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Application of Viewshed and Spatial Aesthetic Analyses to Forest Practices for Mountain Scenery Improvement in the Republic of Korea

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Abstract: Forest practices for mountainous areas can enhance the scenery value and function of forests. However, forest scenery management is rarely implemented except for conservation areas and public forests. In this study, we first used the viewshed analysis to extract visible and invisible zones from the surface areas of ordinary mountains in Korea, and then we used spatial aesthetic analysis to interpret the human-recognized characteristics on the visible zones of mountain scenery. Finally, based on the results of both analyses, reasonable guidelines for forest practice planning were proposed to improve the scenery of ordinary mountains. The result shows that the viewshed analysis made it possible to extract visible and invisible areas from the surface areas of ordinary mountains, and to determine the scale of zoning for forest practices to improve mountain scenery. In addition, using spatial aesthetic analysis, it was possible to explain the characteristics of mountain scenery according to distance and elevational differences between viewpoint and target, and to suggest a treatment target and direction for forest practices to improve the mountain scenery. This study is meaningful in that the viewshed and spatial aesthetic analyses were applied to evaluate the current scenery of ordinary mountains and to present guidelines for forest practice planning to promote their own scenery values.

Keywords: ordinary mountain; visible/invisible area; human-recognized characteristics; viewpoint and target; distance and elevational differences

1. Introduction

Forests play an important role in providing natural and recreational resources, and appropriate forest practices that increase the value of forest scenery are needed to promote forest biodiversity and sustain their functions [1,2]. The analysis for decision-making processes on forest management is based on various scientific data and these processes help to make the results about forest practices more objective [2]. The scenery is an aesthetic element of natural resources, and aesthetic satisfaction and evaluation vary greatly according to individuals. Therefore, previous studies have been made to apply viewshed analysis and spatial aesthetic analysis to scenery assessment as quantitative attempts.

As spatial analysis tools, represented by Geographic Information System (GIS), have evolved, the use of 3D topographical data has become more efficient to measure forest vegetation, terrain and land-use conditions [2–4]. On the basis of these tools, various landscape analysis techniques including viewshed analysis and spatial aesthetic analysis have been developed. The viewshed analysis is a technique that separates areas observed at a given viewpoint into visible and invisible zones [5,6]. It is often used to identify target zones for the most efficient evaluation of scenic values [7–9], and led to the development of various algorithms and analyzing tools, such as Vertical Visibility Index (VVI) [3] or Graphics Processing Unit (GPU)-based parallel algorithms [4]. The spatial aesthetic analysis, proposed by Hermann Maertens [10] during the late 1800s, was used to determine the flat size of an urban square and the height of buildings in the urban architectural field of modern Europe [10,11]. It was also used to evaluate scenery characteristics such as diversity and visibility perceived as the angle of view [12,13], and later contributed to the development of tools quantifying ecosystem services, such as Artificial Intelligence for Ecosystem Services (ARIES) and Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) approaches [14,15]. The aforementioned two analyses are techniques that can quantify spatial elements in a mountainous region, which may be used as tools to select and manage the target zones for forest practices to improve mountain scenery.

In the Republic of Korea during the mid-1950s, only 3.5 million ha of forests remained after a massive scale of forest denudation during the periods of Japanese colonial rule (1910–1945) and the Korean War (1950–1953) [16]. Since then, the government has made an effort to recover the devastated mountainous areas, and these areas have been restored to the current green and healthy forests totaling approximately 6.4 million ha [17]. During this process, the forest policy of Korea mainly focused on devastated forest recovery (1953–1972) and the forest rehabilitation (1973–1997). The policy of the forest resource and utilization was launched during the 1990s, and the policy for sustainable forest management started in the 2000s [18]. In particular, the 2000s were a period of increased social interest in the nonmarket values of forests based on forest ecosystem services worldwide [19–21]. Of these values, the most easily recognizable target is mountain scenery, which can be a valid measure of the approximate evaluation of forest value as well as the quality of life in surrounding areas [22–24].

Although there are 4612 mountains in Korea [25], only a small portion of them have high elevation and vertically varied mountain scenery. These mountain areas are currently managed as national parks [26,27]. However, most mountains in Korea have severe topographic relief. Therefore, visible and invisible areas are distinguished when viewed from a given viewpoint. In addition, the mountain scenery created by the topographical features is very complex and there is a limitation in having it serve as the main factor for forest practices. Furthermore, since the collective forest recovery project was initiated in 1973, the forests now consist of similar species and ages, which may be among the influential factors for mountain scenery degradation. Nevertheless, ordinary mountains, where the scenery value is not excellent, have not been managed for its improvement. Although the Korea Forest Service (KFS) has recently made efforts to improve the scenery of the ordinary mountains by proposing specific measures for forest practices considering the scenic conditions of the mountains [28,29], quantitative standards have not yet been provided for the selection of specific target zones for forest practices, which can be described as the beginning of the improvement of the mountain scenery.

From this background, this study utilized both viewshed and spatial aesthetic analyses to plan forest practices for improving the scenery value of ordinary mountains. We first used the viewshed analysis to extract visible and invisible zones from the surface areas of ordinary mountains in Korea, and then used spatial aesthetic analysis to interpret the human-recognized characteristics on the visible zones of mountain scenery. Finally, based on the results of both analyses, guidelines for planning forest practices were proposed to improve the scenery of ordinary mountains.

2. Study Sites

The Republic of Korea is situated from 33° to 38° N in latitude and 125° to 131° E in longitude. There are large proportions of mountainous areas that are naturally connected to sedimentary plains. In this study, eight mountains were selected as study areas. They are in the metropolitan provinces Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk and Gyeongnam (Figure 1). The sites are relatively unknown to people and are ordinary mountains in nonurban areas but are near human habitation. Thus, the sites do not include renowned areas such as national parks, state parks, recreational forests, and scenic beauty. The topographical, climatic and forest conditions of these eight mountains are described in Table 1.

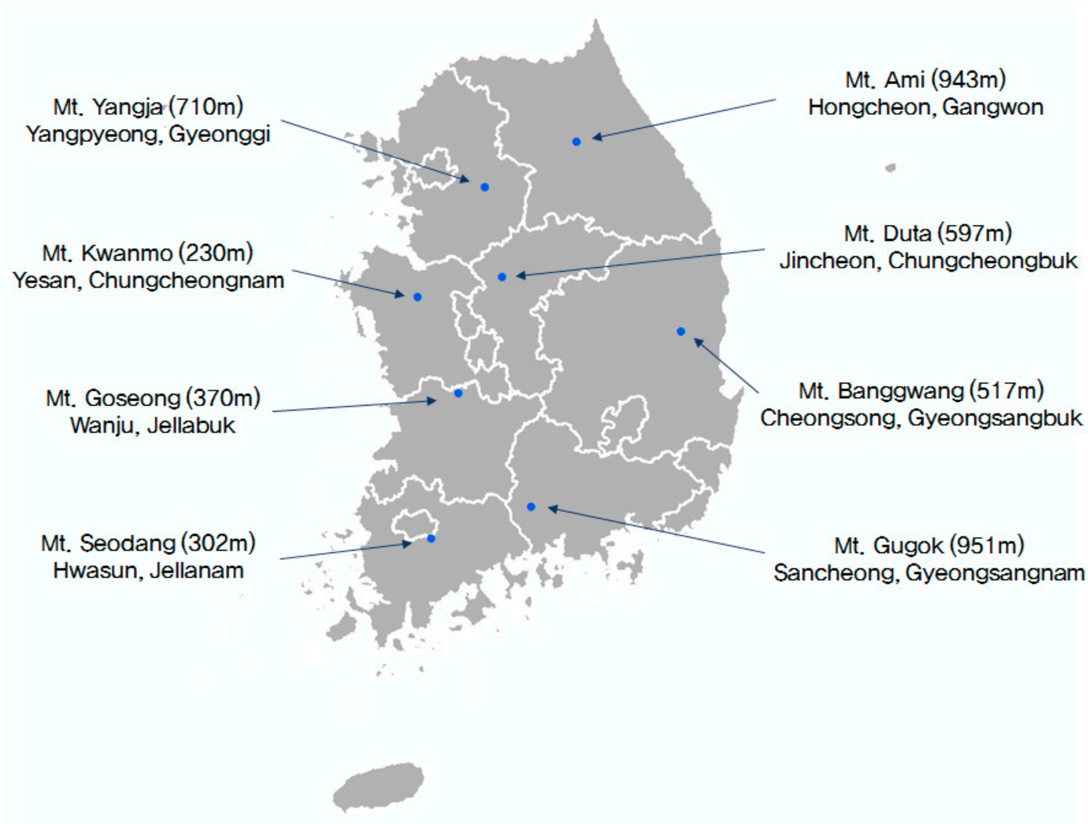


Figure 1. Locations of study sites in the Republic of Korea.

Table 1. General information of the study sites in the Republic of Korea.

Study Site	Mountain Name	Geology	Climate Condition during Last 10 Years			Forested Mountain Area (m^2)			
			Mean Annual Precipitation (mm)	Mean Annual Temperature (°)	Station Name	Coniferous Forest	Deciduous Forest	Mixed Stand Forest	Total
A	Mt. Yangja	Daebo Granite Dancheon Comp.	1365	11.9	Yangpyeong	2,690,758 (15.9%)	12,805,291 (75.6%)	1,447,740 (8.5%)	16,943,792 (100%)
B	Mt. Ami	Daebo Granite Dancheon Comp.	1183	11.2	Hong cheon	7,767,235 (68.9%)	2,430,330 (21.6%)	1,079,003 (9.6%)	11,276,568 (100%)
C	Mt. Duta	Sindong Gp. Hanbongsan Gp. Bakcheon Gp., etc.	1168	13.3	Cheongju	4,990,260 (29.4%)	9,958,274 (58.7%)	2,022,687 (11.9%)	16,971,220 (100%)
D	Mt. Kwanmo	Buncheon Granite Hongjesa Granite Iwon Comp., etc.	1160	12.3	Cheonan	286,652 (52.4%)	170,772 (31.2%)	90,135 (16.5%)	547,559 (100%)
E	Mt. Goseong	Ogcheon Gp.	1196	13.7	Jeonju	507,197 (60.6%)	221,527 (26.5%)	107,767 (12.9%)	836,491 (100%)

Table 1. *Cont.*

Study Site	Mountain Name	Geology	Climate Condition during Last 10 Years			Forested Mountain Area (m^2)			
			Mean Annual Precipitation (mm)	Mean Annual Temperature (°)	Station Name	Coniferous Forest	Deciduous Forest	Mixed Stand Forest	Total
F	Mt. Seodang	Daebo Granite Dancheon Comp. Yucheon Gp., etc.	1300	14.4	Gwangju	548,123 (50.1%)	365,059 (31.3%)	217,462 (18.6%)	1,166,643 (100%)
G	Mt. Banggwang	Daebo Granite Dancheon Comp.	974	12.5	Andong	1,109,353 (58.9%)	553,897 (29.4%)	221,607 (11.8%)	1,884,857 (100%)
H	Mt. Gugok	Granitic Gneiss Seosan Gp. Yulri Gp., etc.	1456	13.2	Sancheong	4,344,187 (35.5%)	7,283,015 (59.4%)	625,351 (5.1%)	12,252,553 (100%)
Mean		-	1225.3	12.8	-	2,780,471 (36.0%)	4,223,521 (54.6%)	726,469 (9.4%)	7,730,460 (100%)

3. Methods

3.1. Selection of Viewpoint

The evaluation of natural scenery often varies from person to person [30]. To avoid this variation, researchers are making continuous efforts to quantitatively evaluate the surrounding scenery [31,32]. Recently, GIS-based scenery evaluation has been actively conducted [33–35]. A viewpoint is a point representing the surroundings or a continuous line [36] and is among the elements of scenery evaluation. It is used as a control point for surveying the distance, elevational difference and vertical angle from the viewpoint and target (bottom and top). Therefore, the selection of a viewpoint is a very important step in natural scenery assessment. In this study, firstly, we selected central areas (e.g., areas near township offices or small markets) with relatively higher human traffic because of the better accessibility compared to the surrounding areas of the eight study areas. Then, we randomly selected dozens of viewpoints, which are located within the central areas and do not have buildings on imaginary horizontal lines connecting to top elevation points of the studied mountains. Finally, based on the results of following viewshed analysis, we compared visible areas of the studied mountains from dozens of viewpoints randomly selected, and established the viewpoints that had the largest visible area of the studied mountains.

3.2. Viewshed Analysis

The first step in analyzing scenery is to distinguish visible and invisible areas of the target mountains [5]. This is possible by drawing multiple arbitrary lines of sight that connect between any viewpoint and target to determine whether or not the visible lines are shielded by topography (Figure 2).

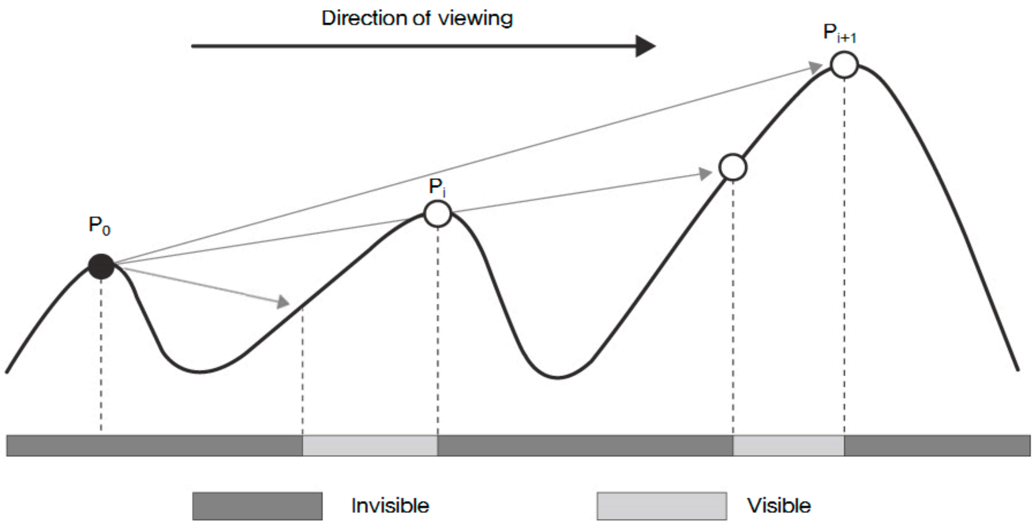


Figure 2. Basic concept of viewshed analysis [37].

In the past, the distinction between visible and invisible areas was directly determined by experts in the field and the results were manually drawn [38–41]. Recently, however, viewshed analysis tools have been developed and utilized to analyze the visibility at given viewpoints using a digital elevation model (DEM) or digital surface model (DSM) based on the GIS [42–45]. In general, viewshed analysis of natural environments is used to assess the scenery value by topographic substrate and vegetation through the division of visible and invisible areas. Recently, it has been applied in various fields such as determining the problem related to viewing rights because of shielding by buildings in urban areas and the analysis of visible areas of closed-circuit televisions installed for the prevention of forest fires in mountainous areas [46–49].

Using viewshed analysis, this study distinguished the visible and invisible areas of the eight studied mountains and showed the visible areas as the preferred target zones to improve forest scenery. The tool used for the analysis was the Viewshed Tool in ArcGIS 10.2 [50]. Initially, we tried to use DSM, which adds stand height to DEM. However, it was impossible to obtain highly reliable data that could reflect the heights of forest stands in the study sites throughout Korea. Although LiDAR data, often used to create DSM, were available from the National Geographic Information Institute in Korea, they did not entirely cover our study sites. In addition, the National Forest Inventory database from KFS is too coarse to be employed for the analysis, even though it has information of height, diameter at breast height, and density of forest stands. Consequently, we used only DEM, which are verified data at the national scale.

The elements for the analysis are as follows: (a) the vertical distance to be added to the elevation of a viewpoint; (b) the vertical distance to be added to the top elevation of a target; (c) the start point of the azimuth; (d) the end point of the azimuth; (e) the elevation angle; (f) the depression angle; (g) the distance between the viewpoint and observational starting point; and (h) the distance between viewpoint and observational ending point (Table 2). In this study, the elevation of a viewpoint is the sum of the ground elevation and the human eye level (1.6 m). In addition, the azimuth angle was set at a total of 120°, including 60° to the left and right of the imaginary horizontal lines connecting the viewpoints and the studied mountains' top elevation points, which was based on the suggestions by Weitkamp et al. [51].

Table 2. Parameters used in the viewshed analysis.

Classification		Explanation	Value
(a)	Offset A	Vertical distance to be added to the elevation of a viewpoint	1.6 m
(b)	Offset B	Vertical distance to be added to the top elevation of a target	0 m
(c)	Azimuth 1	Start point of azimuth	Horizontal reference angle − 60°
(d)	Azimuth 2	End point of azimuth	Horizontal reference angle + 60°
(e)	Vert 1	Elevation angle	90°
(f)	Vert 2	Depression angle	−90°
(g)	Radius 1	Distance between the viewpoint and observation starting point	0 m
(h)	Radius 2	Distance between the viewpoint and observation ending point	Distance between the viewpoint and target (m)

In this study, we used a digital topographic map (1:5000) provided by the National Geographic Information Institute and a forest type map provided by the KFS. First, the digital topographic map was used for the production of a DEM with a 5 m × 5 m cell size for viewshed and spatial aesthetic analyses. Second, a forest type map was used to exclude areas not included in mountainous areas by assessing the boundaries of the studied mountains.

3.3. Spatial Aesthetic Analysis

Numerous scientists have conducted scenic evaluation employing a variety of factors, such as "light (or shade)", "climate", "distance", and "angle". Particularly, the "distance between observer and target" and the "vertical angle of observer view" are often used as quantitative indicators of scenery value analysis [28,52,53].

First, the "sight distance between observer and target" is an indicator that can be considered to quantitatively assess human visual ability. This is mainly classified into three zones: near-, middle- and far-distance. Each zone has its own characteristics that the observer can perceive. KFS [28] classified the sight distance (d), i.e. the horizontal distance between observers' viewpoints and the target mountains, as less than 500 m as the near-distance view, 500–2000 m as the middle-distance view, and further than 2000 m as the far-distance view. It defined that an observer can note differences in a number of characteristics: the color and form of leaves and trees of the foreground within the near-distance zone; the colonies of forest physiognomy and the crown of the trees from the target mountains within the middle-distance zone; and only the ridge and/or boundary shape within the far-distance zone.

Second, Ladd [11] presented observational features recognized by observers in accordance with the sight distance (d) and the elevational difference (h) between the viewpoint and target, referring to the results of Maertens [10] who performed spatial aesthetic analysis on buildings and sculptures in urban areas. Specifically, this previous study stated that the object is observed in great detail when the distance and elevational difference between the viewpoint and target are the same ($d/h = 1$); further, it is observed relatively clearly when the distance is twice the elevational difference ($d/h = 2$), it is observed in combination with the surrounding landscape when the distance is three times the elevational difference ($d/h = 3$), and finally it is observed as part of the landscape as shown in landscape pictures or paintings when the distance is more than four times the elevational difference ($d/h = 4$). In Korea, scenic characteristics depending on the d-h relationship, i.e., the vertical angle of the observer's view, are often used not only in the field of urban engineering and landscape architecture but also in the field of forestry (see [12,28,54]).

In this study, a scenery assessment of only the visible area in the studied mountains was conducted by extracting the sight distance between the viewpoint and target as well as the vertical angle of the observer's views. The scenery features recognized according to the distance (d) between viewpoints and targets (Figure 3) and the vertical difference (h) between the elevation of a viewpoint (h_1) and the top of the studied mountains (h_2) were estimated (Table 3).

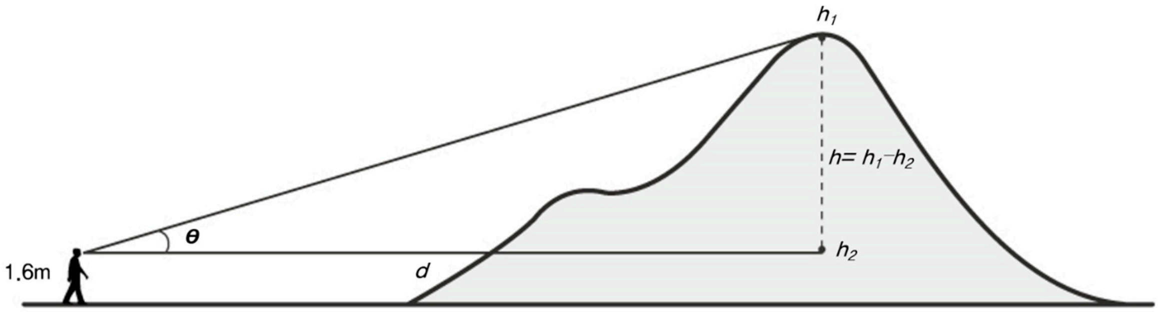


Figure 3. Basic concept and evaluation method of the spatial aesthetic analysis.

Table 3. Scenery perception contents according to distance (d) and elevational difference (h) between the viewpoint and target [11,28].

	Classification	Scenery Perception Contents
d	near-distance view (<500 m)	Differences in the colors and forms of leaves and trees
	middle-distance view (≥500 m and <2000 m)	Difference in the vegetation community of the upper layer of forest stands
	far-distance view (≥2000 m)	Difference in the shape of mountain ridges and/or boundaries
d/h	1	Very detailed scenery of viewing target
	2	Relatively clear scenery of viewing target
	3	Vertical and less panoramic scenery of viewing target
	≥4	Panoramic scenery of viewing target

Note: The near-distance view is less than 500 m, the middle-distance view is farther than 500 m and less than 2000 m, and the far-distance view is farther than 2000 m.

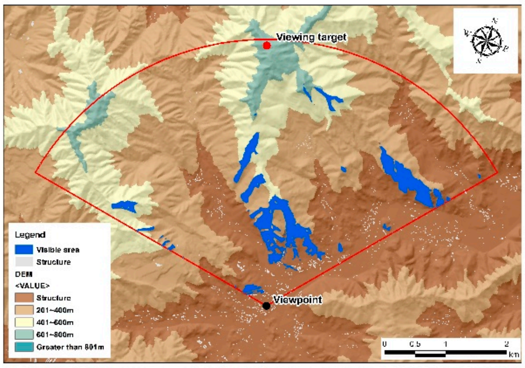
4. Results

4.1. Extracting the Visible and Invisible Areas by Viewshed Analysis

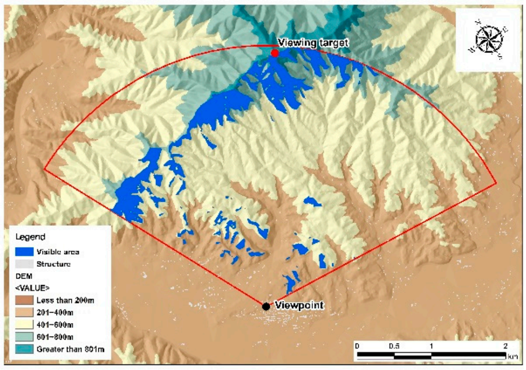
The results of extracting the visible and invisible areas of the eight studied mountains using the viewshed analysis are shown in Table 4 and Figure 4. The areas of the study sites ranged from 547,559 m^2 (Mountain *D*) to 16,971,220 m^2 (Mountain *C*), with a mean of approximately 7,741,369 m^2. In these mountainous areas, the actual visible areas from the selected viewpoints ranged from 256,471 m^2 (Mountain *D*) to 4,390,748 m^2 (Mountain *C*), with a mean of approximately 1,350,952 m^2. Consequently, the proportions of the visible areas to the mountain areas ranged from 6.8% (Mountain *A*) to 46.8% (Mountain *D*) and their mean was approximately 17.5%.

Table 4. Results of the viewshed analysis of the eight studied mountains.

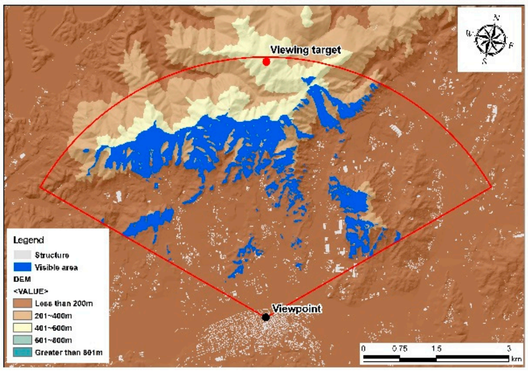
Study Site	Mountain Name	Forested Mountain Area (m^2)	Visible Area		Invisible Area	
			(m^2)	(%)	(m^2)	(%)
A	Mt. Yangja	16,943,792	1,148,286	6.8	15,795,506	93.2
B	Mt. Ami	11,276,568	1,261,731	11.2	10,014,837	88.8
C	Mt. Duta	16,971,220	4,390,748	25.9	12,580,472	74.1
D	Mt. Kwanmo	547,559	256,471	46.8	291,088	53.2
E	Mt. Goseong	836,491	320,913	38.4	515,578	61.6
F	Mt. Seodang	1,166,643	390,655	33.5	775,988	66.5
G	Mt. Banggwang	1,884,857	210,723	11.2	1,674,133	88.8
H	Mt. Gugok	12,252,553	2,803,186	22.9	9,449,367	77.1
Mean		7,741,369	1,350,952	17.5	6,390,416	82.5



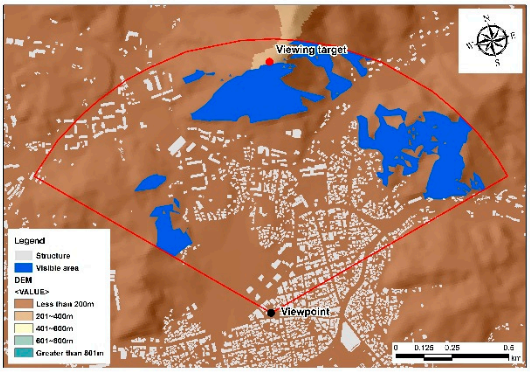
(Mountain *A*)



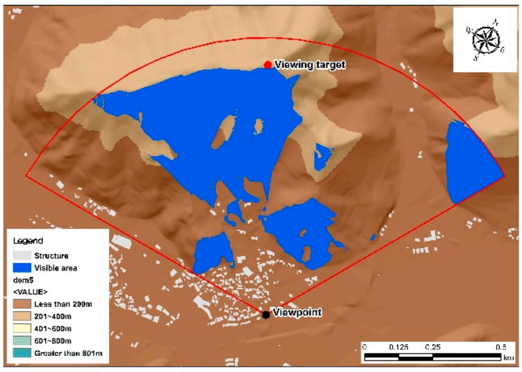
(Mountain *B*)



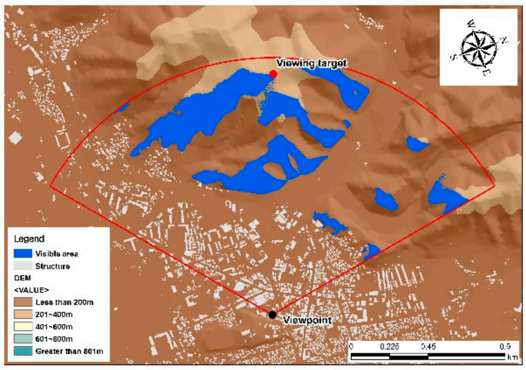
(Mountain *C*)



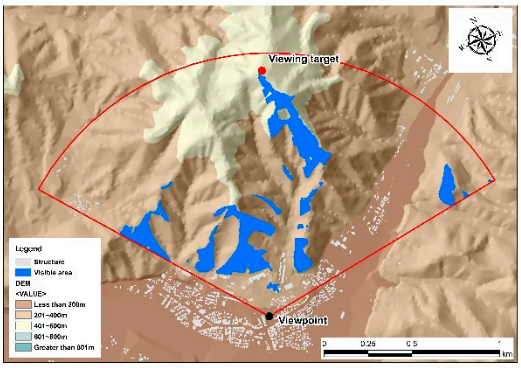
(Mountain *D*)



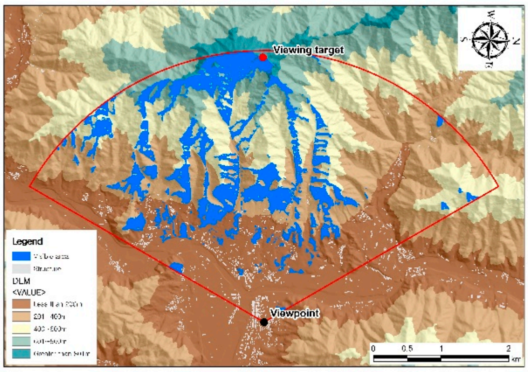
(Mountain *E*)



(Mountain *F*)



(Mountain *G*)



(Mountain *H*)

Figure 4. Images displaying the visible areas extracted from the viewshed analysis of the eight studied mountains.

4.2. Extracting the Human-Recognized Elements by Spatial Aesthetic Analysis

The results of the spatial aesthetic analysis of the studied mountains are shown in Table 5. The horizontal sight distances (d) between viewpoints and studied mountains ranged from 914 m (Mountain E) to 5369 m (Mountain C), with a mean of approximately 2530 m. In particular, the sight distance d showed differences among mountains with relatively larger (Mountains A, B, C and H) and smaller (Mountains D, E, F and G) areas: that is, the d of Mountains A, B, C and H for the relatively larger mountainous area was within the range of 3513–5369 m, corresponding to the far-distance view; however, the d of Mountains D, E, F and G for the relatively smaller area was within the range of 914–1401 m, corresponding to the middle-distance view.

Table 5. Results of the spatial aesthetic analysis of the eight studied mountains.

Study Site	Mountain Name	d (m)	h_1 (m)	h_2 (m)	$h_2 - h_1 = h$ (m)	d/h
A	Mt. Yangja	4374	109.1	710.1	601.0	7.3
B	Mt. Ami	3513	327.3	942.6	615.3	5.7
C	Mt. Duta	5369	58.6	597.1	538.5	10.0
D	Mt. Kwanmo	1210	31.6	230.0	198.4	6.1
E	Mt. Goseong	914	88.7	370.0	281.3	3.2
F	Mt. Seodang	1401	71.5	301.6	230.1	6.1
G	Mt. Banggwang	1401	198.4	517.4	319.0	4.4
H	Mt. Gugok	3901	111.0	951.3	840.3	4.6
Mean		2760	124.5	577.5	453.0	6.1

Note: d denotes the distance between the viewpoint and target. Additionally, h_1 and h_2 denote the elevations above sea level of the viewpoint and target, respectively, and their difference is expressed as h.

In addition, the ground elevations (h_1) of the viewpoints ranged from 31.6 m (Mountain D) to 327.3 m (Mountain B), with a mean of approximately 124.5 m. The peak (h_2) of the studied mountains ranged from 230.0 m (Mountain D) to 942.6 m (Mountain B), with a mean of approximately 577.5 m. The differences (h) in these two elevations (i.e., h_1 and h_2) were used to calculate the d/h using the sight distance d previously estimated. The results show that Mountains A, B, C and H, which have relatively larger areas, have longer sight distances (d) than the elevational differences (h), with total values greater than 4.0. This pattern was the same as Mountains D, F and G, which have relatively smaller areas. However, the d/h of Mountain E was near 3.0 (i.e., 3.2) because of the impact of the shortest sight distance (d) among the eight studied mountains.

5. Discussion

5.1. Zoning for Forest Practice Using the Results from Viewshed Analysis

The results of the viewshed analysis previously described can be explained based on the mean mountain area (7,741,369 m^2) of all the studied mountains. Of the studied mountains (A, B, C and H) with larger mountainous areas than their mean, Mountains A and B have lower proportions of visible area than the mean (17.5%) of all the studied mountains, whereas Mountains C and H have slightly higher proportions of visible areas than the mean. In addition, this study found that, of the studied mountains (D, E, F and G) with smaller mountainous areas than their mean, Mountains D, E and F have higher proportions of visible area than the mean, whereas Mountain G, despite a lower proportion (i.e., 11.2%) of mountainous area, was separated from Mountains D, E and F because of its lower proportion of visible area.

In general, there are many different heights of mountain masses between the viewpoints and targets in mountainous areas with severe terrain. Thus, as shown in Figure 2, the hillside views of the higher-elevation mountains are shielded by the hillsides of the mountain masses with lower elevations, resulting in a reduction of the visible area. The difference in the visible area proportion because of these topographical gradients appears to be equally applicable, regardless of the relative size of the mountainous area. As a consequence, the mountain topography can be seen as a form of development of not only larger mountain textures consisting of wider areas but also smaller mountain textures consisting of narrower areas. Previous studies [55–57] report the formation, development and relevant landform characteristics of the Korean Peninsula, which shows relatively high gradient and complex topographic distribution. In particular, Park [57] reported that, compared to other countries in the East Asian regions, the Korean Peninsula has a relatively lower elevation but higher topographic diversity. Here, a high degree of topographic diversity means that the formation of different topographical features exists within a limited area. This is the reason the proportion of visible area is high or low depending on the topographical structure, regardless of the relative size of the studies mountains.

The aforementioned results of the viewshed analysis may be among the main factors affecting the "zoning size for forest practice" to improve the scenery of the visible area. In other words, under the assumption that there are no other restricted conditions, large zones can be designated for forest practices because of the densely interconnected visible areas in the mountains with a large proportion of visible area. In contrast, it would be desirable to establish small zones for forest practices because of the relatively dispersed visible areas in the mountains with a small proportion of visible area.

5.2. Treatment Target and Direction for Forest Practice Using the Results from Spatial Aesthetic Analysis

The identification of the sight distance in spatial aesthetic analysis may determine the "treatment target of forest practices" to enhance mountain scenery. KFS [28] suggested the exposed degree and diversity of certain scenery and the size and shape of continuous scenery were major factors for designing and managing the mountain scenery. In particular, the former (i.e., exposed degree and diversity of certain scenery) was proposed as an element to be considered in the range of a near-distance view (less than 500 m) and the latter (i.e., size and shape of continuous scenery) was proposed as an element to be considered in the ranges of the middle- (500–2000 m) and far-distance views (farther than 2000 m). Because all of the studied mountains are in the ranges of middle- and far-distance views (Table 5), forest practices should be devised to treat the size and shape of continuous mountain scenery; that is, the difference in vegetation community of the crown layer can be distinguished at Mountain *E* from the middle-distance view (Table 3), and thus it would be desirable to set the scale of forest practices targeted to the upper layers of forest stands on a vegetation community basis. Only the shape of visible areas can be distinguished at the remaining seven mountains (i.e., *A*, *B*, *C*, *D*, *F*, *G* and *H*) from the far-distance view (Table 3), and thus it would be desirable to set the scale of forest practices targeted to mountain ridges and/or boundaries.

Meanwhile, the *d/h* should be interpreted as the "ultimate direction to be considered on forest practices" to improve mountain scenery. Suh and Kim [12], Kim [54] and Choi et al. [58] used the viewing angle *d/h* as one of the main elements for the analysis of natural scenery in Korea. They indicated that the object appears panoramic when the viewing angle is small (i.e., the *d/h* is high), whereas the viewing target's situation is more detailed when the viewing angle was large (i.e., the *d/h* is low). In addition, the "size and shape of continuous scenery", which was previously presented by the KFS [28] as a key factor for the design of mountain scenery in the middle-distance and far-distance views, is based upon the premise that there is "continuity" in single continuous scenery with a relatively large visible area. Therefore, it is likely that forest practices should consider the lateral continuity of mountain scenery because the viewing target with a *d/h* greater than 4.0 creates a panoramic view with low and wide scopes (Table 3). However, for the target with a *d/h* of 3, the verticality of the viewing target is perceived to some extent and appears relatively less panoramic (Table 3), requiring the management of the mountain scenery considering some vertical along with lateral continuity.

5.3. Policy Implications for Forest Practices by Mountain Scenery Type

The results, obtained from the viewshed and spatial aesthetic analyses, can be organized into five scenery types for creation of sustainable mountain scenery (Table 6). Of the studied mountains with larger areas (i.e., *A*, *B*, *C* and *H*), Mountains *A* and *B* have lower proportions of visible area, far-distance views, and *d/h* ratios greater than 4.0 (Type I in Table 6). Mountains *C* and *H* also have far-distance views and *d/h* ratios greater than 4.0, but their proportions of visible area were high, making them different from those of Mountains A and B (Type II in Table 6). In contrast, of the studied mountains with smaller areas (i.e., *D*, *E*, *F* and *G*), Mountains *D* and *F* have higher proportions of visible area, middle-distance views, and *d/h* ratios greater than 4.0 (Type III in Table 6). Mountain *E* also has a higher proportion of visible area and a middle-distance view, but its *d/h* ratio was near 3.0, which was different from those of Mountains *D* and *F* (Type IV in Table 6). Finally, Mountain *G*, as shown for Mountains *D* and *F*, also has a middle-distance view and a *d/h* ratio greater than 4.0, but its proportion of visible area was low (Type V in Table 6).

Table 6. Mountain scenery types categorized from the viewshed and spatial aesthetic analyses of the eight studied mountains.

Study Site	Mountain Name	Forested Mountain Area	Visible Area Proportion	d	*d/h*	Scenery Type
A	Mt. Yangja	Large	Low	Far-distance	Greater than 4	I
B	Mt. Ami	Large	Low	Far-distance	Greater than 4	I
C	Mt. Duta	Large	High	Far-distance	Greater than 4	II
D	Mt. Kwanmo	Small	High	Middle-distance	Greater than 4	III
E	Mt. Goseong	Small	High	Middle-distance	Approximately 3	IV
F	Mt. Seodang	Small	High	Middle-distance	Greater than 4	III
G	Mt. Banggwang	Small	Low	Middle-distance	Greater than 4	V
H	Mt. Gugok	Large	High	Far-distance	Greater than 4	II

Note: *d* denotes the distance between the viewpoint and target and *h* denotes the difference between the elevations above sea level of the viewpoint and target.

The goal of forest practices for enhancing forest ecosystem services, such as forest scenery provision, forest recreation and water resource cultivation, is obviously to ensure that each service is properly functioning, and there is unlikely to be any need or limitation of a specific forest practice in achieving the goal. For example, if only on-site physical conditions (e.g., accessibility and stability) are not problematic, the following forest practices should be implemented in common regardless of the type of public service: promoting growth of the remaining trees by thinning the trees damaged by diseases and cut out of survival competition [59,60]; creating vertically multiple layers of forest stands by thinning and pruning suitable trees of upper layers to increase amount of light entering lower layers, thereby inducing settlements of shrubs and herbaceous plants [61]; and inducing horizontal diversity of forest stands by planting or regenerating various tree species, and also by allowing deciduous, coniferous and mixed-stand forests to be distributed with a mosaic pattern [62,63].

However, the strategy of forest management may be distinct by each forest ecosystem service. The strategy for forests to create and provide a great mountain scenery may include the shielding of unnecessary scenery elements; the plantation or generation of tree species that can give a sense of season and are harmonized with the surrounding forest scenery; and the tending of trees for maintaining proper stand density and thus improving mountain scenery. In particular, for areas with excessively unique scenery or the opposite, the thinning and/or pruning should be carried out to control the amount of light under the upper layer. Besides, in the conspicuous ridge or boundary, the settlement and survival of native species should be induced, and the evergreen coniferous trees should be maintained for preserving the scenery during the winter. One thing planners need to be aware of is that it is desirable for the forest practices to have different priorities and intensities for sustainable and effective management of mountain scenery, and thus they need to identify not only the on-site conditions but also the scenic conditions (i.e., the results from viewshed and spatial aesthetic analyses) shown at the viewpoints.

Based on the scenic conditions, Table 7 shows guidelines of forest practice planning to enhance the mountain scenery for the five scenery types mentioned above. The forest practices in scenery Type I should be targeted to the mountain ridges and/or boundaries after dispersed zoning of forests covering a relatively smaller visible area, and this should be done while considering the lateral continuity of mountain scenery. The forest practices in scenery Type II should be targeted to the mountain ridges and/or boundaries after interconnected zoning of forests covering a relatively larger visible area, and this too should be done while considering the lateral continuity of mountain scenery. The forest practices in scenery Type III should be targeted to the upper layers of forest stands on a vegetation community basis after interconnected zoning of forests covering a relatively larger visible area, while still considering the lateral continuity of mountain scenery. The forest practices in scenery Type IV should be targeted to the upper layers of forest stands on a vegetation community basis after interconnected zoning of forests covering a relatively larger visible area, and this should be done while considering not only lateral but also the vertical continuity of mountain scenery. Lastly, the forest practices in scenery Type V should be targeted to the upper layers of forest stands on a vegetation community basis after dispersed zoning of forests covering a relatively smaller visible area, and should be done while considering the lateral continuity of mountain scenery. Although we could not suggest the detailed forest practices regarding their priorities and intensities here, our findings are meaningful in that they provide the reasonable guidelines for forest practice planning to enhance the value of mountain scenery.

Table 7. Guidelines of forest practice planning for enhancing mountain scenery by scenery type.

Scenery Type	Study Site	Guideline of Forest Practice Planning for Enhancing Mountain Scenery
I	*A*, *B*	Small-scale and dispersed zoning of forests covering a relatively smaller visible area Targeting mountain ridges and/or boundaries Considering lateral continuity of mountain scenery
II	*C*, *H*	Large-scale and interconnected zoning of forests covering a relatively larger visible area Targeting mountain ridges and/or boundaries Considering lateral continuity of mountain scenery
III	*D*, *F*	Large-scale and interconnected zoning of forests covering a relatively larger visible area Targeting upper layers of forest stands on a vegetation community basis Considering lateral continuity of mountain scenery
IV	*E*	Large-scale and interconnected zoning of forests covering a relatively larger visible area Targeting upper layers of forest stands on a vegetation community basis Considering not only lateral continuity but also vertical continuity of mountain scenery
V	*G*	Small-scale and dispersed zoning of forests covering a relatively smaller visible area Targeting upper layers of forest stands on a vegetation community basis Considering lateral continuity of mountain scenery

6. Conclusions

Many approaches for sustainable conservation and use of natural resources, such as a social representation approach [64], multidirectional temporal analysis approach [65], and dynamic and spatially explicit modeling approach [66], have been carried out. However, there are still a lot of knowledge gaps for the establishment of comprehensive management strategies that should be completed with these approaches. As a part of efforts to fill the gaps, two analyses were used to plan forest practices for improving the scenery value of ordinary mountains in this study. We found that the viewshed analysis made it possible to extract visible and invisible areas from the surface areas of ordinary mountains and to determine the scale of zoning for forest practices to improve mountain scenery. In addition, using the spatial aesthetic analysis, it was possible to explain mountain scenery characteristics according to distance and elevational difference between viewpoint and target, and suggest treatment target and direction for forest practices to improve mountain scenery.

Mountain scenery management has been conducted on a portion of the mountain area adjacent to roads only. Therefore, it was difficult to create a large-scale spectacular view from a specific vista points, which in turn served as a limitation to the use of scenery views. Specifically, countries with severe topographic relief and even-aged forests such as Korea, from a local perspective, have a rather complex landscape due to the size and shape of a small mountain area. Conversely, from a broad perspective, a very simple landscape would be viewed across a huge mountain area in those countries. This may be the reason the quantitative analysis techniques of mountain scenery could not be clearly established.

In this regard, it is meaningful that the viewshed and spatial aesthetic analyses attempted in this study were used to evaluate the current scenery of ordinary mountains and to present guidelines for forest practice promoting it to the maximum extent possible. Such an attempt, using the best available knowledge, data, and analysis, provides clear direction to ensure the long-term sustainability of natural resources and the environment. Furthermore, it may be considered as an approach to improve forest household income at a small economic scale and may contribute in part to invigorating depressed mountain villages in the future. However, for generalization and wide use of the two analyses presented here, it is deemed necessary to ensure the adequacy and objectivity of the selected viewpoints and then establish a quantitative basis for classifying forest practice technologies by mountain scenery type.

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