



Using GIS-based multicriteria decision support system for planning road networks with visual quality constraints: a case study of protected areas in Ankara, Turkey

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Abstract Protected areas are important zones due to their natural and cultural assets and their biodiversity preservation functions. Ecotourism activities in these areas have gained great importance for visitors in recent decades. Road networks established in protected areas have ecotourism-related functions, such as providing visitors with continuous access to/within these areas and offering visual richness to visitors while cruising on the roads. Road network planning that prioritizes visual quality is one of the scientific issues discussed today regarding the sustainable management of protected areas. This study focuses on planning new road networks that prioritize visual quality in protected areas and determining the optimum route that maximizes the visual quality experience of visitors. The study area was selected from the protected areas between the Kızılcahamam and Çamlıdere Districts of Ankara, Turkey, and their surroundings. In the model application, a road network was planned using the multicriteria decision support system (MDSS) method by considering visual quality parameters. In this stage, the road network that

prioritized visual quality during spring and autumn seasons was investigated. Hence, weighted linear combination (WLC) was used as a geographic information system (GIS)-based MDSS method. Then, the GIS-based network analysis method was used to determine the optimum route that provided access to the scenic viewpoints (existing and proposed viewpoints) in the study area and maximized the visual quality during both seasons. In the new road network planned by considering the visual quality parameters, the total road length was calculated as 121.21 km for the spring and 129.47 km for the autumn. The lengths of the optimum routes that allowed visitors to reach the scenic viewpoints and ensured the maximum visual quality were 30.91 km and 30.70 km on the new road network for the spring and autumn seasons, respectively. This study introduced a new methodology that utilized GIS-based decision support systems to plan a road network that prioritized visual quality and determined the optimum route with the maximum visual quality. It is anticipated that this methodology can be used for sustainable management and effective planning of protected areas to reach and protect resources with high visual quality.

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Introduction

Due to recent developments in ecotourism with respect to alternative tourism, one of the most important sectors of

the economy, protected areas have consistently gained value for visitors. The protected areas, which have a high value in terms of cultural assets, visual landscape quality, and ecotourism activities around them, provide communication between nature and humans (Düzgüneş and Demirel 2015). In Turkey, the number of protected areas is increasing every year and draws great demand by the visitors. According to the General Directorate of Nature Conservation and National Parks, the total number of visitors to all protected areas that took place in Turkey in 2018 reached approximately 35.3 million (NCNP 2019).

Legal orders and management policies on protected areas are often related to planning for carrying capacity, resulting in restrictive or regulatory decision-making related to visitor activities (Marion and Leung 2011). Within the concept of sustainable management in protected areas, where visitor activities are intense, planning the necessary road networks to reach esthetic assets in these areas should be carefully handled. The effectiveness of visual assets and road network planning in protected areas depends on both existing physical and social inventory systems and assessments (Boers and Cottrell 2007). Before visual assets are available for visitors, the road network should be planned by resource managers, with a comprehensive inventory and map planning, while anticipating future problems (Brown 2003).

Road networks that provide a linkage between people and nature are effective landscape elements that people use to see and perceive natural values (Sezen and Yilmaz 2010). On the other hand, the location of road networks can negatively affect natural resources while contributing to human perception of the environment (Martín et al. 2016). Thus, road networks should be located within the optimum areas to minimize the negative environmental impacts in protected areas while simultaneously increasing the appreciation of visitors in terms of visual landscape quality (Yang et al. 2014). People's esthetic demands should be considered during the design stage when planning road networks and other public facilities in protected areas (Blumentrath and Tveit 2014). During the road network projects for scenic areas, in addition to the landscape characteristics (i.e., landforms, vegetation), ecological, technical, and esthetic conditions should also be evaluated with a comprehensive approach (Yuan and Cheng 2017).

Road networks play an important role for the interaction between people and landscapes in terms of the landscape characteristics (Martín et al. 2018). Visual

quality assessments (Huang 2015), which are important components of landscape modeling and spatial analysis, offer many opportunities in road network planning (Burley 1996). The optimum design of road network components while considering esthetic factors significantly affects the visual quality during the usage of the road network (Akay et al. 2016). In recent years, computer-based analysis has been carried out to increase visual quality, which has contributed to the development of road networks in protected areas (Ucar et al. 2018). The GIS-based visual quality modeling approach (Bishop and Hulse 1994; Wu et al. 2006) and road network design techniques (Abdi et al. 2009) have been used to develop various spatial decision-making applications (Gounaridis and Zaimis 2012).

GIS techniques and methods play an important role in the analysis of decision support problems (Malczewski 2006). Multicriteria decision support systems form the basis of effective GIS-based decision support systems (Jiang and Eastman 2000; Feizizadeh and Blaschke 2014). The GIS-based multicriteria decision support system consists of the decision-maker's preferences using geographic data and can be used to change the processes in accordance with the restricted rules (Farkas 2009; Feizizadeh and Blaschke 2014). In this study, we aimed to plan a road network that prioritized visual quality for the spring and autumn seasons in protected areas using the GIS-based multicriteria decision support system (MDSS) and to determine the optimum route that offers maximum visual quality to visitors. It is expected that road network planning while considering visual quality will contribute to visitor-oriented planning in protected areas, and the developed approach will add functionality to the design of ecotourism activities.

Materials and methods

Study area

This study was conducted in the protected areas and their surroundings between the Kızılcahamam and Çamlıdere Districts of Ankara-Turkey. The geographical location of this area is between 40° 29' 56.81"–40° 26' 09.83" North latitudes and 32° 32' 13.30"–32° 38' 30.19" East longitudes. The study area is approximately 6233 ha, and 2744 ha (44%) is covered by three protected areas (i.e., Soğuksu National Park, Cinereous Vultures Wildlife Development Area, and Aluçdağı Nature Park) (Fig. 1). The

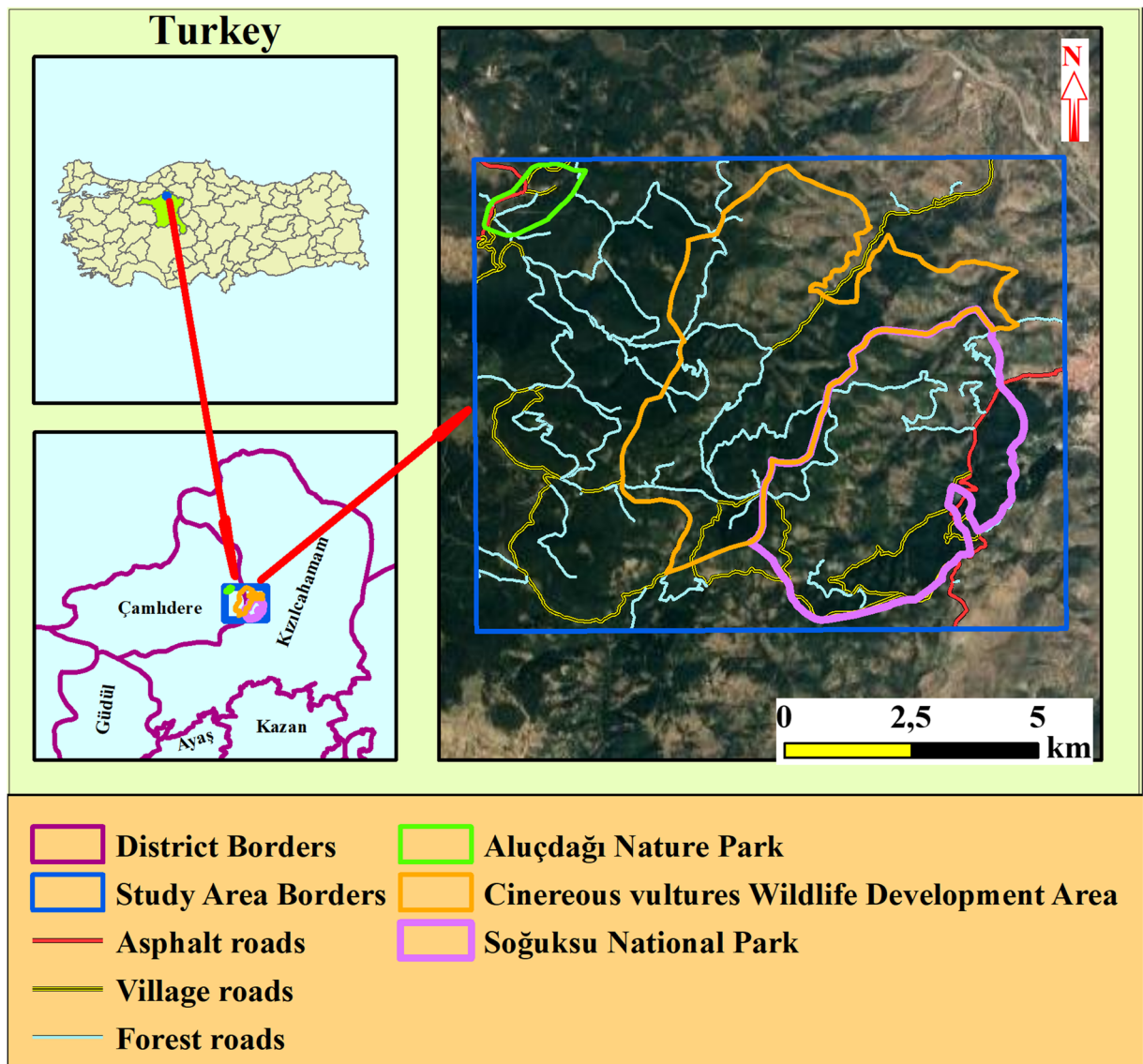


Fig. 1 Borders of the study area and protected areas

cinereous vulture, formerly known as the black vulture, is classified as near-threatened at the world level (Collar et al. 1994) and classified as vulnerable at the European level (Tucker and Heath 1994). The total road network is 110.95 km, and the lengths of forest roads, village roads, and asphalt roads are 67.31 km, 35.62 km, and 8.02 km, respectively (GDF 2018; GEP 2018).

Methods

In the scope of the study, road network planning was performed with the GIS-based MDSS method by

considering visual quality parameters. A spatial database was generated for each parameter by using the ArcGIS 10.5 program by ESRI. Then, the parameters were classified using visual quality assessments for road network planning with the MDSS method. The parameters and class ranges that guided the visual quality assessment are given in Table 1. The visual quality parameters include the land use (LU), aspect I (AI for elevations < 1000 m), aspect II (AII for elevations > 1000 m), stream distance (SD), slope (S), mass movement (MM), visual quality value (VQV) of scenic viewpoints, wildlife impact distance (WID), road density

Table 1 Visual quality parameter classes used in this study

Parameter classes	Ranges	References
Stream distance (m)	> 60	(Akay et al. 2006)
	45–60	
	30–45	
	15–30	
	0–15	
Wildlife impact distance (cinereous vultures— <i>Aegypius monachus</i> —nests) (m)	> 800	(Torres et al. 2016)
	600–800	
	400–600	
	200–400	
	100–200	
Land use	0–100	(GDF 2018)
	Nonvegetated open areas in forests	
	degraded forests	
	Forests	
	Afforestation areas	
	Stony	
	Settlement	
Aspect I (elevation < 1000 m)	Agriculture	(Tampekis et al. 2015)
	North	
	Northwest and northeast	
	West and east	
	Southwest and southeast	
	South	
Aspect II (elevation > 1000 m)	Flat	(Tampekis et al. 2015)
	South	
	Southwest and southeast	
	West and east	
	Northwest and northeast	
Mass movement (coefficient)	North	(Eker and Aydin 2016)
	Flat	
	0–0.2	
	0.2–0.4	
	0.4–0.6	
Road density (m/ha)	0.6–0.8	(Galliano and Loeffler 2000)
	0.8–1	
	0–0.62	
	0.62–4.35	
	4.35–10.56	
	10.56–29.2	
	> 29.2	

Table 1 (continued)

Parameter classes	Ranges	References
Slope (°)	0–10	(Acar et al. 2017)
	10–20	
	20–30	
	30–40	
	40–50	
	> 50	
Visual quality value (VQV) of scenic viewpoints (coefficient)	> 2.58	(ESRI 2018)
	2.58–1.96	
	1.96–1.65	
	– 1.65 to – 1.65	
	– 1.65 to – 1.96	
	– 1.96 to – 2.58	
	< – 2.58	
Existing viewpoints and unwanted locations for road plans (m)	> 1000	(Sener et al. 2010)
	750–1000	
	500–750	
	250–500	
	50–250	
	0–50	

(RD), existing viewpoints (EVP), and unwanted location (UL). Since the effects of aspect change as the elevation increases in mountainous areas, its effect was evaluated for two elevation classes (i.e., elevations < 1000 m and elevations > 1000 m) in visual quality assessment (Tampekis et al. 2015). The ranges of the parameters with respect to their visual quality were determined based on the previous studies indicated in Table 1. The stages of the methodology are indicated in the flowchart of the study shown in Fig. 2.

Determination of scenic viewpoints

There are currently four scenic viewpoints that visitors are willing to see in the study area. In two of these viewpoints, there is the Kızılcahamam tulip (*Tulipa armena*), which is endemic to the region. There is a fossil tree and monumental pine tree (*Pinus nigra*) at the third and fourth viewpoints, respectively. In addition to the existing scenic viewpoints located in the study area, potential viewpoints were proposed based on the field observations of visual quality by experts and resource managers and previous studies conducted on visual quality assessments. A total of 99 potential scenic viewpoints were determined considering their natural, cultural, and visual landscape values, and then their

UTM coordinates were recorded by using hand-held GPS (Global Positioning Systems). Sample photographs and locations of the existing and potential viewpoints in the study area are shown in Fig. 3. The photographs for the viewpoints were taken in May–June (2018) for the spring season and October–November (2018) for the autumn season. All of the photos were taken from human height and between 10:00 A.M. and 15:00 P.M. during the day.

A questionnaire was conducted to evaluate the photographs of the seasonal (spring and autumn) viewpoints located in the study area. In the questionnaire, surveyors were asked to grade each photograph from 1 and 10 points in terms of its visual quality (Temelli 2008; Tempesta 2010). The questionnaire was conducted with resource managers who are actively working with different titles in the 9th Directorate of General Directorate of Nature Conservation and National Parks under the Ministry of Agriculture and Forestry in Turkey. Since it was not possible to reach all of the resource managers within the time framework, the sampling method was used to reduce the number of surveyors. Considering the total number of resource managers (161) as the population size, the sample size was calculated as 61 by using Russ Lenth’s Java application (Lenth 2016) with a 95% confidence interval. Thus, the questionnaire was conducted with 61 resource managers who played a role in the management, protection, and planning of natural and cultural resources.

Planning of the road network

Weighted linear combination (WLC) is one of the most common methods used to solve GIS-based multicriteria decision-making problems (Malczewski 2000). In this method, decision parameters are standardized according to a defined numerical range and then combined with a weighted average (Drobne and Lisec 2009). In other words, the first-level weights of the parameters are applied and combined with the second-level weights based on a rule (Ayalew et al. 2004). These weights assigned to the parameters can be defined as the value that shows importance and evaluated relative to each other (Drobne and Lisec 2009). In multicriteria decision-making, the relative weights between the couples and their importance levels between each factor and criteria are determined (Gülci 2014). In GIS-based applications, relative weights are evaluated between 0 and 1 or 0 and 100 (Malczewski 2000).

Minimum and maximum values are used as the scaling point to normalize the criteria or factors whose weights are determined. Equation 1 below indicates a linear scale for the value obtained by normalization (Eastman 1999):

$$X_i = \frac{(R_i - R_{\min})}{(R_{\max} - R_{\min})} \tag{1}$$

- X_i : the value obtained by normalization
- R_i : the original value of the factor or criterion
- R_{\max} : the largest value of the factor or criterion
- R_{\min} : the smallest value of the factor or criterion

The suitability value (Z) was computed based on the value obtained by normalization for each cell value (X_i) and the weighted value (W_i) as follows (Eastman 1999; Malczewski 2000):

$$Z = \frac{\sum_{i=1}^n W_i X_i}{\sum_{i=1}^n W_i} \tag{2}$$

After the classification of the parameters in the road network suitability stage in terms of visual quality for the protected areas, a visual quality grade from 0 to 9 was given for each class based on the information obtained from the literature. In this rating, 9 denotes the best value (very high), 1 denotes the worst value (very low), and 0 denotes the absolute absence value (absence) (Table 2).

The visual quality rating (p) was applied for each subparameter class of the visual quality parameter classes. The rating of the visual quality parameters was determined by scoring between the minimum and maximum (1–9) values (r) according to the significance levels, while absolute absence had no effect (0). Thus, this rating was prepared for the calculation of the visual quality grading (DDH) suitability for each purpose function class (Eq. 3).

$$\left\{ \begin{array}{l} r \in [x, \{0\}, Z^+] \rightarrow 0 \leq x \leq 9 \\ p \in [x, Z^+] \rightarrow x \geq 1 \end{array} \right\} \rightarrow \left\{ \begin{array}{l} LU = p_1 r + p_2 r + \dots + p_n r \\ AI < 1000 = p_1 r + p_2 r + \dots + p_n r \\ AI > 1000 = p_1 r + p_2 r + \dots + p_n r \\ SD = p_1 r + p_2 r + \dots + p_n r \\ S = p_1 r + p_2 r + \dots + p_n r \\ MM = p_1 r + p_2 r + \dots + p_n r \\ VQV = p_1 r + p_2 r + \dots + p_n r \\ WID = p_1 r + p_2 r + \dots + p_n r \\ RD = p_1 r + p_2 r + \dots + p_n r \\ EVP = p_1 r + p_2 r + \dots + p_n r \\ UVP = p_1 r + p_2 r + \dots + p_n r \end{array} \right. \tag{3}$$

Maximum and minimum ratings were established to provide flexibility to each class of visual quality

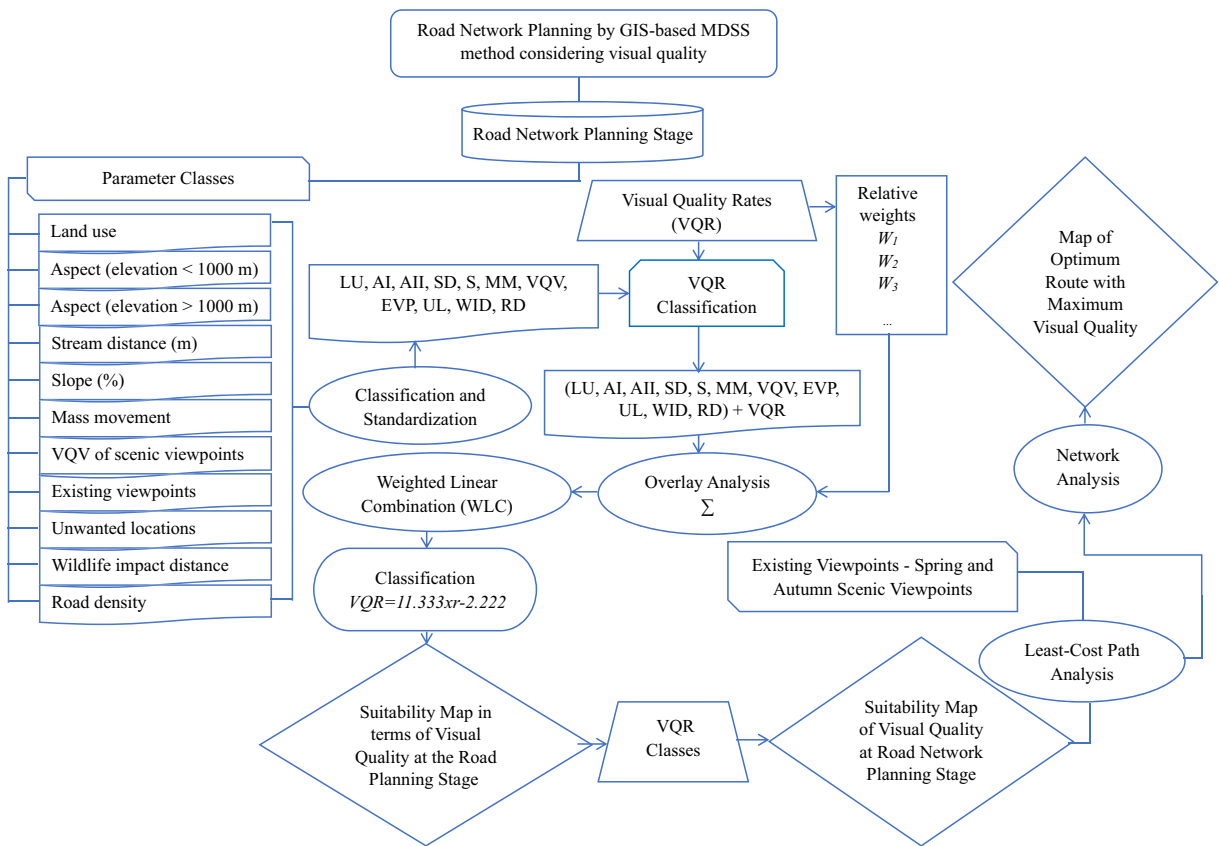


Fig. 2 Flowchart of the methodology

parameters in a way that the researcher was not restricted. Six visual quality rates (VQRs) were defined to determine the values that could not be expressed mathematically but could be expressed verbally in certain classes (very good, good, moderate, poor, very poor, and absence). The average VQR values of the parameter classes were calculated by taking the arithmetic average of the maximum and minimum visual quality rates using the grading method. The averages of the VQRs were weighted to develop the functions of the evaluated visual quality parameter classes (Gülci 2014).

The VQR and weights of the parameter classes were produced by using the linear regression model equation in ArcGIS 10.5. For this purpose, each class of the parameter classes used in percentile (%) cycles of VQR suitability was calculated with the linear regression equation estimation model in the “MS EXCEL” environment. In Table 3, based on VQR classes, the equation with the highest R^2 value was generated by using a linear regression model to determine the objective functions (Eastman et al. 1995). The highest

equation ($R^2 = 0.998$) value determined by simple linear regression in Eq. 4 was calculated to ensure WLC participation. The average value (r) determined for each class range of the visual quality parameter classes in the GIS-based MDSS method was converted to percentages (%) using the model in that equation (Gülci and Akay 2015; Acar et al. 2017). The subparameter classes determined by VQR were used to include the parameter classes into the GIS-based work environment.

$$VQR = 11.333 \times r - 2.2222. \tag{4}$$

Subfactor classes that show the spatial distribution of each of the parameter classes (LU, AI, AII, SD, S, MM, VQV, EVP, UL, WID, RD) were calculated to apply the WLC to determine the road network suitability in terms of visual quality. For the relative weights (W_i) used in Eq. 5, the average of the VQR suitability percentage (\bar{p}_1) was determined without adding an absolute “0” value to the arithmetic averages (Gülci 2014).

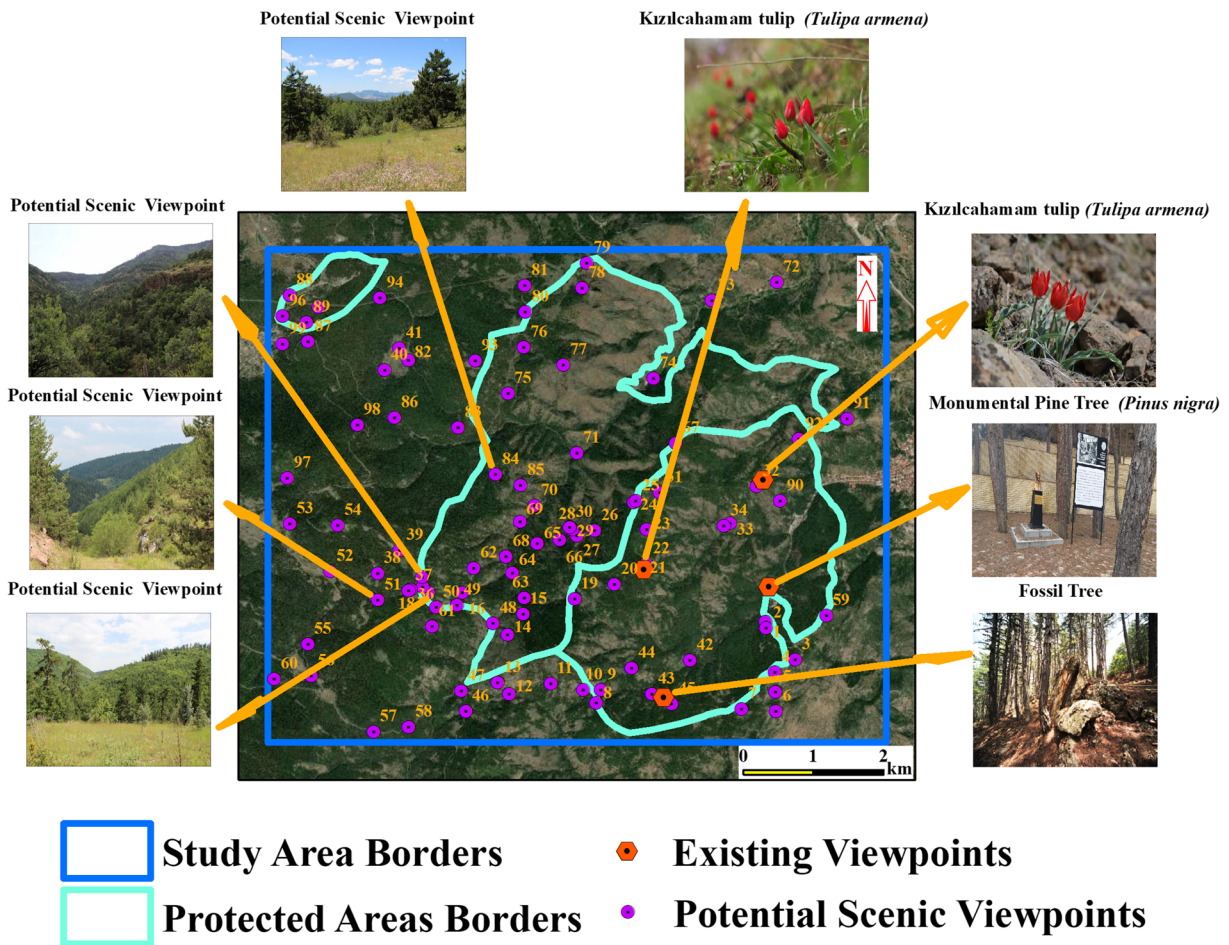


Fig. 3 Locations of existing and potential viewpoints with sample photos in the study area

$$\bar{p}_1 = \frac{\sum_{i=1}^n (p_1w + p_2w + \dots + p_nw)}{p_n} \tag{5}$$

When calculating the weight values of the parameter classes, the normalization process was performed between 0 and 1 by generalizing the visual quality ratings to be displayed in the spatial distribution (Gülci and Akay 2015). Accordingly, the proportional relationships between the parameter pairs and the number of relative pairs (W_i) were determined to calculate the objective functions by using Eq. 6 (Malczewski 2000; Ozturk and Batuk 2011; Gülci and Akay 2015).

$$W_i = \frac{1/\bar{p}_1}{\sum (1/\bar{p}_1)} \tag{6}$$

Relative weights (W_i) determined by the parameter classes were determined by the weighted overlay feature in the Spatial Analyst plugin in ArcGIS 10.5. The map of suitability in terms of visual quality produced with the WLC was reclassified according to the classification of the road network visual quality by the objective functions by using the “Reclassify” feature in ArcGIS 10.5. As a result, a suitability class model was generated to prioritize the visual quality at the road planning stage.

Determination of optimum route

After planning the new road network while considering visual quality, the optimum route that maximized the visual quality experience of the visitors was determined by using the least-cost path analysis (LCPA) approach. LCPA is mainly used to connect the target region to other regions via alternative routes on a road network

Table 2 Rating table for the visual quality parameter classes for the road network

Rates	Objective	Visual quality rates for road network	Explanation
0	Absolutely prohibited areas for road network planning	Absence	Absolutely not suitable area for road network planning
1–2	Very poor areas for road network planning in terms of visual quality	Very poor	In terms of visual quality, it can be a preferred area for road network planning under extraordinary conditions
3–4	Poor areas for road network planning in terms of visual quality	Poor	In terms of visual quality, it can be preferred as a suitable area for road network planning under necessary conditions
5–6	Average areas for road network planning in terms of visual quality	Moderate	In terms of visual quality, it can be a reasonably preferable area for road network planning under normal conditions
7–8	Good areas for road network planning in terms of visual quality	Good	In terms of visual quality, preferable area for ideal road network planning
9	Very good areas for road network planning in terms of visual quality	Very good	In terms of visual quality, it can be a preferred area that is suitable for the most ideal road network planning

and determine the optimum route with the lowest cost. In this study, the network analysis method, one of the most common LCPA methods, was implemented by using the network analyst function in ArcGIS 10.5 to search for the optimum route with the maximum visual quality value. To apply the network analysis method, first, a network dataset in which each road section (link) was represented with the associated visual quality rate was developed. Then, link (ND_Edges) and node (ND_Junctions) layers were produced using the

Table 3 Specified classes for the VQR scale

VQR	VQR (%)	Classes
0	0	Absence
1	10	Very poor
2	20	
3	30	Poor
4	45	
5	55	Moderate
6	65	
7	75	Good
8	90	
9	100	Very good

network database. Finally, the new route method, which is under the network analyst function, was used to determine the optimum route for the spring and autumn seasons, considering the maximum visual quality experience for the visitors.

Results and discussion

Scenic viewpoints

In order to plan the new road network and to determine the optimum route with maximum visual quality, existing scenic viewpoints and new scenic viewpoints were determined in the study area. For the spring and autumn seasons, a total of 99 viewpoints were evaluated, and those that received more than 6 points from the results of the resource manager surveys were considered as a new scenic viewpoint for the new road network. The results indicated that the numbers of new viewpoints for the spring and autumn seasons were 31 and 32, respectively. Figure 4 indicates the locations of the new viewpoints and existing viewpoints (4) in the study area.

Road network that prioritizes visual quality

The new road network was planned in the study area based on visual quality-oriented suitability maps generated by the WLC model. The classified VQR of the visual quality parameters and the suitability model of the parameters were obtained by using their relative weights. The relative weight values of the parameters indicated similar effects on road network planning. The parameter with the highest relative weight was *S* (0.12), followed by

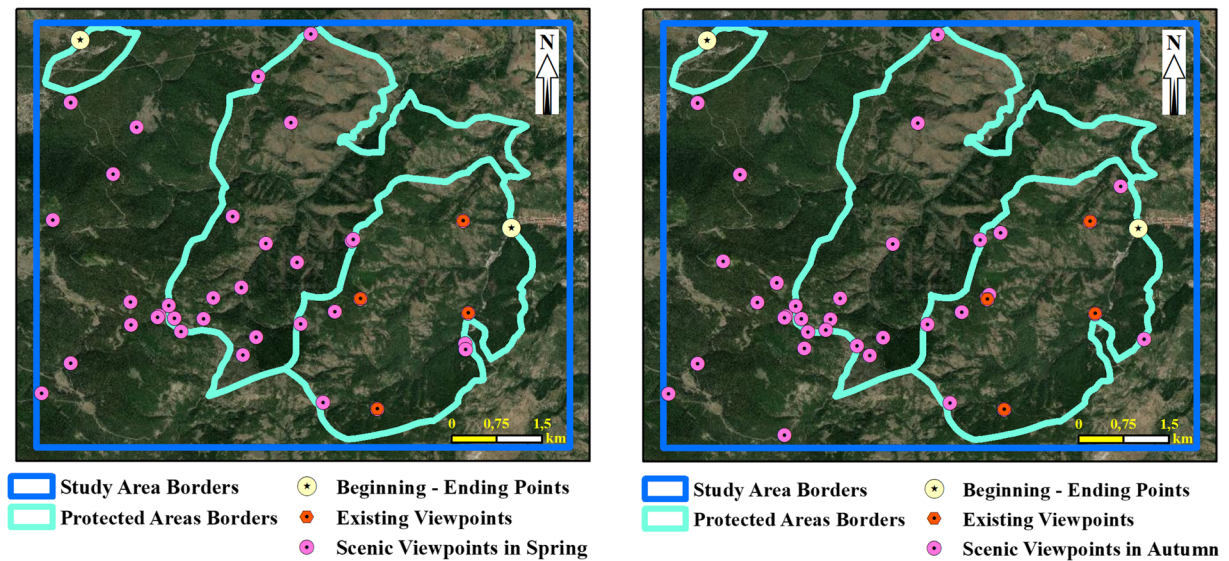


Fig. 4 Locations of new viewpoints, existing viewpoints (4), and beginning-ending points (2) of the road network for spring (left) and autumn (right) seasons

the parameters of MM, RD, and VQV (0.10); EVP, UL, and WID (0.09); and SD, LU, and AI, AII (0.08). The suitability equations of visual quality (SEVQ) developed with the linear regression model and WLC for the spring and autumn seasons are shown in Eq. 7.

$$\begin{aligned}
 SEVQ = & (LU*0.08) + (AI*0.08) + (AII*0.08) \\
 & + (SD*0.08) + (S*0.12) + (MM*0.10) \\
 & + (VQV*0.10) + (WID*0.09) \\
 & + (RD*0.10) + (EVP*0.09) \\
 & + (UL*0.09) \tag{7}
 \end{aligned}$$

The road network suitability obtained with WLC for the protected areas and their surroundings was calculated as the percentage of visual quality rates for spring and autumn seasons. The results indicated that in the spring season, the level of visual quality suitability was low in areas with dense existing road networks near the cinereous vulture nests, streams, steep grounds, and potential falling rock areas. Areas with forests, nonvegetated open areas in forests and areas with low slopes were found to be favorable in terms of visual quality. For the autumn season, the level of visual quality was low in areas with high slopes, potential falling rock areas, and in areas with dense existing road networks near the cinereous vulture nests. On the other hand, the level of suitability in terms

of visual quality was high in low-slope areas in forestlands and nonvegetated open areas in forests.

Within the study area, spatial maps of road network suitability were determined for the spring and autumn seasons using WLC. Objective functions were able to reveal three visual quality classes in the study area as poor, moderate, and good out of the six targeted classes (Fig. 5). For the spring season, 0.19% of the study area was defined as poor areas that could be preferred in road network planning under only mandatory conditions. Approximately 65.19% of the area was determined to be a moderate usage area that could be preferred in road network planning under normal conditions. On the other hand, 34.62% of the study area was determined to be the preferable location for ideal road network planning in terms of visual quality (Table 4).

For the autumn season, 0.19% of the study area was also determined to be poor areas that could be preferred in road network planning under only mandatory conditions. In terms of visual quality, approximately 62.96% of the area was determined to be a moderate usage area, while 36.85% was determined to be the preferable location for ideal road network planning (Table 5).

At the final stage, a new road network that prioritized visual quality was planned based on the visual quality suitability map while ensuring that the existing and new scenic viewpoints were visited in the study area (Fig. 6). The results indicated that the total length of the new road

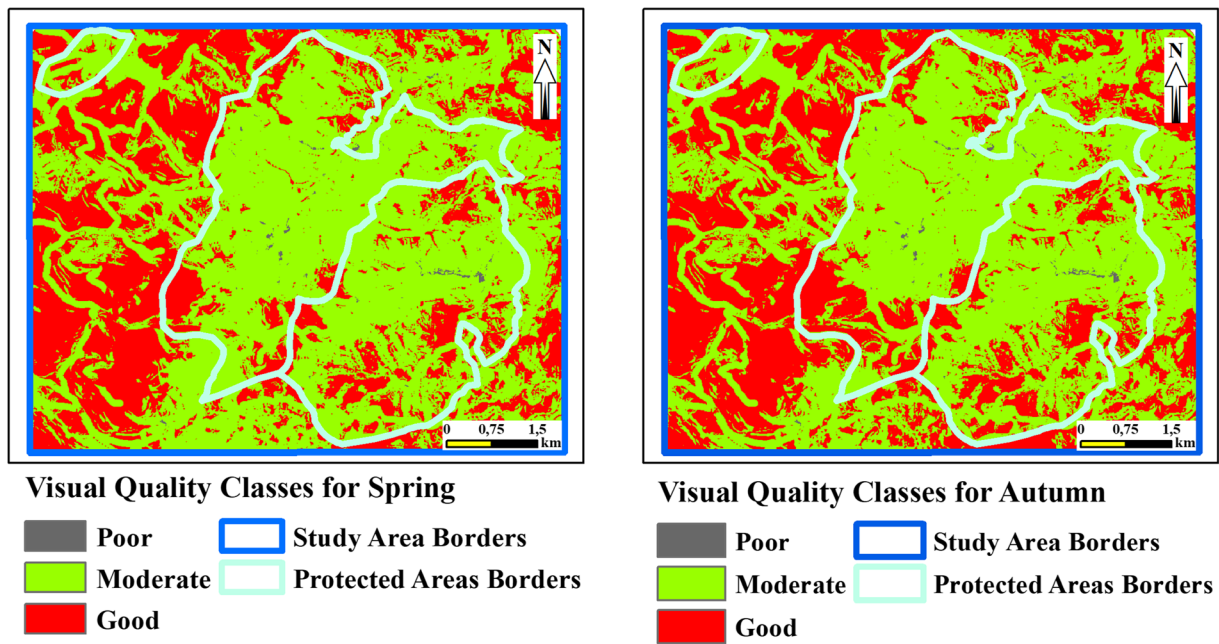


Fig. 5 Visual quality classes according to the objective functions determined by WLC for the spring (left) and autumn (right) seasons

network was 121.21 km and 129.47 km for the spring and autumn seasons, respectively. For the spring, 63.33% of the road network was rated as good, while 36.67% was moderate regarding the visual quality level. For the autumn season, 72.92% and 27.08% of the road network were rated as good and moderate, respectively.

Optimum route with maximum visual quality

The existing scenic viewpoint, new scenic viewpoints, and beginning-ending points of the road network were evaluated to determine the optimum route in terms of visual quality. Therefore, a total of 37 points for the spring and 38 points for the autumn were evaluated during route planning. Figure 7 indicates the optimum route on which the visitors can reach the existing and new viewpoints in the study area during cruising on the

new road network. The total road lengths of the optimum route with access to all of the viewpoints were 30.91 km and 30.70 km for the spring and autumn seasons, respectively. When considering the arrival and return distances to each point from the protected areas to the beginning and ending points of the visitors, the total distance to be traveled by the visitors along the optimum route was 43.59 km for the spring season and 46 km for the autumn season (Fig. 7).

The results from this study indicated that the viewpoints may have different visual quality values in different seasons. Thus, the spatial identity of scenic viewpoints could be evaluated in different ways. The mapping of landscape data can provide decision-makers with a simple way to develop new models using GIS techniques (Yang et al. 2014). In addition, the use of digital data values obtained during the evaluation of visual quality can contribute to

Table 4 Areal distribution of visual quality classes for the spring season

Visual quality classes	Area (ha)	Area (%)
Poor	11.59	0.19
Moderate	4046.56	65.19
Good	2149.29	34.62
Total	6207.44	100.00

Table 5 Areal distribution of visual quality classes for the autumn season

Visual quality classes	Area (ha)	Area (%)
Poor	11.83	0.19
Moderate	3908.29	62.96
Good	2287.35	36.85
Total	6207.47	100.00

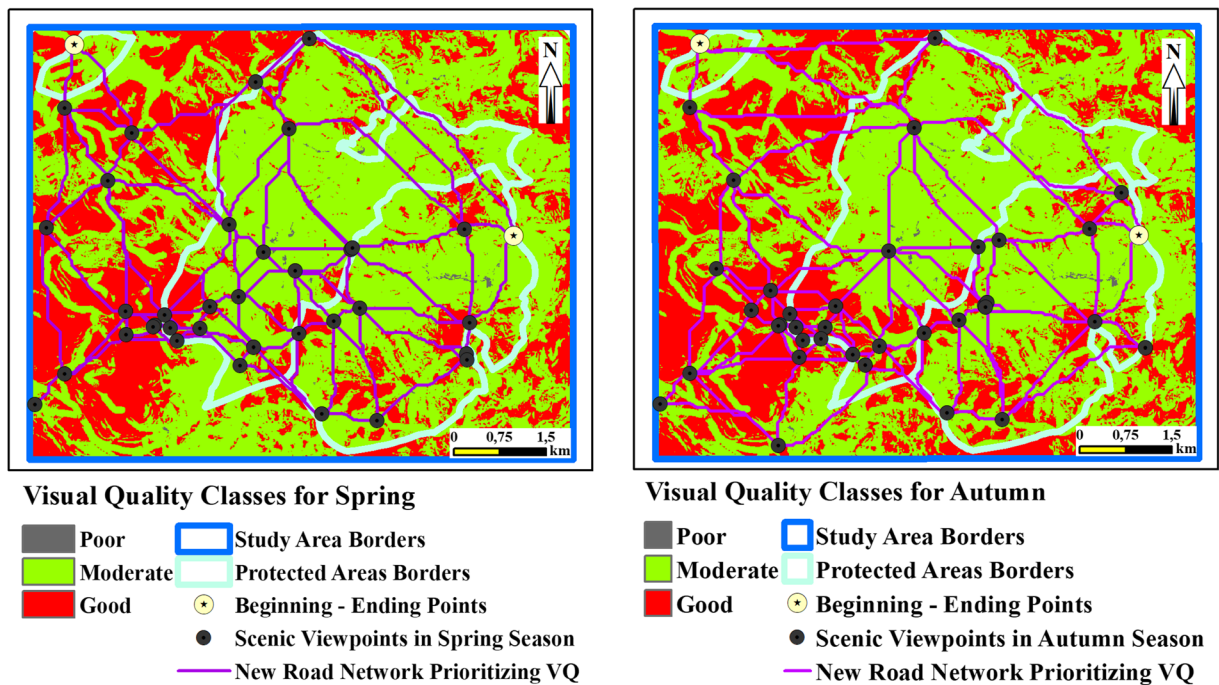


Fig. 6 Road network that prioritizes the visual quality in the study area for the spring (left) and autumn (right) seasons

various map applications (Martin et al. 2016). In a study conducted by Talebi et al. (2019), the existing road network that was suitable for tourism planning and

management was evaluated in the Arasbaran Protected area in Iran by using a GIS-based MDSS (fuzzy logic) method. A new road network was designed using a

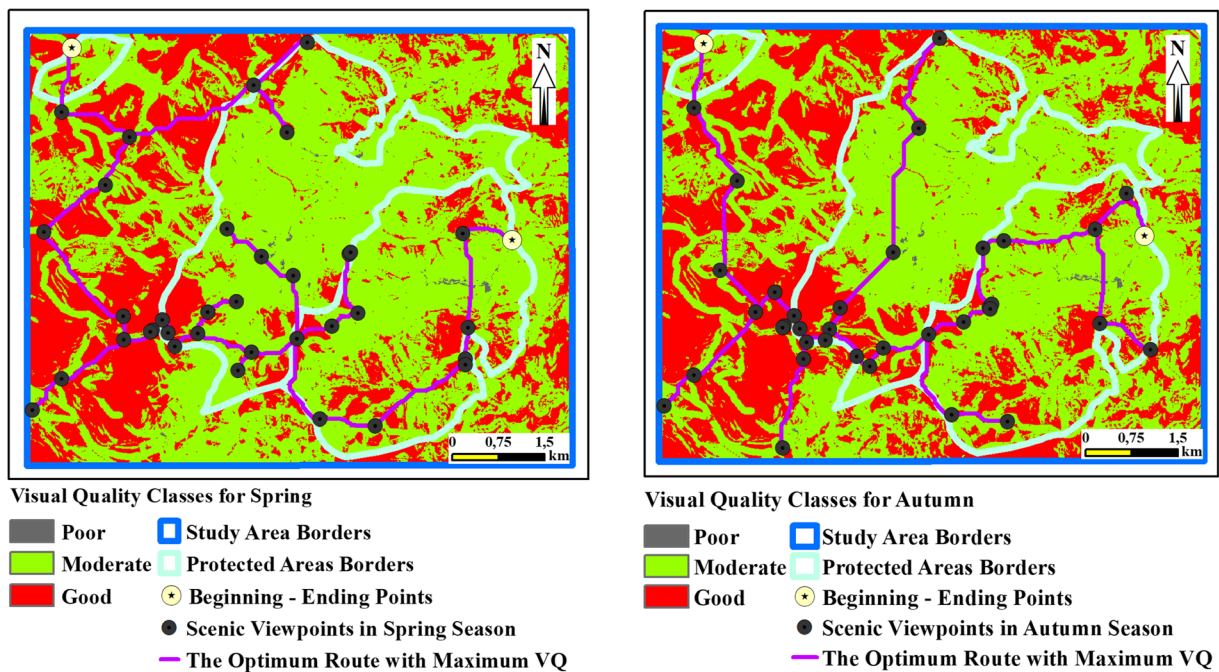


Fig. 7 Optimum route with maximum visual quality in the study area for the spring (left) and autumn (right) seasons

suitability map that considered technical, environmental, and socioeconomic parameters. However, the visual quality parameter was not evaluated in terms of tourism planning and management.

Visual quality parameters should be selected when planning road networks according to the visual quality characteristics in the protected areas. In fact, one of the most important stages in road network planning in these areas is to determine the visual quality parameters. In this study, road network planning that considered the visual quality parameters was developed by using the GIS-based MDSS method. Although similar evaluations have been applied in previous studies (Martin et al. 2016), this study presented three new perspectives to increase the sustainable management of protected areas. These perspectives included planning a road network that takes visual quality into account in protected areas, presenting how to determine the optimum route that maximizes visual quality in protected areas, and offering visitors with a seasonal guide on how to access scenic viewpoints during a certain time frame.

Conclusions

While protected areas are important zones in terms of natural, cultural, and biodiversity aspects, they have also gained great potential for ecotourism developments in recent decades. The road networks located in protected areas provide visitors with continuous access to/within protected areas. In this study, a new road network was planned in protected areas for spring and autumn seasons that considered the visual quality experiences of the visitors. For this purpose, a GIS-based MDSS method was used to develop a suitability map based on the specified visual quality parameters. To ensure the effective usage of the protected areas, an optimum route that maximized the visual quality experience of visitors while cruising on the new road network was determined by using the GIS-based network analysis method. The methodology presented in this study will help to efficiently evaluate landscape visual quality in natural and cultural sources as well as visual landscape sources. It is anticipated that this method can be used easily and quickly as a decision-making tool by resource managers during the planning phase of protected areas.

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A.E.A.; writing—original draft preparation, D.Ş.; writing—review and editing, D.Ş., A.A.; visualization, D.Ş.; supervision, A.A. and A.E.A.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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