Field Application of
A Forest Landscape Zoning Method

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Keywords: Forest landscape zoning, landscape sensitivity, landscape value assessment, GIS

Abstract: The objective of this study is to develop a forest landscape zoning method using the geographical information system (GIS). The method consists of landscape resources assessment procedures which include the inventory process for identifying landscape resources and the evaluation process for analyzing detailed landscape attributes. This method was applied to a case study of a forest scenery management project in the area of Mt. Sambong in South Korea. Initially, the natural and artificial landscape resources were identified and mapped using GIS. Next, the landscape sensitivity was measured in terms of visibility and visual absorption capability (VAC) using GIS to quantify the relative importance of the features identified in a landscape inventory. Then, the scenic attractiveness of the landscape unit was analyzed to estimate the landscape value. The landscape value was estimated as the function of the quality and quantity of various landscape resources as well as the intrinsic beauty of the scenery as influenced by historical and cultural features. Based on the landscape sensitivity and value obtained, the zoning of the mountain forest for landscape management was done.
1. Introduction

A recent forest landscape management (FLM) requires a systematic approach for managing scenery and determining the relative value and importance of landscape in a forest (Bell, 2004). The approach has been successfully applied to the planning and design of forest landscape in many countries.

In the U.S., a scenery management system is used in managing the level of impact of logging on the natural scenery. This system has a highly developed systematic approach intended to prioritize areas within large tracts for different levels of scenic protection (USDA Forest Service, 1995). In Britain, forestry authority provides the guidelines for visual landscape management based on relative sensitivity or landscape importance on the conservation of natural scenery (Aspinall et al., 2000). Forest practices authority of Australia also has a visual management system to provide a practical methodology for identifying the priority of landscape by indicating its values and sensitivity (Forest Practices Authority, 2006).

To achieve this systematic landscape management, forest zoning is essential as a basic framework for use in the design and execution of management techniques in FLM (Bell and Apostol, 2008). However, the zoning is one of important decision-making issues. The process of it inherently requires the evaluation of multiple landscape attributes, which would be complex and difficult to consider the conflicting issues among various objectives involved in forest management.

In the last decade, a number of forest scientists have put efforts in developing the zoning schemes. Canova (2006) analyzed the effectiveness of the protected area system in Lombardy, Italy. Lin (2000) highlighted the relevance of a geographical information system (GIS) for analyzing and reviewing the land use zoning process in a national park in Taiwan. Creachbaum et al. (1998) studied the zoning schemes of national forest...
areas in the U.S. to provide wildlife habitats for the growing population of grizzly bears. Sabatini et al. (2007) also proposed a zoning method for biological diversity protection.

The objective of this study is to develop a forest landscape zoning method for the forest landscape management in Korea and to investigate the field applicability of this method.

2. Materials and Methods

2.1. Study site

Figure 1 shows the location map of the study site, Mt. Sambong area. The study site is located at the southern part of the Korean peninsula and covers about 5,732 ha. Elevation ranges from around 300m to 1,100m. This area has the typical view of mountain forest in
Korea and, recently, the mountain area is required a further intensive forest management program for maintaining and improving landscape scenery for forest recreation activities.

2.2. Procedures of analysis

The method for forest landscape zoning includes three steps of process as shown in Figure 2. In the first step, the landscape resources are collected from national databases and field surveys. Then, the landscape units are set-up using remote sensing data. These procedures provide the base for landscape analysis and evaluation.

The analysis and evaluation steps can be divided into two streams: assessment of the landscape sensitivity and assessment of the landscape value. The forest landscape can be designed based on the results of the assessments associated with the objectives of forest management.

2.2.1. Identification of landscape unit

To achieve proper management zoning units should be relatively large and compact, as well as easily recognizable on the landscape. In the forest landscape zoning, these units should have an explicit ecological
meaning rather than just being based on administrative or land use boundaries. According to Zonneveld (1989), zoning units could be ecologically homogeneous tracts of landscape, which can be mapped by simultaneously considering terrain attributes, such as landforms, vegetation, and alterations caused by humans. For this reason, landscape units were considered as the basic elements of the zoning scheme.

The landscape unit mapping was based on the combination of relevant national GIS layers, supported by visual interpretation of remotely sensed images. In this study, the hierarchical approach was followed to subdivide the study area into landscape units that are homogeneous in terms of landform and vegetation. The area was first subdivided by morphologic types according to ridges and valleys. These divided areas were then partitioned according to vegetation type. The unit boundaries were checked and revised by visual interpretation of orthorectified aerial photograph (pixel cell size: 0.6m). Units smaller than 1 ha were merged with the most similar adjacent units.

2.2.2. Landscape Inventory

Methods to identify and map landscape resources are well established in the scientific literature (Bishop and Hulse, 1994). The landscape resources, such as terrain attributes (slope, aspect, elevation) forest stand information (age class) and manmade features (roads, towns, cultural and historical sites), were mapped using the relevant GIS layers. We used raster map analyses that allowed a more accurate representation and modeling of landscape attributes compared to vector representation. A 10m grid size was selected considering that most of the data layers used were at 1:25,000 scale. In addition, a supplement field survey was carried out in 2009 to determine the specific or temporary resources such as insect damaged areas, logging sites or man-made features which were not included in the national database.
In order to make the inventoried maps comparable, they were normalized along a zero to one range. Boolean maps, such as the ones depicting outstanding natural features, were normalized by assigning one where those features are found and zero if otherwise. All other maps were normalized by applying the maximum standardization method, which offers the advantage of keeping the ratio between actual and standardized values. If a criterion has a positive relation with the evaluation of landscape characteristic (e.g., the higher the criterion value, the higher the landscape value), the maximum normalization was applied by dividing the actual value by the maximum value. If the opposite applied the formula below suggested by Malczewski (1999) was used:

\[ 1 - \left( \frac{\text{actual score}}{\text{maximum score}} \right) \]

2.2.3. Landscape sensitivity assessment

It is not normally the case that all landscapes are treated equal. Not all have the same qualities, are as visible or seen by as many people so that their sensitivity to change varies (Bell and Apostol, 2008). As part of developing the context for forest landscape zoning it is worth assessing the degree of landscape sensitivity of different parts of the area.

Visual absorption capability (VAC) is defined as the capacity of the landscape to absorb physical changes without transformation of its visual character and quality (Amir and Gidalizon, 1990). The VAC is a well-explained variable to interpret landscape sensitivity in the process of designing forest landscape (Ministry of Forests, 1981). It is known that VAC is mainly affected by natural physical characteristics, the VAC scores in the study site were assessed by considering five key factors: slope, aspect, relief, vegetation, and distance from the roads.
Table 1. Key factors for determining the visual absorption capability (VAC) of individual landscape unit.

<table>
<thead>
<tr>
<th>Physical Factor</th>
<th>Description</th>
<th>Criteria</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>Alterations on gentle slope are hard to see</td>
<td>% Slope</td>
<td>Digital terrain map</td>
</tr>
<tr>
<td>Aspect</td>
<td>North exposures absorb alterations quickly due to more rapid green-up and the more frequent occurrence of shade</td>
<td>Transformed aspect (Beers et al., 1966): ( A' = \cos(45 - A) + 1 ), where ( A' ) is the coded value and ( A ) is the aspect in degrees azimuth measured clockwise from the north</td>
<td>Digital terrain map</td>
</tr>
<tr>
<td>Relief</td>
<td>Alterations are readily absorbed by high relief</td>
<td></td>
<td>Digital terrain map</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Forest can physically screen alterations in areas of diversity vegetation</td>
<td>Diversity of stand dominant species</td>
<td>Digital forest map</td>
</tr>
<tr>
<td>Distance</td>
<td>The farther a landscape from a viewer the greater its ability to hide alteration</td>
<td>Distance from the roads</td>
<td>Digital road map</td>
</tr>
</tbody>
</table>

Among those factors, aspect was transformed according to the model of Beers et al. (1966): \( A' = \cos(45 - A) + 1 \), where \( A' \) is the coded value and \( A \) is the aspect in degrees azimuth measured clockwise from the north. Relief was measured by the difference in elevation between highest and lowest point in each landscape unit. The number of tree species in each landscape unit was calculated to estimate the vegetation score by using a digital forest map. Finally, the measured individual key factors including slope and distance from the roads were normalized to calculate the VAC of individual landscape units in the study site.

In the calculation of VAC, the normalized individual key factors were overlaid and aggregated into the previously identified landscape unit polygons by assigning the average value to each unit. The aggregation
values in each unit were classified into three VAC classes as follows: High (5.0-3.5), Medium (3.5-1.5), Low (1.5-0.0).

2.2.4. Landscape value assessment

Landscape value is a joint product of particular features of the landscape interacting with relevant psychological processes in the human observer (Brown and Daniel, 1987). Thus, landscape value is the most subjective of all the factors to be assessed (Daniel, 2001), but in some ways it is easily understood and agreed upon in the case of particular landscapes, beauty spots and the like.

Table 2. Landscape resources for determining the landscape value of individual landscape unit

<table>
<thead>
<tr>
<th>Landscape resources</th>
<th>Description</th>
<th>Criteria</th>
<th>Input</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest age</td>
<td>High age class makes better scenic attractiveness</td>
<td>Stand age class</td>
<td>Digital forest map</td>
<td>0.3</td>
</tr>
<tr>
<td>Surface water</td>
<td>The distinguishing characteristics of rivers, streams, lakes and waterfalls</td>
<td>Boolean data: 1 (exist) and 0 (no exist)</td>
<td>Digital terrain map</td>
<td>0.2</td>
</tr>
<tr>
<td>Damaged area</td>
<td>Areas damaged by man-made alterations or insects in forest are usually unattractive</td>
<td>Boolean data: 1 (exist) and 0 (no exist)</td>
<td>Digitized with GIS</td>
<td>0.2</td>
</tr>
<tr>
<td>Cultural features</td>
<td>Visible features of historical and cultural sites contribute to the image and sense of place</td>
<td>Boolean data: 1 (exist) and 0 (no exist)</td>
<td>Digitized with GIS</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 2 shows the variables that were used to determine the landscape value of a given landscape in this study. The landscape value was estimated as the function of the quality and quantity of various landscape resources as well as the intrinsic beauty of the scenery influenced by
historical and cultural features. The method for assigning a landscape value to each unit was basically the same as the one used in the assessment of landscape sensitivity. However, in the calculation of landscape values the normalized criterion maps were combined through weighted summation according to the results of an expert survey in 2009. The weight assigned by the authors was given after the survey with landscape management experts in Korea (Tab.2). Finally, the aggregation values in each unit were classified into three landscape value classes as follows: Distinctive (1.0-0.7), Typical (0.7-0.3), Indistinctive (0.3-0.0).

2.2.5. Zoning for FLM

Using the data mapped for landscape sensitivity and value, a possible management activity was assigned to all landscape units. These activities reflect the relative scenic importance of discrete landscape units. Table 3 shows the landscape zoning matrix for the development of management activity in a given landscape. Mapped management activities could be used during forest planning to compare the value of scenery with other objectives such as timber or wildlife.

Table 3. Landscape zoning matrix for the development of management activity.

<table>
<thead>
<tr>
<th>VAC(^1)</th>
<th>Landscape value</th>
<th>Distinctive</th>
<th>Typical</th>
<th>Indistinctive</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Retention</td>
<td>Retention</td>
<td>Modification</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Preservation</td>
<td>Retention</td>
<td>Modification</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Preservation</td>
<td>Retention</td>
<td>Retention</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Visual Absorption Capability

3. Results and Discussion

3.1. Landscape unit identification

The landscape unit map identified by landform and vegetation is
shown in Figure 3. The whole study site was divided into 340 landscape units, and the average area of the total landscape units was 16.9 ha. The area of each landscape unit increased along sites with high elevation and steep slope (Tab.4) mainly due to the characteristics of forest sites located in hilly and mountainous areas. The areas with lower and gentle slope were more affected by human disturbances due to the accessibility and availability of these sites. We considered these characteristics in our landscape zoning scheme.

Table 4. Average area of landscape units by terrain attributes.

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Average area of landscape unit (ha)</th>
<th>Slope (%)</th>
<th>Average area of landscape unit (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 500</td>
<td>3.5</td>
<td>&lt; 25</td>
<td>5.6</td>
</tr>
<tr>
<td>500 - 800</td>
<td>27.4</td>
<td>25 - 50</td>
<td>22.9</td>
</tr>
<tr>
<td>&gt; 800</td>
<td>42.8</td>
<td>&gt; 50</td>
<td>37.1</td>
</tr>
</tbody>
</table>
3.2. Landscape assessment

Figure 4. Maps of landscape assessment for determining visual absorption capability (a) and landscape value (b).

Figure 4a shows the results of the landscape sensitivity assessment. The high sensitive units which have low VAC cover 45% of the Mt. Sambong area. The other area was divided into medium (medium
VAC) and low (high VAC) sensitivity units, covering 42% and 13% of the area, respectively (Tab.5). The high sensitive units are found mainly in three regions: the highest peaks in the central sector of the forest, the steep slopes in the eastern sector, and the southernmost peaks in the southern sector of the forest. These regions are located at steep slope and southern aspect. Most medium and low sensitivity areas are scattered in the northern and southern sectors of the forest. Both of them are located in the northern sector which has gentle slopes compared to other regions.

The landscape value map is shown in Figure 4b. Weight set was used to generate the landscape value map of the Mt. Sambong area. The landscape units which have the highest scenic attractiveness cover over 45% of the study site. The northwestern and eastern natural old forests were assigned to the distinctive landscape units. This area is characterized by healthy and rich forests. Moreover, it is dotted by several cultural heritage sites. Indistinctive landscape units are mostly distributed in the sites which were heavily developed by human alterations. This region covers only 17% of the site but it is an important region with regards to improving the landscape quality in the study site.

3.3. Zoning for FLM

The assignment of management activities with respect to each landscape unit was carried out by applying the landscape zoning matrix described in section 2.2.5 thereby obtaining the required management activity for a particular landscape unit (Fig.5). Table 5 shows the results of the landscape zoning scheme for the development of management activities.

The regions which have high landscape value (distinctive) and high landscape sensitivity (medium or low VAC) are classified as the preser-
Figure 5. Landscape zoning for development of management activities.

Table 5. Area distribution (ha) of landscape units for the development of management activity.

<table>
<thead>
<tr>
<th>VAC</th>
<th>Landscape value</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distinctive</td>
<td>Typical</td>
</tr>
<tr>
<td>High</td>
<td>576.2</td>
<td>105.2</td>
</tr>
<tr>
<td>Medium</td>
<td>1133.7</td>
<td>929.5</td>
</tr>
<tr>
<td>Low</td>
<td>911.1</td>
<td>1113.6</td>
</tr>
<tr>
<td>Total</td>
<td>2621.0</td>
<td>2148.3</td>
</tr>
</tbody>
</table>

1Visual Absorption Capability

evation area. A preservation area allows activities that enhance natural landscape values. Alterations beyond this, such as logging or land-use change in a forest, should be kept to a minimum level. Thirty-six percent (2,045 ha) of the Mt. Sambong area was assigned as preservation area. This includes almost all the distinctive landscape units except for the distinctive areas with low landscape sensitivity (high VAC) characteristics.
A modification area which permits a dominant change to the original landscape was also zoned using the developed landscape zoning scheme. The zoned modification area covers only seven percent (414 ha) of the study site but this forest area could be particularly available for other use, such as recreational facilities. However, the disturbance to the environment should be minimized as much as possible. The other fifty-seven percent (3,273 ha) area which is not included in the preservation or modification area is classified as the retention area. The retention area basically maintains its original landscape. Alterations are allowed but these should match the existing landscape character and should not cause an obvious intrusion (Tab.5).

4. Conclusion

This study provides a forest landscape zoning scheme using GIS. The study was performed using currently available data and assumptions mostly made by authors. The developed landscape zoning scheme, however, allows forest managers and other stakeholders to visualize and understand the process that leads to the zoning scheme in a clear and transparent way. It also offers a flexible framework for the maintenance of landscape values through a systematic approach in forest landscape management. The scheme not only considers existing physical and social conditions that affect landscape values, but is also amenable to periodic updating of inventories and assessment to allow for changing conditions. If new alterations on a particular landscape occur, it is easy to redesign the zoning scheme in a new context.

However, it should be pointed out that the developed zoning scheme does not consider several important factors, such as landscape pattern and structure, which affect the aesthetic perception of human beings. Thus, in order to have a better assessment of the landscape value or sensitivity, further development of methodologies for assessing those
landscape features is required. This will allow a more precise estimate of the effects of landscape characteristics on man’s perception of the landscape.

This study provides a forest landscape zoning scheme that is sound and practical. It is believed that this approach can be used for other forest landscapes where there is a need to update or establish a zoning scheme.

Acknowledgement
The authors would like to express our gratitude for the financial support from The Institute of Statistical Mathematics to attend and present this research at the international symposium FORMATH Tachikawa in March 2010.

References


