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# The Analysis and Ranking of Spatial Distribution of Waste Landfill Potential, Using AHP Model and TOPSIS Technique (Case Study: Rasht)

Ameneh Rezaei[a*], Mahdi Zarrini[b]

[a]*Department of Civil Engineering, Astaneh Ashrafieh Branch, Islamic Azad University, Gilan, Iran*

[b]*Department of Civil Engineering, Astaneh Ashrafieh Branch, Islamic Azad University, Gilan, Iran*

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**Abstract**

One of the effects of a gradual population increase in the urban areas is waste in crescent and its disposal. Among the common methods of waste management, land filling is technically, ecologically and economically important. The purpose of this study is to determine the appropriate spatial potential for sanitary landfill of waste in Rasht, based on location criteria and using GIS and remote sensing. Zoning of suitable burial sites was done based on the 4 main criteria of land use, hydrological characteristics, geological characteristics and accessibility. In a current study, SRTM sensor data, which is paired with a short time interval (to reduce changes occurring at ground level) was used to prepare a digital model of land. The maps derived from the digital model of land, included elevation and slope maps that were used to prepare the criteria of the "geological profile." After standardization and preparation of maps, in order to achieve the weight and importance of each layer to find suitable landfills, the weight of the layers used was calculated by hierarchical analysis method. Considering the effective factors in locating the municipal waste landfill and weighing each of the criteria and sub-criteria, five values of very suitable, suitable, relatively suitable, inappropriate and very inappropriate were specified. To determine the priority of the very suitable areas, the TOPSIS method was used. Among the 9 sites introduced to the TOPSIS algorithm, site four, with an area of 89.36 hectare, which is located in the southern parts of Rasht, was determined as the most suitable place for waste disposal.

***Keywords**:* Waste, Hierarchical Analysis, GIS, Location

## 1. Introduction

Today, waste management in cities of a country has become an inevitable necessity that if it is not planned rapidly and accurately, it will produce irreversible effects on the natural and human environment (Karimipour, 2011). From the point of view of health engineers, land filling cannot be regarded as a common problem (Ejtemaee et al., 2018: 128). In developing countries, the source of waste is more related to hospitals, industries, and production market centers (Hussien et al., 2020).

[*] Corresponding author Tel: +98- 9113408098.
*Email address:* aylar.rezai@gmail.com.

High capabilities of GIS spatial information systems in managing and analyzing spatial data have led to presenting an efficient environment in order to conduct different steps of such analysis as location. (Mahdipour and SaadiMesgari, 2006).

According to the estimate made in 2011, Rasht (located in Gilan province) has reached a total population of about 918445 (Statistics Center of Iran, 2008). The highest amount of waste in Rasht is produced in city of Rasht. Rasht landfill is located in the southern part of the city in Saravan area (20 km from the city center). Unhygienic land filling of waste has created many problems for human and animal health (Karimpour, 2003). The studies carried out on waste disposal in recent decades have used a location-based approach focusing attention on spatial models. For instance, Themistoklis et al., in a study conducted to locate the sanitary landfill of solid waste in the Lemtus island in the North Aegean Sea, utilized a multi-criteria spatial decision-making method and identified the suitable sites for the sanitary landfill. In 2015, Paul et al. applied geographic information systems and network analysis tools to determine the most appropriate routes for municipal waste disposal in Calcutta. In another study conducted by Kinobe et al. (2015) in Kampala, multi-criteria models and network analysis were used in GIS, and it was concluded that in the scenario of selecting appropriate landfills, attention needs to be drawn to the Geographic information system (GIS) and network analysis as important requirements. In Iran, several studies have been concerned with the landfill issue. For example, Seidani explored the waste landfill using GIS and hierarchical analysis process (AHP) in Miankuh district of Ardal county. The results revealed that the distance from the population center of environmental protected areas, land use and water resources involve the most important indicators of locating. Moreover, the distance from infrastructure, geological formations and slope are held as the next rank. Eskandari (2011), using multivariate analysis and GIS, located the landfill of hazardous waste in Anarak city, located in Isfahan province. Ultimately, after combining and weighing 9 layers of information via AHP method and GIS software, the final map of landfilling hazardous waste was drawn in four categories of very appropriate, appropriate, average and inappropriate. Inappropriate to appropriate areas were removed and finally, 9 very appropriate areas were identified, taking into account the area required for construction of a hazardous waste landfill. In addition, Ghanbari et al. (2009) investigated the AHP method in locating landfills in Semnan city. In this regard, first a map was made from each of the effective economic, social and environmental factors. In the next step, each of the prepared layers was ranked from zero to five, so as low ranks indicated disproportion or less proportion and high ranks indicated more proportion.

The present study mainly aims to introduce a suitable model with respect to the studies conducted on the accurate locating of the landfills, and identify the district that receives the most adverse effects from municipal landfills in Rasht County. Various methods have been utilized to locate the landfill. Indeed, this study has focused on the analysis of appropriate landfills on the basis of relevant selected criteria using GIS spatial analysis and multi-criteria decision-making methods (AHP and TOPSIS).

In this regard, the authors of the present study attempted to evaluate the efficiency of AHP model along with the TOPSIS technique in order to determine the potential of spatial distribution of landfills in Rasht. To achieve this goal, the performance of the mentioned models has been investigated for 4 different criteria, including land use, hydrological characteristics, geological characteristics and accessibility. Each of the mentioned criteria encompasses some sub-criteria that a total of 18 effective sub-criteria were identified with respect to land filling in this study. The AHP model was applied in order to evaluate the mentioned criteria. It should be noted that, using the weights assigned to each criterion, waste landfill zoning was determined and the spatial potential of waste landfill in Rasht was zoned, as well. Furthermore, the TOPSIS technique has also been used to rank the suitable zones of landfills. In this study, the authors made an attempt to propose a comprehensive method of locating suitable landfill sites, so that it meets the criteria presented by previous researchers and uses new decision-making methods. Since the landfill issue involves social, economic and even cultural dimensions, in addition to environmental dimensions, it is necessary to take into consideration all the aspects in land filling decision models. Therefore, the main purpose of this study is to propose a comprehensive innovative decision-making method in landfill management. It is worth noting that the data collected in most cases were provided to the researcher at the provincial and county scales, and exploration of each of the site son a small- zone scale necessitates a more accurate knowledge of the area. This could be regarded as one of the limitations of the forthcoming study, which can be evaluated in future research via gathering more accurate data.

## 2. Materials and Methods

### 2.1. Locating

Locating is regarded as an activity that analyzes the capabilities of a region in terms of existence of suitable and sufficient land for a specific application. The indicators used in locating are different depending on the type of application, though they all align into choosing a proper location. (FarhadiGugeh, 2000: 36).

### 2.2. Multi Criteria Decision Making Methods

Multi-criteria decision models are used when a number of criteria (sometimes contradictory) are influential in the decision-making process and there is a relationship between the criteria and that issue. Decision-making models are divided into two main categories: multi-objective models and multi-criteria models.

### 2.3. AHP Method

AHP was proposed by a researcher named "Thomas-L-Saati" in 1970 based on the analysis of the human brain for complex fuzzy issues (Asgharpour, 2008: 298). This method is regarded as a decision-making instrument that allows for quantitative and qualitative criteria, financial and non-financial criteria as well as the interaction between them. Moreover, AHP is used to integrate criteria differences to rank the options.

### 2.4. TOPSIS Method

The TOPSIS algorithm is a very powerful compensatory multi-attribute technique applied in order to prioritize the options via simulating the ideal response. In this method, the selected option must have the shortest distance from the ideal answer and the farthest distance from the most inefficient answer. Indeed, m options are evaluated through indices and each problem can be considered as a geometric system containing m points in a n-dimensional space in a matrix. Using Equation (1), the decision matrix is unscaled and normalized. Equation (1): r_ij calculation in TOPSIS algorithm

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (1)$$

By effect of weight of the indices on the normalized matrix, the minimum and maximum values in each index are obtained (Relationship (2)).

Equation No. (2): Introduction of two options of positive ideal and negative ideal in TOPSIS algorithm

$$\text{Positive ideal option} \quad A^{*} = \{(max_i v_{ij} | j \in J) ،(max_i v_{ij} | j \in J') i = 1,2, \ldots, m\}$$
$$= \{v_1^{*}, v_2^{*}, \ldots, v_n^{*}\}$$

$$\textit{Negative ideal option} \quad A^{*} = \{(max_i v_{ij} | j \in J) ،(max_i v_{ij} | j \in J') i = 1,2, \ldots, m\}$$
$$= \{v_1^{-}, v_2^{-}, \ldots, v_n^{-}\}$$

Using Equation (3), positive and negative ideals are specified.

$$S_j^{*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{*})^2} \quad 2$$

Equation No. (3): Calculating the distance from positive and negative ideals

$$S_j^{-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^{-})^2} \quad 3$$

And using Equation (4), the similarity index is obtained and the high and low priorities are calculated.

$$C_{i^*} = \frac{S_{i^-}}{S_{i^*} + S_{i^-}} \quad 4$$
$$0 < C_{i^*} < 1$$

Equation No. (4): Calculating the relative proximity to the ideal solution

## 2.5. Waste

Waste is assumed as solid, (liquid, and gas materials (other than sewage) that are directly or indirectly produced by human activity and is considered waste by the producer. In general, there are three disposal methods for municipal solid waste, including burial, incineration and composting.

## 2.6. Landfill Locating Criteria

Regarding the process of selecting a suitable place for land filling, several instructions have been provided by relevant organizations at the international level, each of which has provided guidance for location according to local conditions. The U.S. Environmental Protection Agency also defines criteria for land filling municipal solid waste as important regional aquifers, airports, floodplains, geologically unstable areas, and archaeological sites (Environmental Protection Agency, 1996-2000).

The Iranian Department of Environment has also proposed some standards concerning land filling in the cities. As a matter of fact, it has provided different locations according to climate and other environmental conditions, some of which are listed in Table 1, (Heidarzadeh, 2001).

**Table 1.** Landfill Standards defined by The Iranian Department of Environment

| Criteria Name | Effect and Rules |
|---|---|
| Fault | Minimum distance 500 meters |
| Surface water resources | 300 meters minimum horizontal distance from river level 5- and 200-meters minimum distance from river level 4 |
| Groundwater | The minimum depth of groundwater table level is 10 meters and the minimum horizontal distance is 300 meters |
| Soil | It has surface soil as much as possible of silty clay and in the next step, of sand material |
| Residential areas | Minimum distance 1 km from rural areas and minimum distance 3 km from city center |
| Geology | It has bedrock as much as possible of igneous and impermeable rocks. |
| Roads | Minimum distance of 250 meters |
| Slope | Slope less than 20% |
| Historical centers | At least 500 meters |
| Wind | Not locating the landfill in the upstream of the prevailing winds in the area |
| Land use | Do not have valuable uses such as agriculture, forests, wetlands and pastures |
| Airport | It has a minimum distance of 3 km and lands with a distance of more than 4 km |

## 2.7. Introducing the Studied Area

Rasht is one of the cities of Gilan province in northern Iran. According to the census of the Statistics Center of Iran in 2008, the population of this city was estimated at 715097 people. Rasht is located at the geographical coordinates $37^{\circ} and\ 1'^{\prime}$ North latitude of the equator and 48° و35́ ^́ to $49^{\circ} and\ 3'$ The longitude of the origin meridian is located between the heights of Talesh and the Caspian Sea. In terms of topography, Rasht is considered as a flat city located on a ridge, which is four kilometers long and two kilometers wide. (Database for Municipality Information of Rasht, 2006). Figure (1) shows the location of the region.

Saravan dumping site is the only landfill site in Rasht, located 20 km south of Rasht. The height of this place is about 20 meters above sea level. The total waste entering this place is about 470 to 540 tons per day, part of which encompass the municipal solid waste produced from the three areas of Rasht. In order to determine the location of landfills, it is important to take into account the boundaries of the area and the distance from the urban borders. Therefore, considering the high density of urban settlements in the Northern provinces, the area under investigation in the current study included a radius distance of about 41 km from the city center.

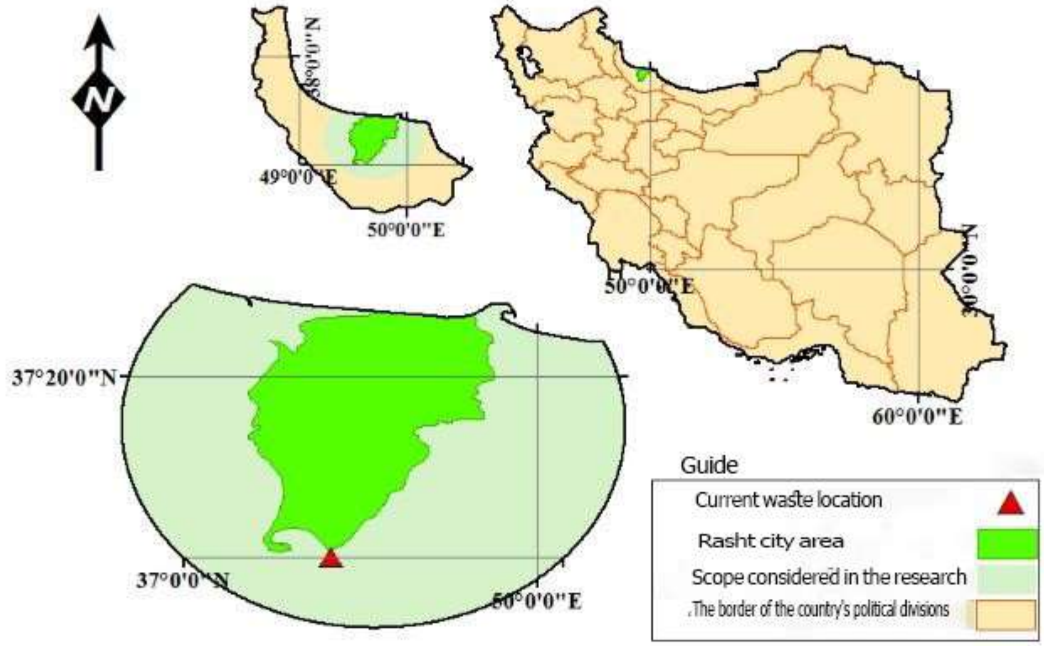



**Figure 1.** Location of Rasht and the area under investigation in this study

The prevailing wind in Rasht is in the westerly direction most of the year, and the northeast winds blow in May. Table (2) shows the directions and velocities of these winds.

**Table 2.** Annual wind speed in Rasht (knot) and hours, which indicates that most of the time

| Months of the year | April | May | June | July | August | September | October | November | December | December | February | March | Yearly | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominant wind direction | Western | Western | Western | Western | Western | Western | Western | Western | Western | Western | Western | Western | Western | - |
| Dominant wind speed | 2.2 | 2.6 | 2.9 | 2 | 2.2 | 2.2 | 2.8 | 2.9 | 2.9 | 2.9 | 2.8 | 2.5 | 2.9 | 2.7 |

Figure 2 shows the windrows of Rasht in all months we have wind stream and its maximum speed is in the southwest. Most winds move towards the west and the maximum turbulence in wind speed is in the south which varies from 7 to 15 meters per second. The wind temperature is higher in the east and northeast which the highest temperature has been reported in the northeast. The relative humidity in all directions except the south is almost same above 70% and in the south, it is 60%.

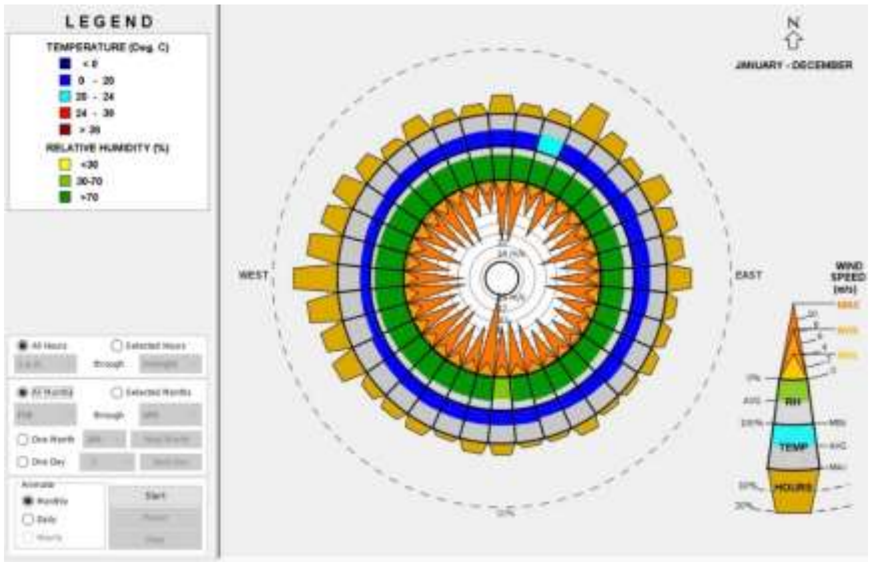



**Figure 2.** Wind speed diagram (Source: Abizi et al. 2019)

## 3. Research Findings

### 3.1. Description of the Method

After investigating the existing resources and related organizational criteria for the establishment of landfills, the criteria and indicators were organized into the four criteria of land use, geological characteristics, hydrological characteristics and access, while, criterion is related to sub-categories. Using pair wise comparisons between the elements of each criterion, which was performed by Expert choice software, the weight of the criteria was calculated. The research information layers, which include 19 effective sub-criteria in landfill, have been turned into raster layers according to the spatial processing tools of GIS, and then categorized into the five values of Very appropriate, appropriate, relatively appropriate, inappropriate and very inappropriate according to the data knowledge and expert opinions. Finally, the layers were combined and suitable sites were identified.

In order to implement the TOPSIS model, the input matrix is prepared according to the selected sites, determined in the previous step,  Options are ranked according to the ratio of the distance from the negative ideal solution to the total distance from the positive ideal and the negative ideal distance, based on the notion that the selected option should be the shortest distance from the positive ideal solution (the most important) and at the same time the farthest distance from the negative ideal solution. In order to facilitate the operation, the MATLAB software wad used. Chart (1) shows the conceptual model of the research.

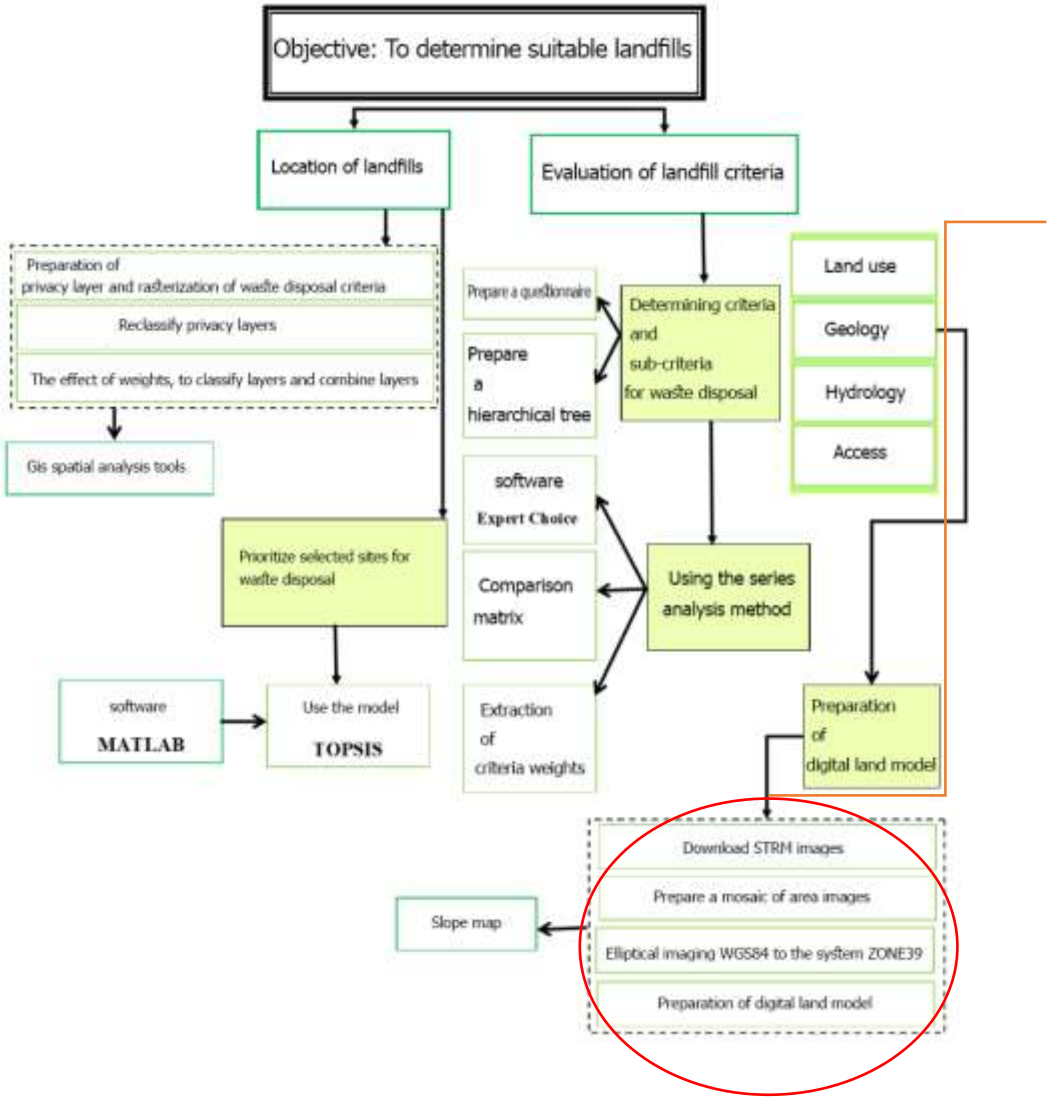



**Chart 1.** Flowchart of the steps of implementing the research method

## 3.2. Using Hierarchical Analysis Method

The hierarchical analysis model begins by drawing a hierarchical tree diagram. This chart consists of three basic levels of goal, criterion and sub-criteria. While, the last level of the tree is dedicated to the options (Chart 2).

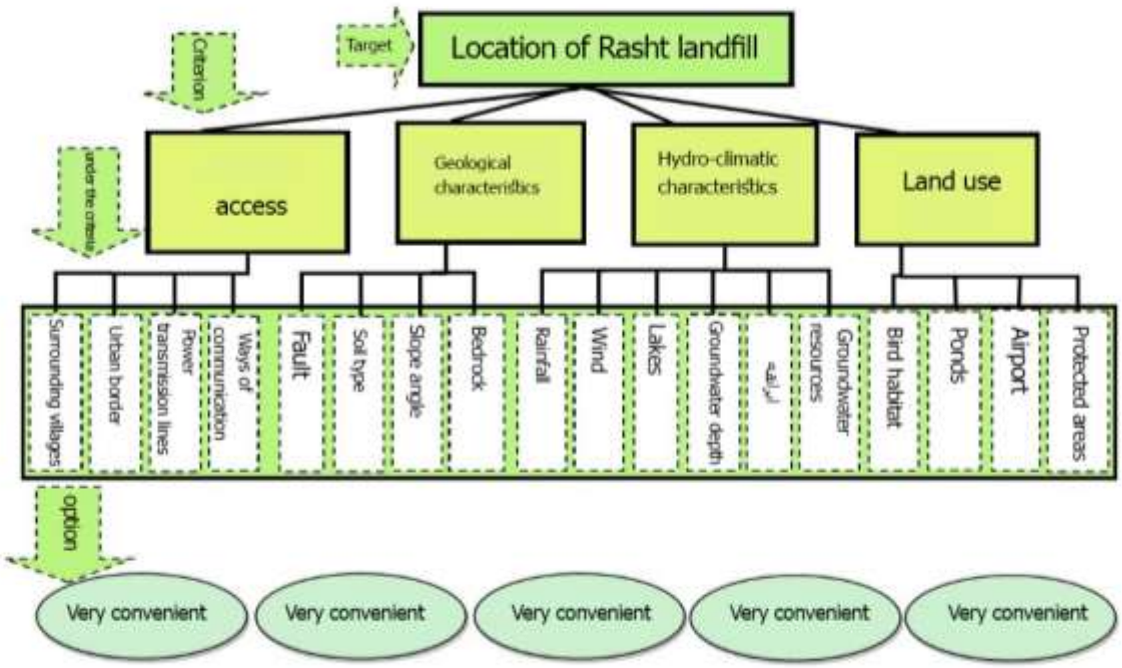



**Chart 2.** Hierarchical tree

## 3.3. Locating the Landfill of Rasht

In order to locate the landfill of the Rasht, the data of the present study were collected according to the research criteria and after making the necessary edits and coordinate changes, were prepared for spatial analysis in the GIS. The steps are as follows. The data and sources used in the research are given in Figure (3) and Table (3).

**Table 3.** Data used in the research

| Information | Source |
|---|---|
| Geological maps 1: 100000 | Geological Survey of the country |
| Soil map of the area | Water and Soil Research Organization |
| Wind speed and direction information and climatic parameters | Meteorological Organization |
| Groundwater depth information | Gilan Regional Water Organization |
| | Land use map of Rasht |

## a. Preparing Information Layers for Spatial Analysis

Some of the criteria used in the research indicate a range of factors involved in waste disposal. The layers needed to be rasterized under initial ranking to enable spatial analysis. Table (4) shows the initial ranking of these types of criteria. In the process of locating landfills, the distance of landfills is more important than other criteria. Applying the privacy layer to these criteria makes it possible to perform spatial analysis in the GIS The operation of applying the distance to the criteria is given in Figure (5).

**Table 4.** Preliminary ranking of effective information zones in waste disposal in Rasht

| Initial criteria / rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Vegetation | Lands without vegetation, shrubs and forests | Medium rangeland canopy | Forest with low canopy | Good pastures and forests with medium canopy | Forest with dense canopy | Irrigated Agriculture | City area | |
| Wind | North | West | North West | South West | East | North East | South | Eastern South |
| Material of bedrock | Basalt and andesite | Mass limestone and masterpiece | Dolomite and fossil lime, shale and marl | Terrace reserves and rocks with low to medium degree of metamorphism | Travertine and sandstone | Tuff and flood deposits | | |
| Soil type | Alfi Sol | Septic tank | Financial Sol | March | Coastal sand | Irrigated Agriculture | | |

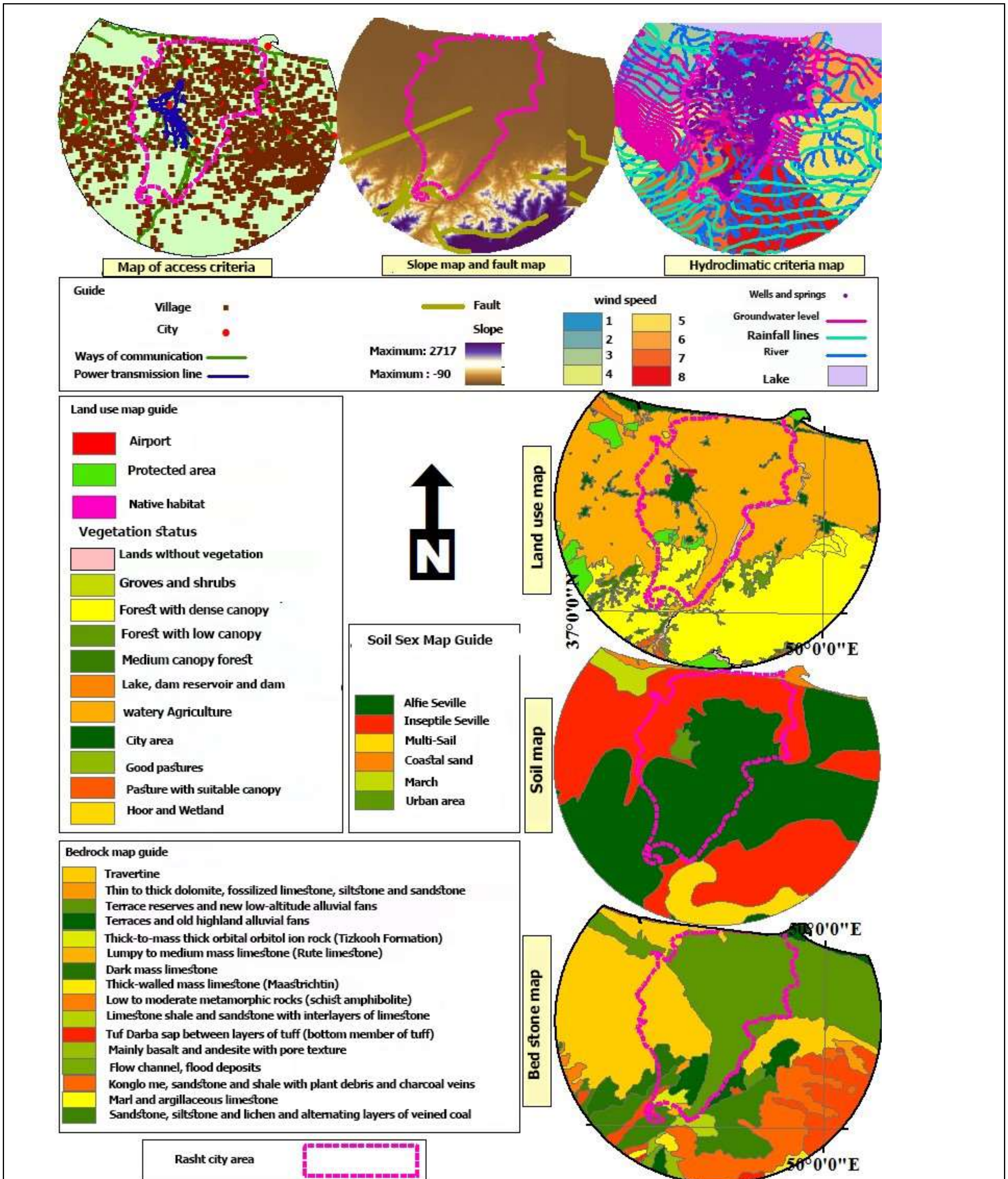
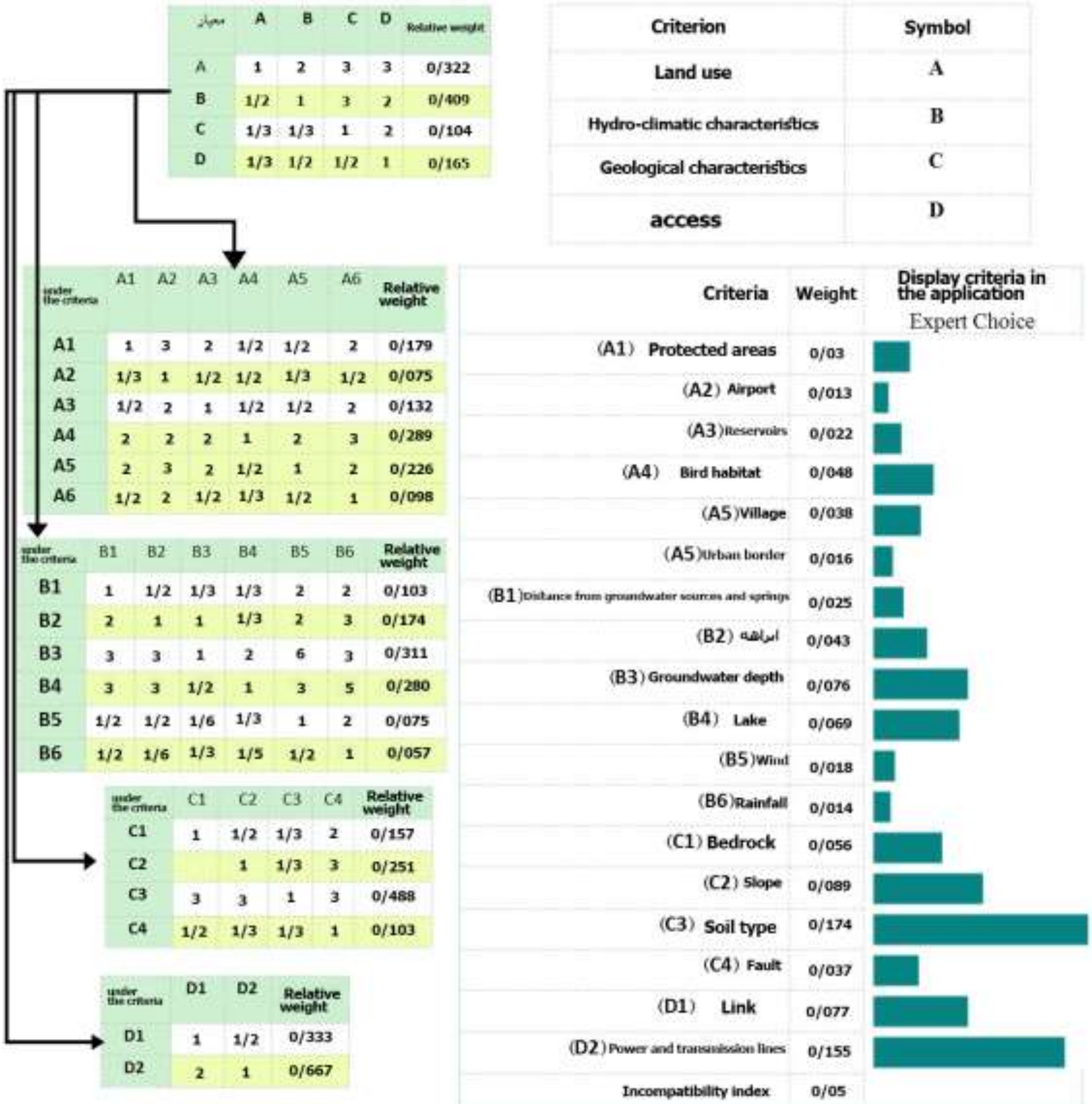



**Figure 3.** Maps used in research



| معیار | A | B | C | D | Relative weight |
|---|---|---|---|---|---|
| A | 1 | 2 | 3 | 3 | 0/322 |
| B | 1/2 | 1 | 3 | 2 | 0/409 |
| C | 1/3 | 1/3 | 1 | 2 | 0/104 |
| D | 1/3 | 1/2 | 1/2 | 1 | 0/165 |

| Criterion | Symbol |
|---|---|
| Land use | A |
| Hydro-climatic characteristics | B |
| Geological characteristics | C |
| access | D |

| under the criteria | A1 | A2 | A3 | A4 | A5 | A6 | Relative weight |
|---|---|---|---|---|---|---|---|
| A1 | 1 | 3 | 2 | 1/2 | 1/2 | 2 | 0/179 |
| A2 | 1/3 | 1 | 1/2 | 1/2 | 1/3 | 1/2 | 0/075 |
| A3 | 1/2 | 2 | 1 | 1/2 | 1/2 | 2 | 0/132 |
| A4 | 2 | 2 | 2 | 1 | 2 | 3 | 0/289 |
| A5 | 2 | 3 | 2 | 1/2 | 1 | 2 | 0/226 |
| A6 | 1/2 | 2 | 1/2 | 1/3 | 1/2 | 1 | 0/098 |

| under the criteria | B1 | B2 | B3 | B4 | B5 | B6 | Relative weight |
|---|---|---|---|---|---|---|---|
| B1 | 1 | 1/2 | 1/3 | 1/3 | 2 | 2 | 0/103 |
| B2 | 2 | 1 | 1 | 1/3 | 2 | 3 | 0/174 |
| B3 | 3 | 3 | 1 | 2 | 6 | 3 | 0/311 |
| B4 | 3 | 3 | 1/2 | 1 | 3 | 5 | 0/280 |
| B5 | 1/2 | 1/2 | 1/6 | 1/3 | 1 | 2 | 0/075 |
| B6 | 1/2 | 1/6 | 1/3 | 1/5 | 1/2 | 1 | 0/057 |

| under the criteria | C1 | C2 | C3 | C4 | Relative weight |
|---|---|---|---|---|---|
| C1 | 1 | 1/2 | 1/3 | 2 | 0/157 |
| C2 | | 1 | 1/3 | 3 | 0/251 |
| C3 | 3 | 3 | 1 | 3 | 0/488 |
| C4 | 1/2 | 1/3 | 1/3 | 1 | 0/103 |

| under the criteria | D1 | D2 | Relative weight |
|---|---|---|---|
| D1 | 1 | 1/2 | 0/333 |
| D2 | 2 | 1 | 0/667 |

Matrix of pairwise comparisons and relative weight of criteria

| Criteria | Weight | Display criteria in the application Expert Choice |
|---|---|---|
| (A1) Protected areas | 0/03 | |
| (A2) Airport | 0/013 | |
| (A3) Reservoirs | 0/022 | |
| (A4) Bird habitat | 0/048 | |
| (A5) Village | 0/038 | |
| (A5) Urban border | 0/016 | |
| (B1) Distance from groundwater sources and springs | 0/025 | |
| (B2) ابراهه | 0/043 | |
| (B3) Groundwater depth | 0/076 | |
| (B4) Lake | 0/069 | |
| (B5) Wind | 0/018 | |
| (B6) Rainfall | 0/014 | |
| (C1) Bedrock | 0/056 | |
| (C2) Slope | 0/089 | |
| (C3) Soil type | 0/174 | |
| (C4) Fault | 0/037 | |
| (D1) Link | 0/077 | |
| (D2) Power and transmission lines | 0/155 | |
| Incompatibility index | 0/05 | |

Final weight of decision criteria for landfill in Rasht

**Figure 4.** Hierarchical analysis process of waste disposal in Rasht

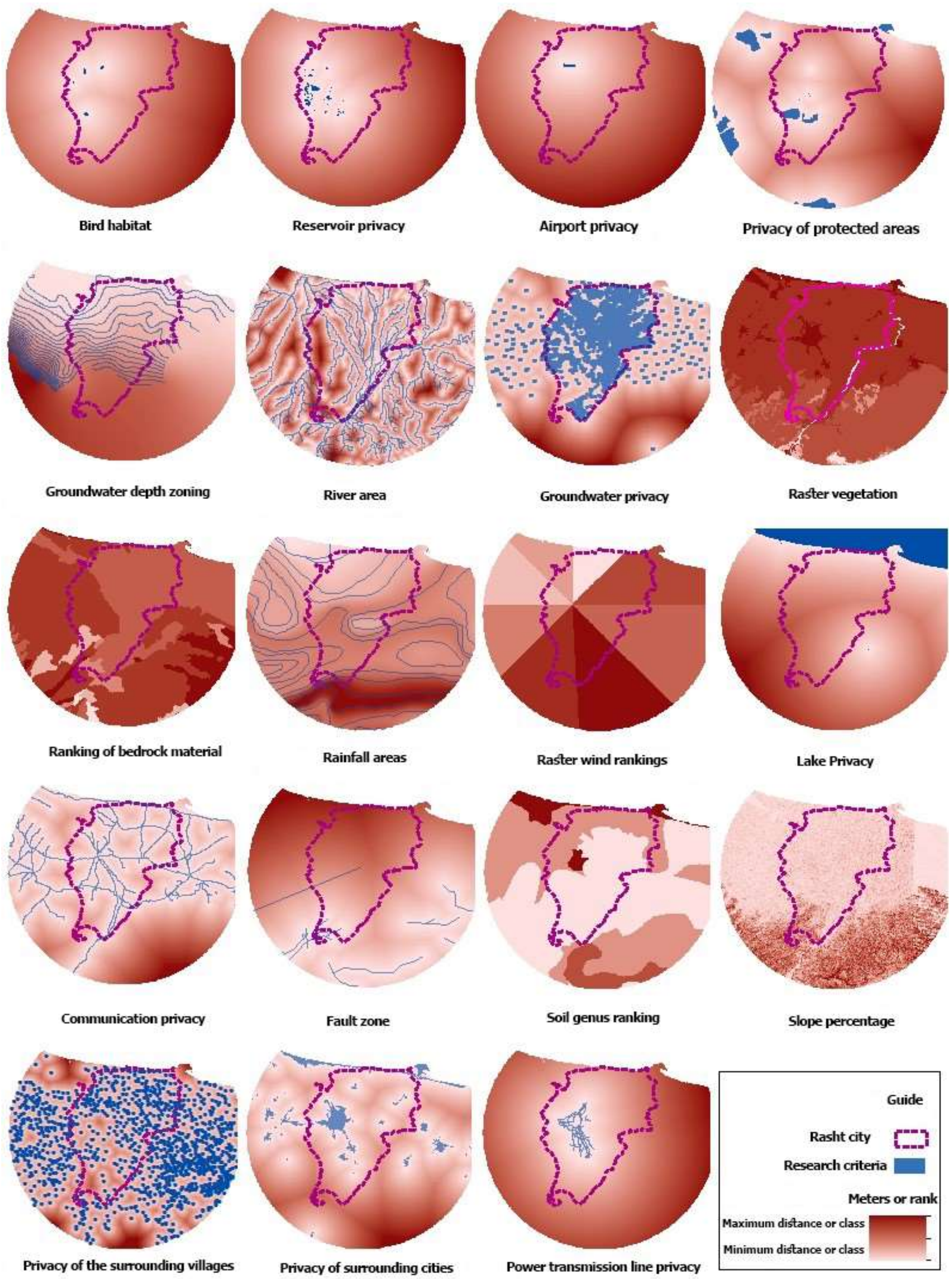



**Figure 5.** Application of privacy and classification of layers involved in waste disposal in Rasht

## b. Reclassification of Privacy Layers and Integration of Information Layers

After reviewing the privacy and permitted classes in determining waste landfills and consulting with experts, the initial standards of waste landfill for the city of Rasht were prepared, which are given in Table (5). Most of the standards have been set according to the opinions of the experts of the Environment Organization of Iran. Afterwards, the classified maps were prepared based on the conditions stated in the table. The process of preparing maps is shown in Figure (6).

**Table 5.** Permitted standards in waste disposal in Rasht

| Benchmark class | 5: Very convenient | 4: Suitable | 3: Fairly convenient | 2: Inappropriate | 1: Very inappropriate | Size | Source |
|---|---|---|---|---|---|---|---|
| Protected areas | 1000 plus | 500-1000 | 300-500 | 150-300 | 0-150 | Meter | Country environment |
| Land use | Lands without | Forest with dense | Forest with low canopy | Irrigated Agriculture | City area | Rank | Country environment |
| Bird habitat | 1000 plus | 500-1000 | 300-500 | 150-300 | 0-150 | Meter | Country environment |
| Reservoir | 1000 plus | 700-1000 | 500-700 | 300-500 | Less than 300 | Meter | Country environment |
| Springs and groundwater | 3000 plus | 2000-3000 | 1000-2000 | 300-1000 | Less than 300 | Meter | Country environment organization |
| Water way | 3000 plus | 2000-3000 | 1000-2000 | 300-1000 | Less than 300 | Meter | Country environment organization |
| Groundwater depth | 25 plus | 20-25 | 15-20 | 10-15 | Less than 10 | Meter | Country environment |
| Fault | 1000 plus | 500-1000 | 200-500 | 80-200 | Less than 80 | Meter | Environmental protection |
| Lake | 3000 plus | 2000-3000 | 1000-2000 | 300-1000 | Less than 300 | Meter | Country environment |
| Wind | South East | East and Northeast | South West | North | Northwest and West | Direction | Meteorological Organization |
| Rainfall | Less than 170 | 170-190 | 190-210 | 210-230 | 230 and above | Mm | Environmental protection |
| Bedrock | Thick basalt and lime | Soft amphibole lime | Sandstone and travertine | Flower stone and chill | Flood deposits | Rank | Country Environment Organization |
| Soil type | Alfi Sol | This septic tank | Financial Sol | March | Coastal sand and town | Rank | Country Environment Organization |
| Slope | Less than 20 | 20-25 | 25-30 | 30-35 | Above 35 | Percentage | Country Environment |
| Urban border | 15000 plus | 10000-15000 | 5000-10000 | 2000-5000 | Less than 2000 | Meter | Environmental protection |
| Village | 15000 plus | 10000-15000 | 5000-10000 | 2000-5000 | Less than 2000 | Meter | Environmental protection |
| Link | 10000 plus | 10000-15000 | 1000-5000 | 250-1000 | Less than250 | Meter | Country Environment |
| Airport | 6000 plus | 5000-6000 | 4000-5000 | 3000-4000 | Less than 3000 | Meter | Country Environment |
| Power transmission line | 3000 plus | 2000-3000 | 1000-2000 | 500-1000 | Less than 500 | Size | Environmental protection |

After classifying the information layers, using the weights extracted from the hierarchical analysis method, the overlapping of maps was performed and potential locations for the disposal of hazardous waste were identified as follows:

"Privacy of protected areas" * 0.03+ "Airport" * 0.013+ "Privacy of catchment area" * 0.022+ " Privacy of bird habitat" * 0.048+ "Privacy of urban borders" * 0.016+ "Privacy of rural areas" * 0.038+ "Privacy of Wells and springs groundwater area" * 0.076+ "Waterway area" * 0.043+ "Groundwater depth zone" 0.076+ "Privacy of Lake area" * 0.069+ "Classification Dominant wind direction" * 0.018+ "Rainfall zone" * 0.014+ " Bedrock" * 0.056+ "Soil material" * 0.174+ percentage of slope" * 0.089+ "Fault zone" * 0.037+ "Road Area" * 0.077+ "Power Line Area" *0.1

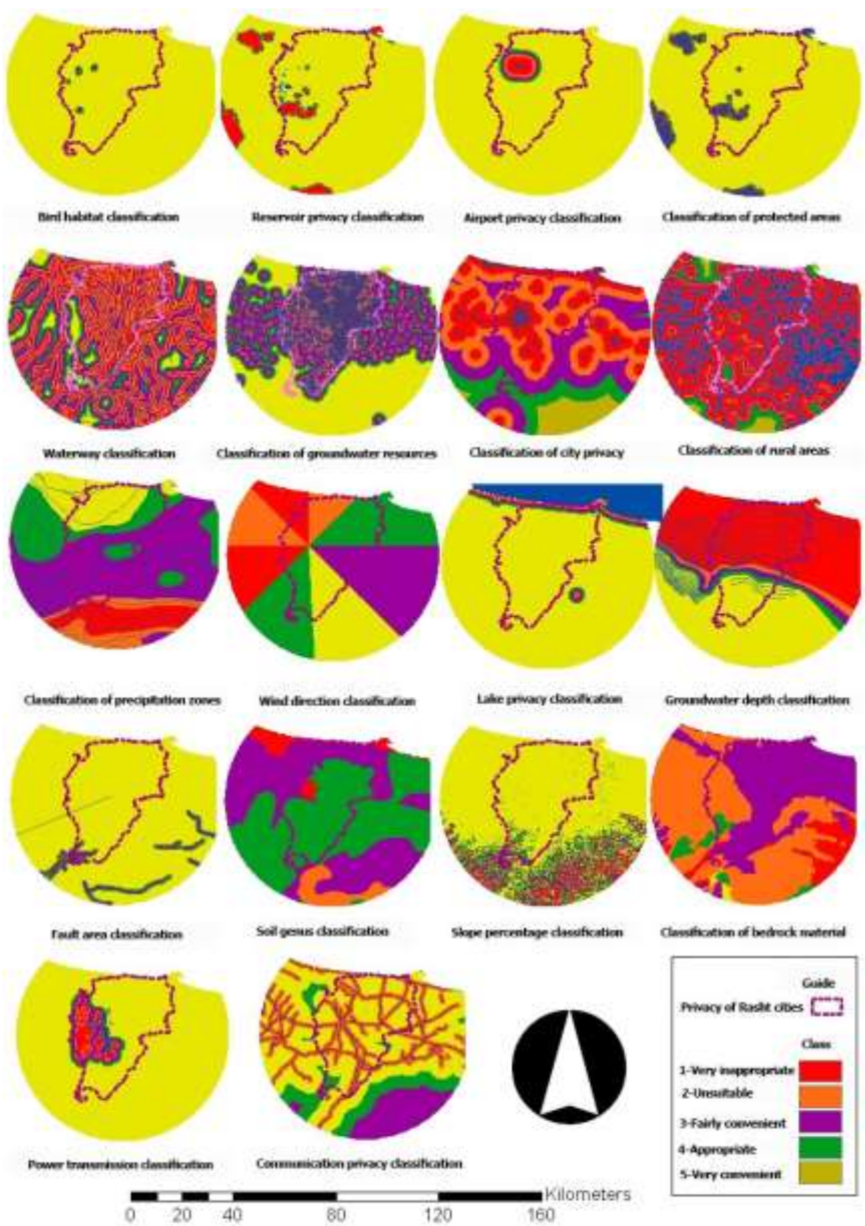



**Figure 6.** Results of classification of landfill criteria in Rasht

Figure (7) shows the results from combining the information layers. According to the figure, suitable areas for waste disposal are mainly located in the southern half of the city. By placing the zones in different classes of proportionality, it was found that the current landfill of Rasht is in the twenty-seventh place out of 32 classes of proportionality and in the fourth place out of 5 classes of proportionality. As a result, can be considered as an acceptable option. Afterwards, nine sites were selected from the zones that were in the upper classes of suitability for waste disposal, and after examining the characteristics of the areas in terms of location criteria for waste disposal, which is given in Table (6), a decision was made about the appropriate choice out of the 9 proposed options, as well as the current site as the tenth option, using the TOPSIS method.

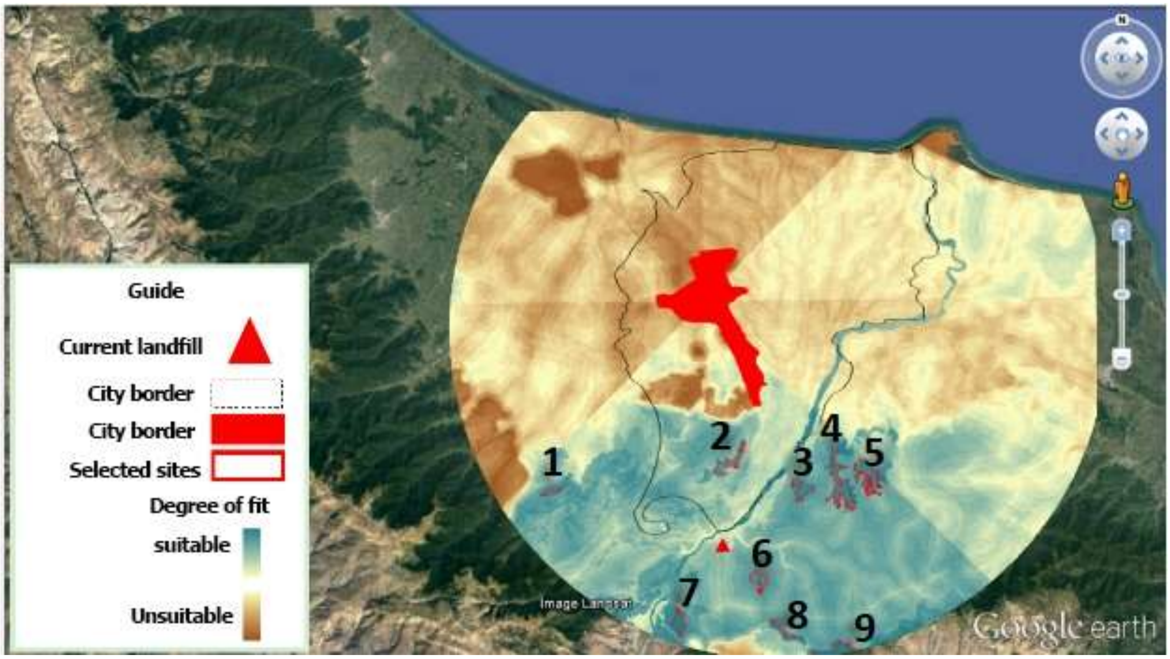



**Figure 7.** Map of the degree of appropriateness of the study area, for landfilling in Rasht

**Table 6.** Environmental and socio-economic characteristics of the proposed waste disposal sites in Rasht

| Site number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Current site |
|---|---|---|---|---|---|---|---|---|---|---|
| Area | 134429 | 568632, | 3696330 | 89369,6 | 595193, | 3511403 | 3307354 | 1057746 | 4947625 | |
| Protected area | 3121,3 | 5640 | 11989,9 | 14771,4 | 16946,3 | 6378.23 | 2881.25 | 742,765 | 3761.98 | 11977.3 |
| Land use | 1 | 3 | 4 | 1 | 3 | 5 | 3 | 3 | 4 | 5 |
| Bird habitat | 9302,95 | 27587,8 | 36311,1 | 24470,3 | 24071,7 | 21787.2 | 19630.8 | 30997.4 | 18132 | 18437.8 |
| Reservoir | 7474,76 | 13336 | 15639,3 | 22296,8 | 2703,7 | 16440 | 28988.8 | 33382.9 | 17612.1 | 17776.7 |
| Village | 926,121 | 67,082 | 6703,97 | 394,588 | 1594,52 | 1385.21 | 371,079 | 3030.15 | 5050.35 | 700,357 |
| Border City | 10414,2 | 3412,23 | 9898,77 | 17515,7 | 15206,5 | 4530.3 | 6768.04 | 7871.33 | 24422.6 | 12579.6 |
| Groundwater | 300 | 6939,34 | 13661,7 | 6735,05 | 4217,32 | 5394.16 | 12826.3 | 7665.04 | 12941.2 | 2227.49 |
| waterway | 123,693 | 3071,74 | 150 | 1482,19 | 201,246 | 1023.96 | 2470,95 | 2972.42 | 2403.37 | 904,489 |
| Groundwater depth | 45,1468 | 44,7873 | 42,3584 | 57,4671 | 5240,66 | 71.5381 | 46,4017 | 50.1024 | 52.0057 | 51.4997 |
| Lake | 27204,4 | 5645,1 | 17763,9 | 2786,07 | 11044,6 | 7595.39 | 40410.8 | 33750.2 | 23136.2 | 23146.5 |
| Wind | 8 | 8 | 7 | 8 | 8 | 8 | 8 | 8 | 7 | 8 |
| Rainfall | 282,301 | 193,753 | 191,326 | 201,358 | 216,089 | 191,087 | 197,756 | 221,324 | 25.1424 | 282,089 |
| Formation sex rank | 6 | 6 | 6 | 1 | 8 | 5 | 3 | 6 | 6 | 4 |
| Slope | 12,4551 | 19,7192 | 22,,164 | 11,8775 | 9,46232 | 42.9548 | 12.1768 | 12.6255 | 25.1424 | 15.2206 |
| Soil rating | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 |
| Fault | 2476,23 | 3630 | 7047,51 | 4470,4 | 3904,38 | 1594.52 | 10830.4 | 3997.21 | 8004.21 | 4703,4 |
| Airport | 31533,5 | 46481,2 | 29670,1 | 39921,5 | 34521,9 | 25145.8 | 30782.1 | 45339.2 | 50278.3 | 35430.5 |
| Power transmission line | 23181,2 | 36606,4 | 17197,4 | 21976,1 | 28192,4 | 7635.1 | 28525.8 | 12415 | 15014.1 | 17885.7 |
| Way | 7795,5 | 6251,89 | 5165,32 | 3684,02 | 5839,45 | 2428.7 | 20499.5 | 6901.04 | 14718.5 | 1905,41 |

## 3.4. Determining the Priority of Selected Sites for Waste Disposal Using TOPSIS Model

In a current study, the prioritization of selected locations was done in several main steps, according to the relations related to the implementation of TOPSIS algorithm as follows:

A. Preparing decision matrix and conversion of quality into quantity units in decision matrix (scaling)

B. Obtaining the weight of each criterion with the help of weights obtained by AHP method

C. Multiplying each of the weights in the unmeasured matrix resulting in a weighted scaleless matrix

D. Determining the ideal positive and negative solutions

E. Calculating the distance of each option from the positive and negative ideal

F. Prioritization of selected areas

To avoid computational errors and repetitive mathematical operations, the above steps were performed using MATLAB software. And after introducing the TOPSIS decision matrix, which was formed according to the opinions of experts and analyzing the environmental and social characteristics of the selected sites (Table 7), the calculation process was performed, which is shown in Figure (8).

**Table 7.** TOPSIS decision matrix for 9 selected landfill sites in Rasht

| 0.023 | 0.022 | 0.007 | 0.02 | 0.012 | 0.04 | 0.026 | 0.013 | 0.062 | 0.025 | 0.107 | 0.031 | 0.056 | 0.071 | 0.052 | 0.064 | 0.068 | 0.169 | 0.132 | Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D5 | D4 | D3 | D2 | D1 | C4 | C3 | C2 | C1 | B6 | B5 | B4 | B3 | B2 | B1 | A4 | A3 | A2 | A1 | |
| 6 | 4 | 8 | 6 | 4 | 2 | 3 | 6 | 1 | 2 | 2 | 6 | 3 | 1 | 1 | 1 | 1 | 5 | 3 | 1 |
| 1 | 1 | 6 | 10 | 9 | 3 | 2 | 4 | 1 | 8 | 2 | 1 | 2 | 10 | 6 | 2 | 8 | 4 | 5 | 2 |
| 5 | 10 | 4 | 4 | 2 | 8 | 3 | 3 | 1 | 9 | 1 | 4 | 1 | 2 | 10 | 3 | 10 | 3 | 8 | 3 |
| 9 | 3 | 3 | 7 | 7 | 6 | 3 | 8 | 4 | 6 | 2 | 8 | 9 | 6 | 5 | 7 | 7 | 5 | 9 | 4 |
| 8 | 7 | 5 | 8 | 5 | 4 | 3 | 9 | 1 | 4 | 2 | 3 | 8 | 3 | 3 | 8 | 6 | 4 | 10 | 5 |
| 2 | 6 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 10 | 2 | 2 | 10 | 5 | 4 | 4 | 5 | 2 | 6 | 6 |
| 3 | 2 | 10 | 9 | 3 | 10 | 1 | 7 | 3 | 7 | 2 | 10 | 4 | 8 | 8 | 9 | 4 | 4 | 2 | 7 |
| 4 | 8 | 7 | 2 | 8 | 5 | 1 | 5 | 1 | 3 | 2 | 9 | 5 | 9 | 7 | 10 | 9 | 4 | 1 | 8 |
| 10 | 9 | 9 | 3 | 10 | 9 | 1 | 2 | 1 | 5 | 1 | 5 | 7 | 7 | 9 | 5 | 2 | 3 | 4 | 9 |
| 7 | 5 | 1 | 5 | 6 | 7 | 1 | 10 | 1 | 1 | 2 | 7 | 6 | 4 | 2 | 6 | 3 | 1 | 7 | 10 |

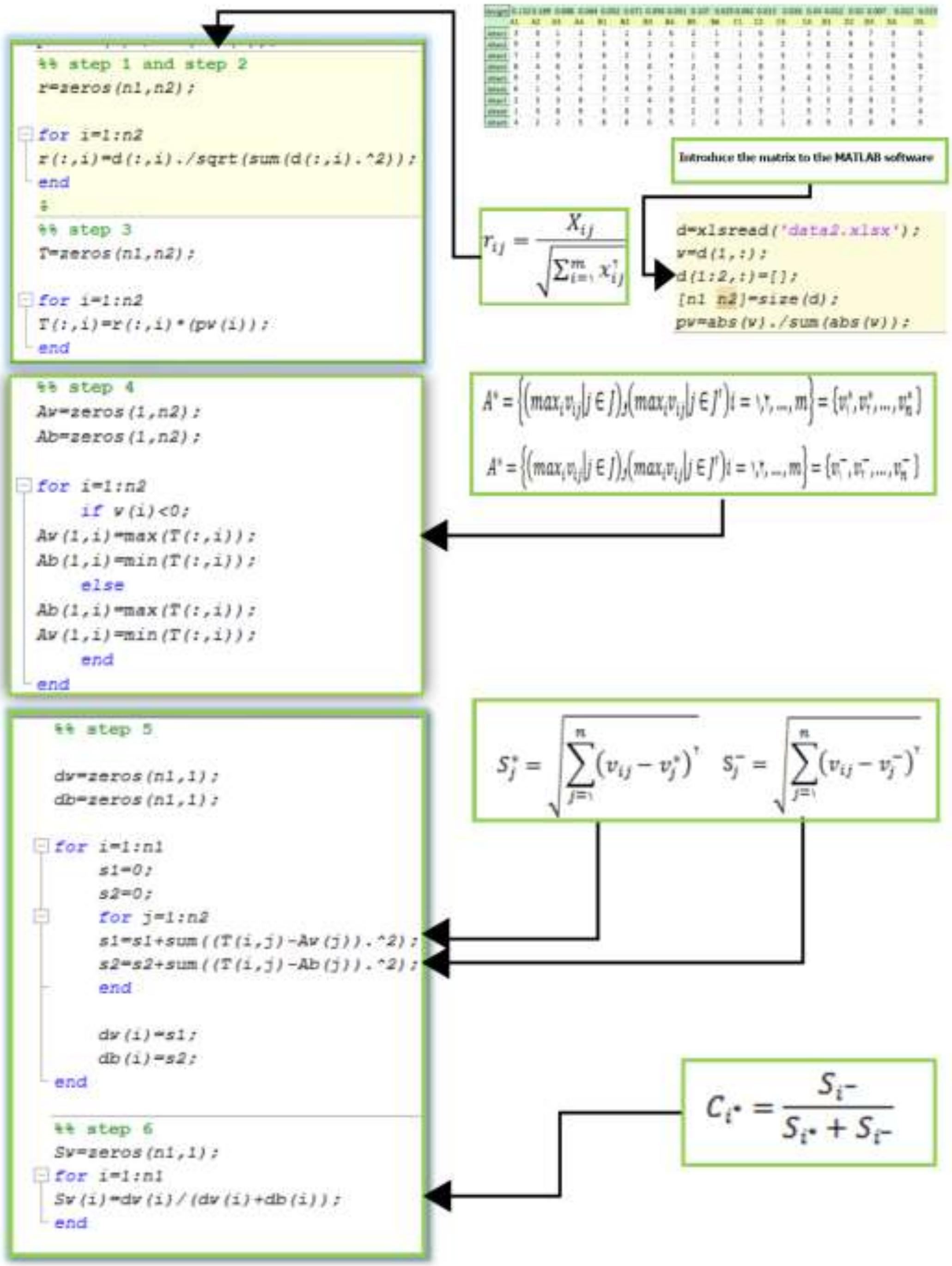



**Figure 8.** Calculation process of TOPSIS method in determining the priority of selected waste landfill sites in Rasht

According to the application of TOPSIS algorithm, the priority of 9 selected options, which are mainly located in the southern parts, was examined; and it was found that, sites 4, 5 and 2 have the highest degree of desirability, respectively. Besides, the current landfill is ranked 10th and has the lowest priority for land filling. Figure (9) shows landfill sites by priority. The blue lines show the path of the waterways.

| Site number | Similarity index | Priority |
|---|---|---|
| 1 | 0.35336 | 7 |
| 2 | 0.52596 | 3 |
| 3 | 0.47203 | 5 |
| 4 | 0.90289 | 1 |
| 5 | 0.69684 | 2 |
| 6 | 0.33836 | 8 |
| 7 | 0.51305 | 4 |
| 8 | 0.46751 | 6 |
| 9 | 0.33227 | 9 |
| Current location | 0.30333 | 10 |

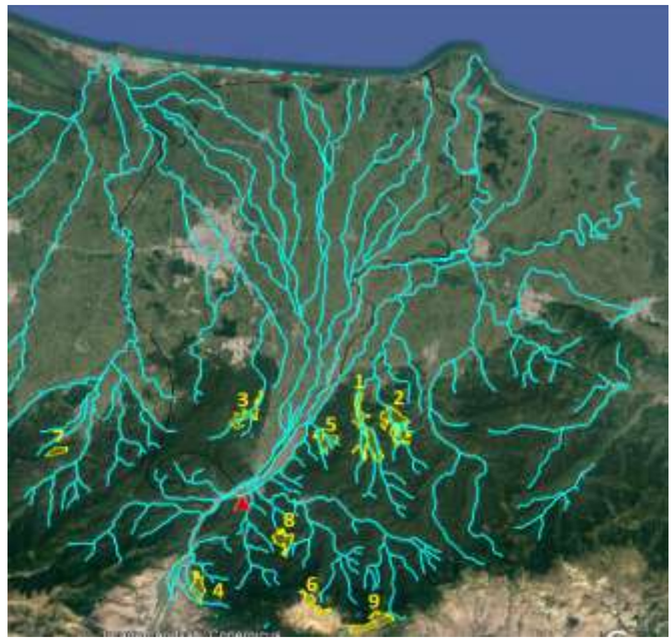


**Figure 9.** Showing the optimal landfill sites of Rasht, based on their priority

## 4. Discussion

In this article, after reviewing and identifying theoretical perspectives on the issue of landfill besides indexing them, Necessary ground was provided for selecting a suitable landfill site. Compared to new landfill location methods, which pay close attention to network analysis, in this paper little attention has been paid to this factor. This is because the network factor is only important if the landfill is on a smaller scale and influences spatial analysis to select optimal routes. But, in a current study, the location of landfills in Rasht has been considered on a large scale. Due to the special conditions of this city, which, like other northern cities of Iran, faces many environmental problems, in choosing the optimal landfill sites, attention to hydro-climatic and environmental criteria is more important. as a result, 19 indicators 4 main criteria of land use, hydrological characteristics, geological characteristics and accessibility were evaluated, and suitable places were identified. Considering the estimated costs of moving the landfill, it does not seem necessary to suggest another location for the landfill. Of course, it is necessary to mention that the selection of optimal landfills, without considering the soil criteria and technical and operational knowledge of the area, does not provide the desired result. The results from agrology and lithological study of the research are presented on a large scale and the details of the classes that influence the choice of the appropriate location can be used for future research.

## 5. Conclusion

In this study, according to the percentage of decision rules compliance with, with four land use criteria; 4 main criteria of land use, hydrological characteristics, geological characteristics and accessibility, it was concluded that multi-criteria decision-making method for locating landfills in Rasht can lead to desirable results. Findings show that the selected areas have the optimal conditions for being used as a landfill location

Moreover, in a part of the research, we examined the sites that have the most appropriate classes for waste disposal and using the TOPSIS decision algorithm, we examined the priority of the zones introduced for waste disposal. Then, with the formation of Matrix, a decision that is based on the value of each site in relation to the location criteria of landfills, 9 sites and the current location of landfills were evaluated. The results showed that the current landfill site is in the lowest priority compared to other optimal sites. And, the most suitable option is site number 5, which is located at the southern end of the city. Moreover, site No. 4, which covers residential uses, cannot be a good option for being used as a landfill. Sites 5 and 2, which are the next priorities of the TOPSIS model, are on the waterway. Site No. 7, which is in the fourth priority of the TOPSIS model, is not on the waterway and the site has been chosen Figures (10) and (11).

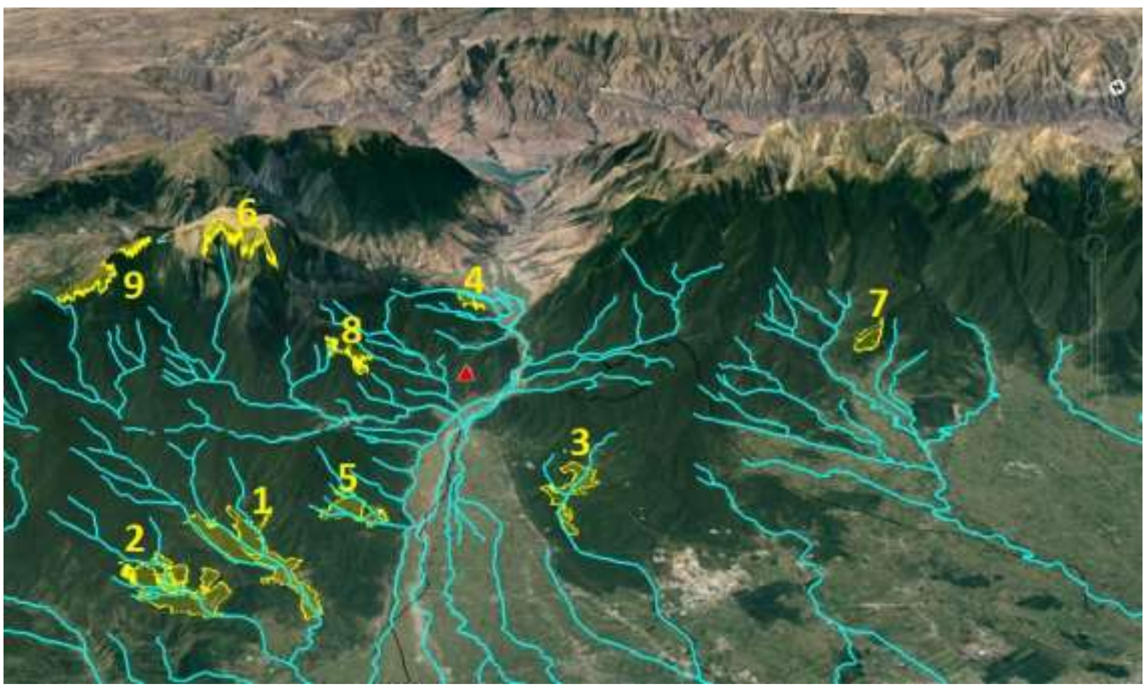



**Figure 10.** Three-dimensional view of the location of waste disposal sites in Rasht

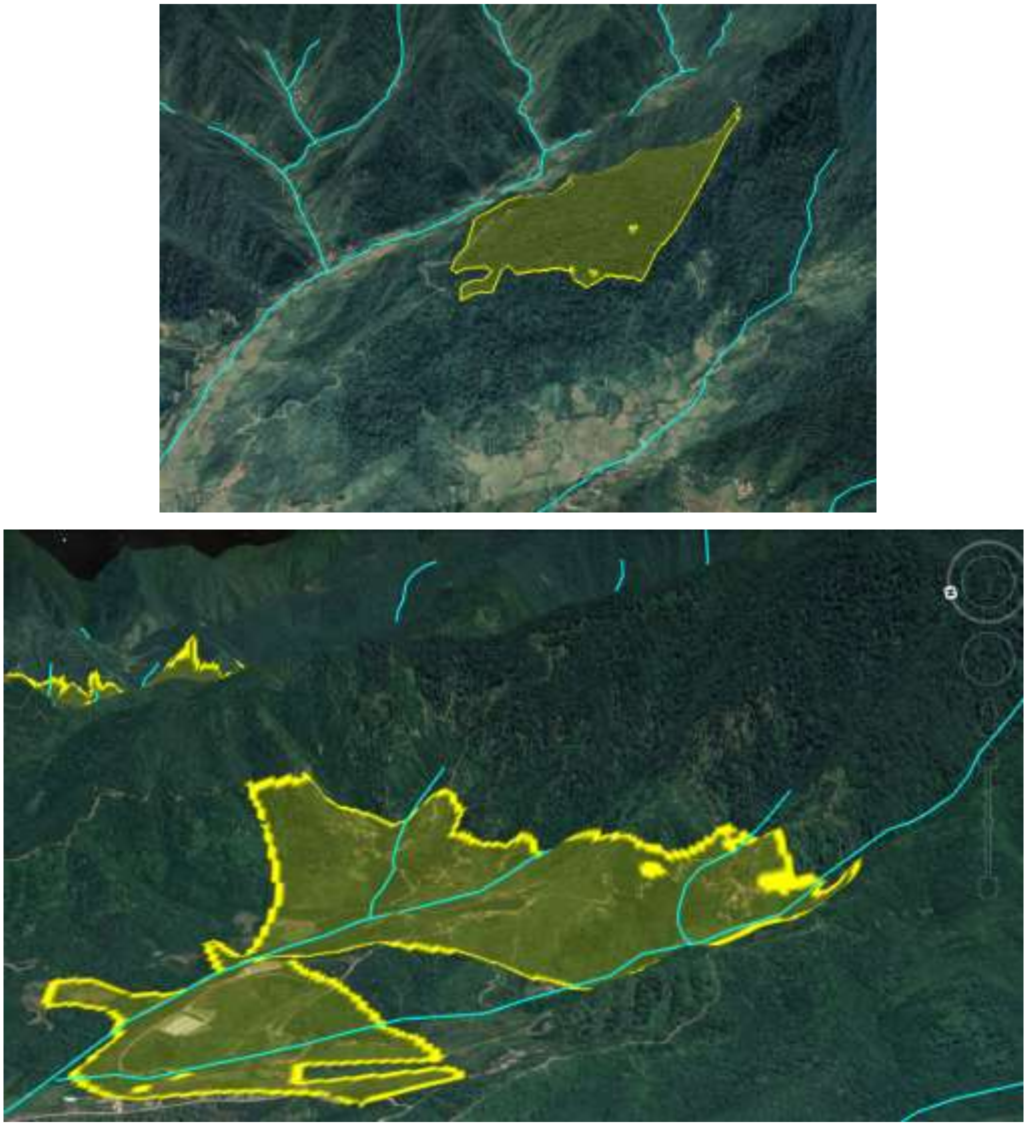


**Figure 11**. Three-dimensional view of site No. 7, the site selected for landfill in Rasht

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