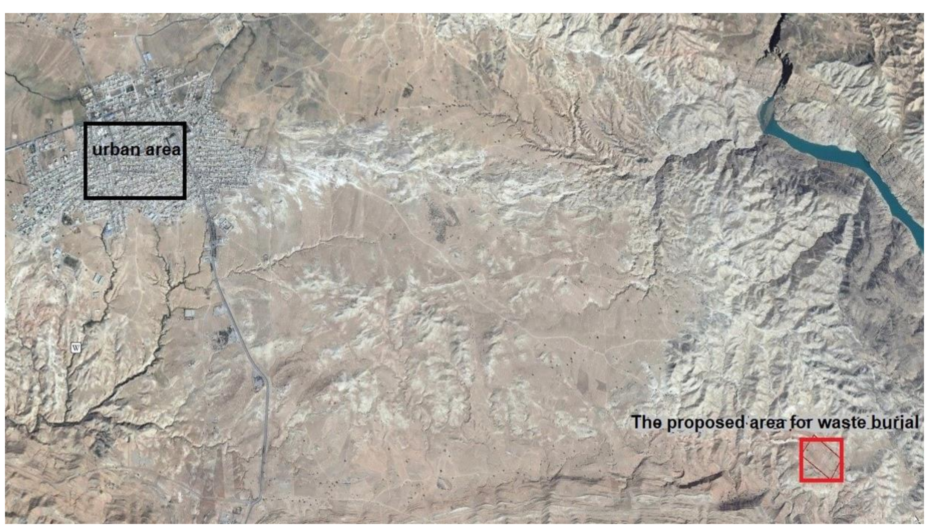

Fig. 9- The current location and the proposed location of the Lali garbage dump

4. Conclusion

The current location of the waste burial site of Lali city is located 5 km from Lali city and in an area called Ab-Shor area on the northern side of the city, 200 meters from the road connecting Lali to Indika, which is one of the recreational areas of Lali city. By examining the development map of Lali city in recent years, it was found that the expansion of residential and urban areas is mainly towards the west and to a lesser extent towards the north and south.

Depending on the geological and morphological conditions of the region, among the effective parameters in locating a suitable place for waste disposal, the slope is the most important and the distance from the underground water is the least important. Because a large part of the area has a high slope, the highest weight was given to the slope, and since the groundwater level in this area is very low, the distance from the groundwater is less important for location purposes and less weight is given to it. became.

According to the analysis and the direction of the prevailing winds, the proposed areas for landfilling are located in the southeast part of the study area, where the city has the least development in this direction. According to the conducted investigations and field visits in the region, the best place has been suggested in the range of latitude 325560.56 North and longitude 3574185.41 East at a distance of 11 kilometers from Lali city Fig. 9.

Studying morphological changes in river systems can help river management. In this study, the meandering evolution of the Dez River in mountainous and agricultural areas from 1995 to 2021 was investigated. For this purpose, the river SI in these areas was calculated at the time of the study. The results showed that the SI was constant in mountainous areas (2.10) and it changed in agricultural areas (2.10-2.14), but the river was very unstable in both areas. To investigate the reasons for river change in agricultural areas, the parameters of height, slope, monthly runoff changes, and riverbed soil type were examined.

Variations in altitude and slope were small and probably did not have much effect on river changes. But, the riverbed soil was loam and clay loam that have high erodibility. Also, the study of monthly runoff during this period showed that from 2018 to 2020, its amount increased compared to the previous year. Therefore, it is likely that the increase in runoff and the high erodibility of riverbed soil can be a reason for changes in river direction during this period. It is suggested that for future studies, the impact of human activities on changes in river course be examined, too.

Declarations

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AuthAuthors'tributions (All co-authors contributed to the manuscript)

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