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# Identification and comparison criteria and sub-criteria for siting urban forest parks

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**Abstract**
Increasing urbanization and population take humans away from environment. Consequently, siting public green spaces necessitates social requirements. The scientific siting of public green spaces is critical for sustainable urban environment development, therefore this study aimed to identify suitable criteria and sub-criteria for siting urban forest parks. Accordingly, criteria and sub-criteria for siting urban forest parks were defined by reviewing previous studies and experts' opinion. The criteria and sub-criteria were identified using Delphi technique, random sampling, and then the questionnaires were designed. The questionnaires were filled by 10 experts and their consistencies were assessed by the Super Decision software. In this study, Multi-criteria decision analysis was used for appointing importance of effective criteria and sub-criteria on siting suitable urban forest. For this purpose, determinant criteria and sub-criteria were weighted in Analytical Hierarchy Process, and pairwise comparison was conducted. The results of important criteria weighing process for selecting suitable forest park location showed that environmental, natural, biological community, landscape, sociocultural, economic, physical, and accessible with the weight of 0.41, 0.17, 0.11, 0.101, 0.063, 0.061, 0.052, and 0.033 were placed in priorities respectively. The most important sub-criteria related to natural, physical, landscape, biological community, environmental, accessible, sociocultural, and economic criteria were precipitation, slope, waterfalls, forest diversity, noise pollution, distance to roads, security, land ownership by weight of 0.675, 0.67, 0.749, 0.578, 0.37, 0.424, 0.674, 0.461 respectively.

**Keywords** urban forest park; multi-criteria decision analysis; Analytical Hierarchy Process; pairwise comparison; Delphi technique; Super Decision software.

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## 1 Introduction
With the expansion of urbanization, the city's populations are increasing, while the green urban area is reducing (Tashakkori et al., 2023). The continuous urbanization and rapid economic developments, meeting the production and living needs of the city's population will inevitably have a severe impact on the

environment (Wu et al., 2014; Zhang et al., 2022; Peng et al., 2018; Li et al., 2022), including social health challenges (Tashakkori et al., 2023), traffic congestion (Li et al., 2019; Lu et al., 2021; Zhao and Hu, 2019; Li et al., 2022), environmental degradation (Ojuederie and Babalola, 2017; Zhang et al., 2018; Li et al., 2022), vegetation destruction, and air pollution (Huang and Du, 2018; Kanniah, 2017; Syrakoy, 2018; Wang, 2016; Valavanidis et al., 2013; Chen et al., 2017; Kabisch and Haase, 2013; Li et al., 2022). Green spaces and their impacts on the cities are unavoidable. They are important for the controlling urban environment, reducing air pollution, recreational purposes, and fostering humankind both physically and mentally (Dunnett et al., 2002; Yousefi et al., 2016). The most significant impact of urban green area involves its environmental functions and combat inappropriate use of technology and adverse impacts of industrial development, hence enhancing urban ecological capability (Tahmasebi et al., 2014). The urban green area holds so much importance that it finds its position among the development indicators (Bahmanpour, 2002; Tahmasebi et al., 2014). Some of functions it offers are include oxygen production, CO2 and other toxic gasses absorption, urban climate moderation (Saeednia, 2005; Tahmasebi et al., 2014), and noise pollution reduction (Tahmasebi et al., 2014). The most attractive point about green area is that it leads to mental safety and is the most active factor in air pollution reduction. Green area can link isolated human to environment and meets aesthetic needs of city population. Green area can be taken as useful resources as for hygiene, environmental and social-mental needs (Ostad-Ali-Askari et al., 2018).

Urban forest parks are essential for improving air quality, reducing noise pollution, and fostering sustainable urban growth (Pirmoradian and Ashtari, 2020; Kothencz et al., 2017; Zhang et al., 2015; Li et al., 2022). The current global COVID-19 pandemic has raised the demand for urban green area (Zhu and Xu, 2021; Sung et al., 2022; Li et al., 2022). The ecological requirements and park areas of many urban hardly meet their populations' needs. In order to resolve the supply and demand issue, new urban parks must be built. Therefore, an urban forest park site assessment model must be created, utilizing decision-support tools in order to identify the most suitable locations for future urban park. This approach aims to alleviate these challenges and promote sustainable urban growth (Wang et al., 2021; Li et al., 2022). Selecting appropriate sites for urban park development should be based on spatial criteria that determine the best land suitability for this purpose (Galdavi et al., 2022).The Geographic information systems (GIS) emerge as the most popular technique for studying land-siting considerations (Uyan, 2013; Li et al., 2022). Multi-criteria decision analysis (MCDA) is a powerful technique that is used to assist with land siting decisions (Zhang et al., 2017). The method's scientific validity has been shown through the analysis of various land-siting issues (De Feo and De Gisi, 2014; Yesilnacar et al., 2012; Li et al., 2022). The integration of MDCA with GIS represents a substantial development in solving complex land placement challenges, in terms of current multi-objective land decision problems (Gigovic et al., 2016; Musakwa, 2018; Sahani, 2019; Sardar et al., 2019; Li et al., 2022). GIS is valuable in urban planning for appropriate land use distribution. To this end, the Analytic Hierarchy Process (AHP) is used to fine the most realistic results, contributing to effective decision-making in urban development initiatives (Ostad-Ali-Askari et al., 2018).

Since 1980 Analytical Hierarchy Process (AHP) has been one of the frequently used multi-criteria decision-making methods coupled with GIS in various urban planning cases (Yousefi et al., 2016). Saberi et al. studies different uses of the given region concluded that AHP is an ideal method for obtaining positive results. Hosseini et al. conducted a study on the importance of resource management in different aspects of development plan, highlighting the usefulness of GIS in forestry plans. Ahmadi et al. evaluated green areas, proposing a good model for areas. There are various publications related to green areas such as green areas and their positive effects on mental health by producing oxygen, reducing air pollution and controlling winds (Ostad-Ali-Askari et al., 2018).

Overall, the main objective of this study was to use AHP to determine suitable areas for siting urban forest parks. The adopted methodology helps to identify and prioritize the criteria to prepare an urban forest park siting map. The outcome of this study assists planners and decision-makers in making scientific site selection decisions for urban forest parks (Li et al., 2022).

## 2 Methodology

In this research, suitability site selection for urban forest parks was carried out using Multi-criteria decision analysis (MCDA) and Analytical Hierarchy Process (AHP) (Galdavi et al., 2022). AHP is a simple, flexible, and effective method used for decision making when conflicting decision-making criteria complicate seeking the best alternative (Bertolini et al., 2006; Tahmasebi et al., 2014; Zhang, 2019). Previous studies show that AHP can be employed in urban planning because of its simplicity and flexibility, simultaneous use of quantitative and qualitative criteria, and judgment consistency (Vaidya and Kumar, 2006; Healey and Ilbery, 1990; Tahmasebi et al., 2014). Then this approach, a widely accepted method for weighting the criteria, was exerted to weight them. This method is a flexible and powerful tool for quantitative and qualitative analysis of multi-criteria problems based on pairwise comparisons (Galdavi et al., 2022). Then the pair-wise comparison matrices planned based on Saaty`s scale were filled by ten experts (Saaty, 1959; Yousefi et al., 2016). The criteria weighing scale was performed from 1 to 9 points and were prioritized based on expert opinion (Galdavi et al., 2022). Excel software was used for calculations and quantitative description of qualitative data, presented in diagrams (Fig. 1). Then, the AHP matrix was performed in the Super Decision software and the weight of the layers was calculated. Subsequently the Super Decision software tested the inconsistency factor to determine the accuracy of the weight assigned to the criteria. Inconsistency values less than 0.1 indicate that the weighting performed by experts is approved (Galdavi et al., 2022).

### 2.1 Criteria and sub-criteria definition

This research methodology was based on combination of literature studies and field surveys (Yousefi et al., 2016). The effective criteria for developing urban forest parks should be identified before providing any plan. To achieve this, a wide variety of researches in this field were investigated (Galdavi et al., 2022). To this end, initially, the criteria and sub-criteria were identified from the literature, the online resources, and experiences (Yousefi et al., 2016; Khezri et al., 2017). Subsequently, the final selection of criteria and sub-criteria was accomplished through the design of a questionnaire, utilizing the Delphi method. According to the Delphi method, the prepared questionnaire distributed among 10 experts (Yousefi et al., 2016). Finally, some criteria were identified to determine suitable places for urban forest parks.

### 2.2 Structuring a hierarchy

In the first place, structuring involves three levels, including goals, criteria, and sub-criteria (Changa et al., 2007; Tahmasebi et al., 2014). Transforming a problem into a hierarchal structure holds the major significance in hierarchical analysis (Cimren et al., 2007; Tahmasebi et al., 2014). In this method, each criterion has a certain weight to be employed by the user and can be broken down into sub-criterion to make a weighted comparison (Sanaei-Nejad and Faraji-Sbokbar, 2002; Tahmasebi et al., 2014).

### 2.3 Determining the weight of criteria and sub-criteria

There are several techniques and methods to determine the criterion and sub-criterion weight, among which pair wise comparison is the most usual (Bertolini et al., 2006; Marla et al., 2005; Tahmasebi et al., 2014). Accordingly, pair wise comparison between every two criterion and sub-criterion is carried out to determine the importance of one relative to the other. There is one standard method, introduced by Saati, to accomplish this process (Tahmasebi et al., 2014). According to the Saati method, the prepared questionnaire distributed among 10 experts (Khezri et al., 2017). To carry out a pair wise comparison, each comparison is assigned a value between 1 and 9, whose interpretations are demonstrated in Table 1 (Tahmasebi et al., 2014).

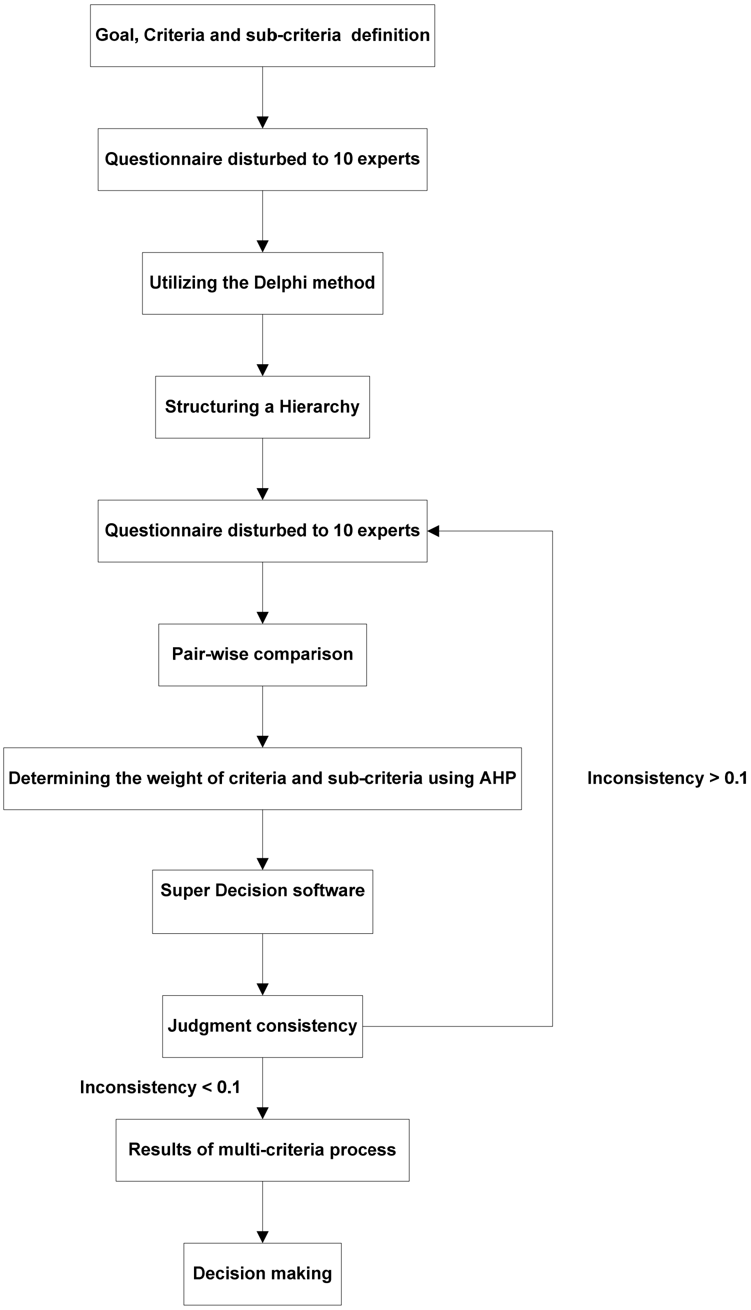


**Fig. 1** The flow chart of the study process.

**Table 1** Scale pair wise comparisons introduced by Saati (Bertolini et al., 2006; Bowen, 1990; Tahmasebi et al., 2014).

| Score | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | The two criteria have the same importance in attaining the goal |
| 3 | Moderately more important | Based on experience, i is more important than j in attaining the goal |
| 5 | Strongly more important | Based on experience, i is strongly more important than j in attaining the goal |
| 7 | Very strongly more important | Based on experience, i is very strongly more important than j in attaining the goal |
| 9 | Extremely important | Absolute importance of i over j has been proved |
| 2,4,6,8 | | When intermediate intervals exist |

### 2.4 Super Decision software

In the next stage, by entering the relative weights into the Super Decision software, the final weights of criteria and sub-criteria were calculated. Geometric mean method was used to aggregate individual judgment by the Excel Software for obtaining a collective judgment. The geometric mean method for n element of $x_1, x_2, \ldots, x_n$ is presented in Eq. (1) (Nilashi et al., 2015). To ensure the compatibility of weights, the inconsistency ratio was computed, which, according to Saaty's recommendation (1999), should generally be less than 0.1 (Khezri et al., 2017).

$$GM = \sqrt[n]{\prod_{i=1}^{n} x_i} \qquad (1)$$

## 3 Results and Discussion

After defining criteria and sub-criteria, the hierarchy tree was planned (Fig. 2). In this study, the natural (temperature, precipitation), physical (elevation, slope), landscape (aspect, waterfalls), biological community (forest diversity, herbaceous diversity, animal diversity), environmental (water quality, air quality, noise pollution), accessible (distance to city, distance to roads, distance from available parks, distance from limiting structures), sociocultural (security, visitors consent, health facilities), and economic (local markets, land ownership, land price), were selected as criteria and sub-criteria.

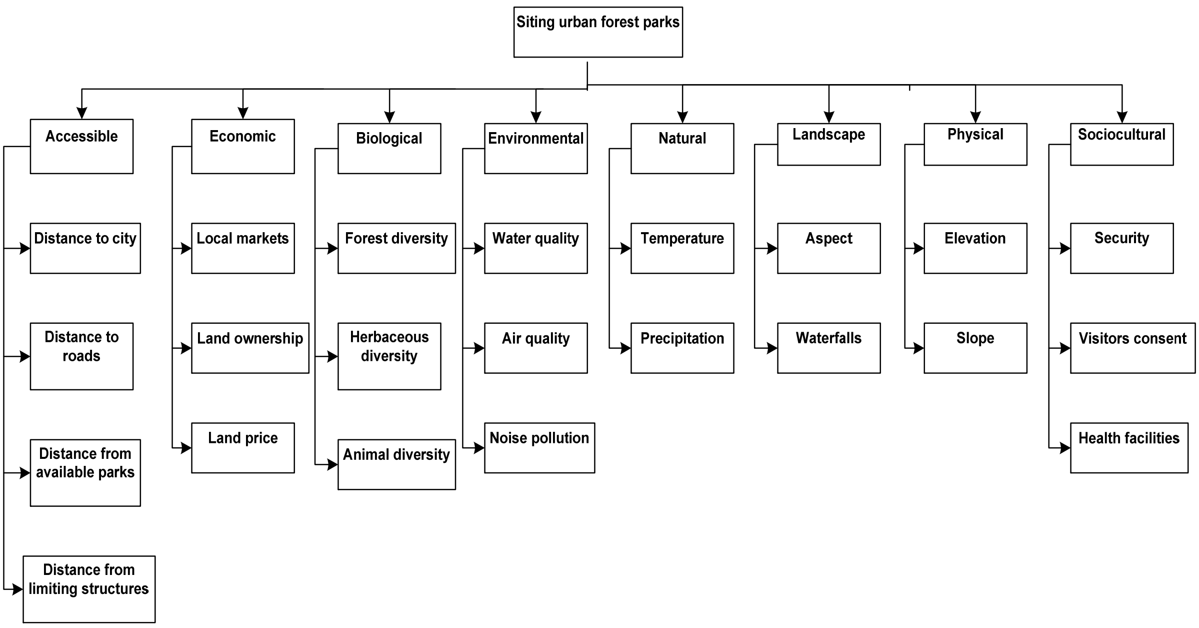


**Fig. 2** The hierarchy tree of the case study.

At the end of this part, there were ten pair-wise comparisons for criteria and sub-criteria based on each criterion. Criterion pair-wise comparison based on one of the expert's opinion is presented in Table 2 as an example. For the first time, in some cases, the Super Decision result was more than 0.1, so the survey was repeated. The next time, the results were acceptable. In so doing, first, the criteria and sub-criteria underwent a pair wise comparison resulting in an inconsistency less than 0.1 which was acceptable (Fig. 3). The results of comparison criteria for siting urban forest parks were indicated that environmental criterion holds significant importance with a weight of 0.41. According to the results of the AHP, the natural, biological community, landscape, sociocultural, economic, physical, and accessible criteria had the highest weight with the weights of 0.17, 0.11, 0.101, 0.063, 0.061, 0.052, and 0.033, respectively. Next, the sub-criteria were compared in regard to the criteria. Fig. 4 demonstrates the comparison between sub-criteria based on criteria.

**Table 2** An example of sub-criterion pair-wise comparison based on Saaty's scale.

| Sub-criteria | Security | Visitors consent | Health facilities |
|---|---|---|---|
| Security | 1 | 5 | 3 |
| Visitors consent | 0.2 | 1 | 2 |
| Health facilities | 0.33 | 0.5 | 1 |

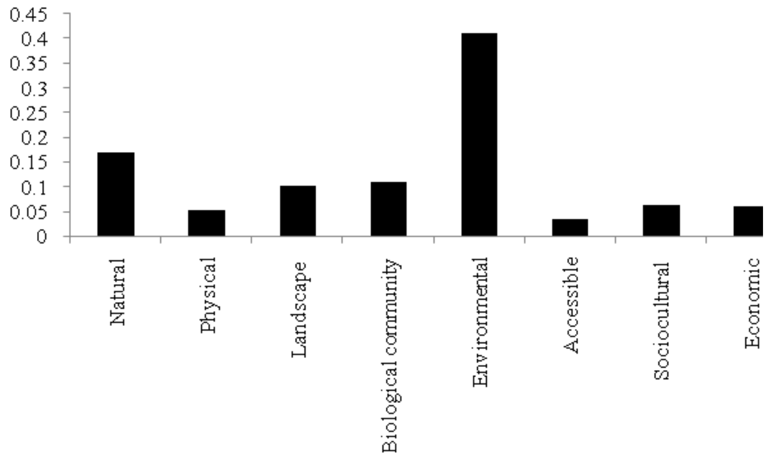


**Fig. 3** Weighting of the urban forest park location criteria.

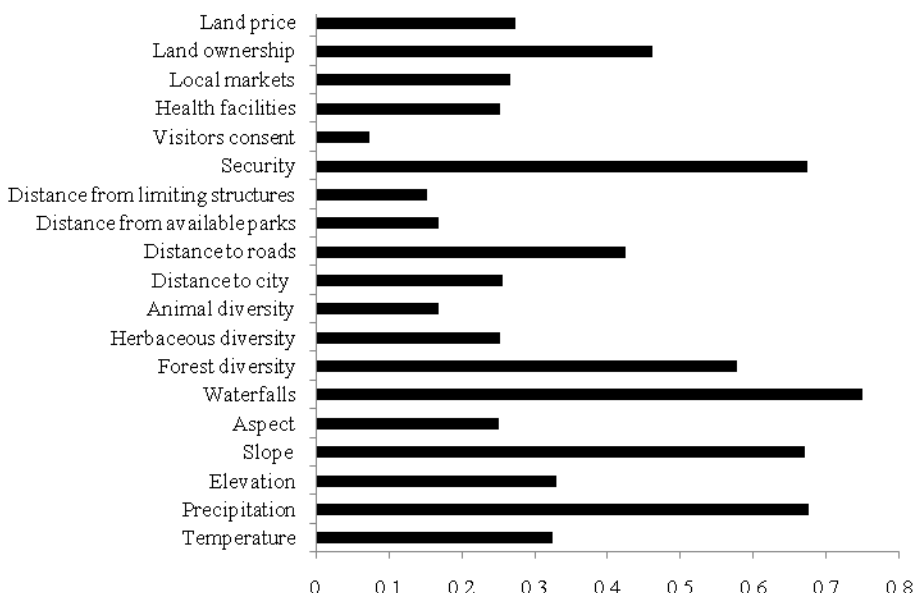


**Fig. 4** Weighting of sub-criteria for the urban forest park location

Easy access to and utilization of urban green spaces are the essential needs of modern societies. This is because the increasing urbanization has led to disconnect between human beings and nature. In this research, definition and comparison criteria and sub-criteria for siting urban forest parks was carried out using the MCDA. To achieve this, initially, the appropriate criteria were identified through reviewing resources and experts' opinions. Weighting of these criteria was then performed using the AHP. The results of criteria weighting based on experts' opinion indicated that environmental, natural, biological community and landscape are the most important criteria in identifying new areas for the development of urban forest parks. Weighting of the urban forest park location criteria and sub-criteria is presented in Table 3. The results of research, by identifying and comparing criteria and sub-criteria for the development of urban forest parks can provide the opportunity for people to spend their time in urban green spaces.

**Table 3** Criteria and sub-criteria weighting for siting urban forest park using AHP.

| Criteria | Weight | Sub-criteria | Weight |
|---|---|---|---|
| Natural | 0.17 | Temperature | 0.325 |
| | | Precipitation | 0.675 |
| Physical | 0.052 | Elevation | 0.33 |
| | | Slope | 0.67 |
| Landscape | 0.101 | Aspect | 0.251 |
| | | Waterfalls | 0.749 |
| Biological community | 0.11 | Forest diversity | 0.578 |
| | | Herbaceous diversity | 0.253 |
| | | Animal diversity | 0.169 |
| Environmental | 0.41 | Water quality | 0.352 |
| | | Air quality | 0.278 |
| | | Noise pollution | 0.37 |
| Accessible | 0.033 | Distance to city | 0.256 |
| | | Distance to roads | 0.424 |
| | | Distance from available parks | 0.168 |
| | | Distance from limiting structures | 0.152 |
| Sociocultural | 0.063 | Security | 0.674 |
| | | Visitors consent | 0.073 |
| | | Health facilities | 0.253 |
| Economic | 0.061 | Local markets | 0.266 |
| | | Land ownership | 0.461 |
| | | Land price | 0. 273 |

## 4 Conclusions

The results showed that the criteria selected in this research are not at the same level of decision-making in terms of urban forest parks location. Table 4 indicates the ranks of criteria and sub-criteria for urban forest park location. The environmental criterion, with a weight and importance of 41%, was identified as the most significant criteria for siting urban forest parks. The water resources criteria has been one of the most important influential criteria selected in the research studies of Mogheli et al. (2015), Salehnasab et al. (2016), Fakoor et al. (2013), and Piran et al. (2013). Furthermore, the natural criterion was introduced as the second important criterion for siting urban forest parks in this study. Climate criterion importance is in line with the results of the research studies by Salehnasab et al. (2012), Bunruamkaew and Murayama (2012). Moreover, the importance of biological community, landscape, sociocultura, economic, physical, and accessible criteria is such that one cannot ignore their influence on siting urban forest parks process. The results of present research indicate that in the process of siting urban forest parks, sub-criteria such as waterfalls, precipitation, security, slope, forest diversity and distance to roads are considered decisive sub-criteria (Khezri et al., 2017).

**Table 4** Ranking of criteria and sub-criteria for the urban forest park location

| Criteria | Ranking | Sub-criteria | Ranking |
|---|---|---|---|
| Environmental | 1 | Noise pollution | 1 |
| | | Water quality | 2 |
| | | Air quality | 3 |
| Natural | 2 | Precipitation | 1 |
| | | Temperature | 2 |
| Biological community | 3 | Forest diversity | 1 |
| | | Herbaceous diversity | 2 |
| | | Animal diversity | 3 |
| Landscape | 4 | Waterfalls | 1 |
| | | Aspect | 2 |
| Sociocultural | 5 | Security | 1 |
| | | Health facilities | 2 |
| | | Visitors consent | 3 |
| Economic | 6 | Land ownership | 1 |
| | | Land price | 2 |
| | | Local markets | 3 |
| Physical | 7 | Slope | 1 |
| | | Elevation | 2 |
| Accessible | 8 | Distance to roads | 1 |
| | | Distance to city | 2 |
| | | Distance from available parks | 3 |
| | | Distance from limiting structures | 4 |

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