Landscape Ecological Methodologies to Evaluate Landscape Connectivity

Sangbum Lee
Research Staff

Leading Researcher:
Sangbum Lee (Korea Environment Institute)

Participating Researcher:
Juchul Jung (Korea Environment Institute)
Taehyung Kim (Korea Environment Institute)

Copyright © 2007 by Korea Environment Institute
All rights reserved. No part of this publication may be reproduced or transmitted in any form or any means without permission in writing from the publisher

Publisher        Jeong Hoi-Seong
Published by     Korea Environment Institute
                 613-2 Bulgwang-Dong (290 Jinheungno),
                 Eunpyeong-Gu, Seoul, Republic of Korea
                 Tel.(822) 380-7777 Fax.(822) 380-7799
                 http://www.kei.re.kr
Published and printed in December 2007

The Paper Used in this Report is Certified by Eco-Labeling
Chapter I. Introduction

Chapter II. Landscape Ecological Concepts of Landscape Connectivity

Chapter III. Analysis of the Landscape Connectivity of Forests

Chapter IV. Policy Implications of Landscape Connectivity Analysis

Chapter V. Conclusion
Chapter I. Introduction

Urbanization and other developments encroach upon natural green space and fragment ecological habitat significantly. Consequently, massive habitat loss and fragmentation threaten wildlife and decrease biodiversity throughout the world. At the same time, it is inevitable to develop forest areas and covert cropland into paved residential areas or shopping malls.

To maintain a balance between development and conservation, many countries have adopted the Prior Environmental Review System (PERS)/Environmental Impact Assessment (EIA) and have started to adopt Strategic Environment Assessment (SEA). While EIA is focused on the environmental impact at the individual development project level, SEA is focused on minimizing environmental problems and conserving critical green space at the policy and planning levels.

Unlike site-specific conservation on a local scale, the problem of habitat fragmentation from vast development plans should be dealt with on a larger regional scale. The landscape ecological approach is especially appropriate to deal with the problems of habitat loss and fragmentation at regional/landscape scales. From the 1980’s, many researchers developed various tools to measure landscape composition and configuration among landscape patches. Among landscape configuration, landscape connectivity is an important concept in ecosystem management which looks to conserve and enhance biodiversity, however its concept is often confused.

In addition to the confusion of landscape connectivity, as landscape ecology is a relatively new research field in ecology, the concepts and tools of landscape ecology are not applied effectively in PERS/EIA to minimize the effects of land development on the ecosystem. But the landscape ecological approach in PERS/EIA would be the most effective way to minimize the negative effects of land development on the ecosystem at any scale.

The research objectives of this study are 1) to summarize previous studies and define the concept of landscape connectivity; 2) to analyze
currently-available GIS data to grade forest patches based on essential landscape ecological features in order to arrange alternative forest conservation plans; 3) to discuss the applicability of landscape ecological methodologies in PERS/EIA to evaluate alternative spatial land use plans.
Chapter II. Landscape Ecological Concepts of Landscape Connectivity

The key landscape ecological concepts are:

- Landscape Change and Habitat Loss
- Habitat Degradation/Deterioration
- Habitat Isolation/Fragmentation
- Edge Effect
- Landscape Connectivity

Like other nations, landscape changes due to urbanization are a significant environmental problem in Korea. Typically landscape change means the modification of native vegetation cover that leads to the loss of habitat for many species, while the suitable habitat for some opportunistic species may increase.

Anthropogenic landscape changes associated with agriculture, urbanization, and timber extraction always degrade or destroy natural landscapes. Such transformations occur through five main spatial processes that have distinct ecological effects. Perforation creates a hole or gap (e.g., clear-cut, housing development) in the original land cover. Dissection is a subdivision of land cover into sections by equal-width alterations (e.g., roads, power lines). The well-studied fragmentation causes the splitting-apart of large areas of land cover into smaller ones. Shrinkage is the size reduction of given land-cover elements. The complete loss of an element, attrition, is most common for small patches. Although these processes overlap in time, perforation, and dissection peak during initial stages of land transformation, fragmentation, and then shrinkage dominate during intermediate phases, and attrition is prominent at the end when original land cover is almost nonexistent. Landscape changes resulted from these five processes significantly impact on habitat for native species and thus decreases species richness and biodiversity.

The habitat loss resulted from landscape change is closely related to species richness, e.g., biodiversity. This phenomenon is called the species-area relationship at multiple spatial scales (landscape, region, continents) as proved by many previous studies. Usually larger remnant patches of original vegetation support more species than smaller ones.
Mechanisms underlying species-area relationships include immigration and extinction rates, disturbance, habitat diversity, and random placement. Although key mechanisms regarding species-area relationships are defined, they are closely related. Larger patches are not only lower extinction rates because of the large population size they support, they are also less disturbed and have high environmental variability. As many studies suggest an increase of species richness and patch size, additional studies are needed regarding the relative importance of the potential causal mechanisms of the species-area relationship.

The mechanism of migration and extinction rates are well studied in island biogeography. In island biogeography, the number of species on an island arises from the dynamic equilibrium between the local extinction and local immigration of species. Larger islands have larger population sizes and that means fewer species would suffer extinction on larger islands. The same reasoning has frequently applied to patches of native vegetation in modified landscapes.

While natural disturbance plays an extremely important role to maintain appropriate biodiversity, small and large patches have different susceptibility to disturbance, which is a factor of species-area relationships. Larger patches are likely to contain some area unaffected by disturbance and which will be important refugia for some species. Disturbance in larger patches creates a greater range of niches and types of habitat that support more species.

The other two mechanisms, habitat diversity and random placement, are closely related to patch areas because larger patches cover more area and therefore are expected to contain more habitats that will sustain more diverse species. Random placement describes the phenomenon that larger areas are more likely to capture more patchily distributed species than small areas.

According to the mechanisms described above, many studies propose equations to calculate species richness \( S \) for a given area. A widely used expression is:

\[
S = cA^z
\]

Where \( A \) is the area, and \( c \) and \( z \) are fitted constants. Usually, the logarithm of \( A \) is used in this equation, and normally the value of \( z \) is taken to be about 0.25, with a range of about \( 0.15 \leq z \leq 0.40 \). The value \( z \) can vary according to (1) whether areas are part of continents or islands, (2) the latitude of the area in question, and (3) the range in size of the areas in question.
If habitat loss is defined as a process occurring in short time, habitat degradation can be defined as a process of habitat quality change over time. Habitat degradation is common in landscapes subject to human modification. It is a process that can eventually lead to habitat loss if it is not reversed. Habitat degradation can be represented by two mail types: the decline in food resources and the decline in shelter availability. These two processes may seem to have no direct relation to landscape connectivity, but, when it comes to corridor or stepping stone habitats, habitat quality becomes a significant issue in landscape connectivity.

The main reason is that habitat degradation is the simplification of the structural complexity of vegetation and the physical environment. Unlike landscape heterogeneity, structural complexity is a locally scaled attribute defining the range and variability in vertical attributes of a given local area. The results of habitat degradation/deterioration are the food decline and the shelter decline, which are the main features determining the abundance of a species. Among many habitat degrading processes, forest management is one of the main processes and the most controversial land use. Although forest management maintains vegetation cover, it degrades the habitat suitability significantly.

Habitat fragmentation is not always the result of habitat loss, but usually it is. While habitat loss is mainly about the local aspect of habitat reduction, habitat fragmentation is mainly about the regional aspect of habitat isolation with less habitat loss. Thus it is more focused on the spatial arrangement of habitat patches and the species mobility to move between isolated habitats.

Edge effect is related to habitat shape and affects habitat suitability. As a result of habitat destruction, once a landscape with many big circle-shaped habitat patches is changed into a landscape with narrow elongated habitats, most interior species that only inhabit the core forest area cannot survive and more edge species appear. Many non-native species are edge species and out-compete native species along the destructed or deteriorated habitat edge.

The reviewed landscape ecological concepts are well interconnected, so all these aspects of a landscape should be considered to preserve biodiversity and enhance ecological integrity. The following sample study utilizes these landscape ecological concepts in the planning process of forest conservation. Due to the limited data availability and the research scope, not all landscape ecological indices are used in the sample study, but some essential features, such as forest area, quality, and proximity, are analyzed from preexisting GIS data and integrated into the planning process.
Chapter III. Analysis of the Landscape Connectivity of Forests

In chapter two, the ecological landscape concepts of landscape connectivity are reviewed. In this chapter, the landscape connectivity of forest patches is analyzed for forest conservation planning by using pre-generated GIS data. The purpose of this analysis is to evaluate the simplified landscape ecological methodology to analyze the forest patch grade and landscape connectivity of forest patches.

1. Methodology

a. Analysis of Forest Patch Grade and Conservation Priorities

Of the many characteristics of forest patches, the area, the quality, and the proximity of forest patches, are the most important features for biodiversity conservation. The pre-existing GIS data, Land Use/Land Cover map, is the primary dataset for this analysis.

From the LULC map, forest polygons are extracted and the connecting polygons are merged into a single polygon to disregard the difference of forest types. The merged forest patch area is the most important forest characteristics for biodiversity because the forest area is considered a habitat area. The merged forest patch polygons are used to measure the distance between forest patches.

The individual forest patch is graded based on the forest patch area and the NND of forest patches. The forest patch is mainly graded by forest patch area and then additionally weighted by the nearest forest patch area. By integrating all the data, all forest patches are graded from 0 to 10.

After the forest patch grade is given, the conservation priorities of forest patches are defined based on the forest patch grade, the proportion of old-growth forest, and the NND of forest patch and classified into three priority classes: priority conservation forest, moderate conservation forest, and buffering forest. In addition to the LULC map, the current vegetation map is
used to analyze the proportion of old-growth forest within each forest patch as an indicator of forest quality. By changing classification criteria, three alternatives of forest conservation are generated. The first alternative is the conservation-oriented plan with more priority conservation forest patches and the second one is the development-oriented plan with more buffering forest patches. The third alternative is the compromised plan between the conservation-oriented plan and the development-oriented plan. The other forest characteristics, forest quality and patch proximity, are minor forest features, but are important for biodiversity and landscape connectivity. Figure 3-1 shows the research methodology of this study.

b. Evaluating the Alternatives and Planning a Green Axis

The generated three forest conservation alternatives need to be evaluated quantitatively in order to select the most pro-environmental plan. To differentiate the ecological implication of the three alternatives, the landscape connectivity and fragmentation of forest patches are analyzed for each conservation class. FRAGSTATS and USDA DigitalVision’s ‘Connectivity’ and ‘Fragmentation’ are used to measure landscape connectivity and fragmentation. Based on the analysis results, the best alternative with high connectivity and low fragmentation is selected for biodiversity conservation. Based on the selected alternative, the regional-scale Green Axis is defined to ensure regional ecological connectivity and integrated into regional land use planning.

2. Results

Figure 3-2 shows the results of the forest patch grade based on patch area and proximity. Most large forest patches are given a high grade which means high habitat suitability and small patches are given a low grade. Based on the forest patch grade and the current vegetation map, forest patches are classified into three conservation priority classes: priority conservation forest, moderate conservation forest, and buffering Forest. In the classification of the conservation priorities of forest patches, three different alternatives are made by changing classification criteria (Figure 3-3~5). The three alternatives are tallied by patch number, area, and proportion (Table 3-1~3) and by political boundary basis (Table 3-4~6).
The landscape connectivity computed by FRAGSTATS is ‘CONNECTANCE’ and is shown in Table 3-7-10. While the landscape connectivity of the entire forest patches (Table 3-7) is consistent with the visual comparisons (Figure 3-3-5), showing the best landscape connectivity of priority conservation forest patches in the selected alternative, the landscape connectivity of each conservation class (Table 3-8-10) show contrary results to the visual comparisons. The priority conservation forest of the selected alternative shows the best landscape connectivity among the three alternatives (Figure 3-3-6), but the FRAGSTATS’s ‘Connectance’ of the priority conservation forest of the selected alternative is worse than that of alternative I (Table 3-8).

Unlike the inconsistencies between the visual comparisons and the FRAGSTATS results, USDA DigitalVision’s ‘Connectivity’ and ‘Fragmentation’ (Table 3-11-13) show no inconsistency problem in analyzing the landscape connectivity of the conservation classes. With the exception of the moderate conservation forest class, the selected alternative shows the best landscape connectivity and the least fragmented landscape among the three alternatives. The results of the visual comparisons and the quantitative analysis done by FRAGSTATS and DigitalVision’s ‘Connectivity’ and ‘Fragmentation’ confirms that the conservation-oriented alternative is the most ecologically favored forest conservation plan among the three alternatives. After the best alternative for the purpose of land use planning is defined quantitatively, the Green Axis is defined based on the priority conservation forest class of the selected alternative to ensure the landscape connectivity of forest patches (Figure 3-9). By defining the Green Axis, crucial forest patches for regional landscape connectivity are identified for strict land use management.
Chapter III. Analysis of the Landscape Connectivity of Forest Patches

Figure 3-1. Research Methodology
Figure 3-2. Forest Patch Grade
Figure 3-3. Selected Alternatives of Forest Conservation Planning
Figure 3-4. Alternative I of Forest Conservation Planning
Figure 3-5. Alternative II of Forest Conservation Planning
Table 3-1. Patch Number, Area, and Proportion of the Conservation Classes of the Selected Alternative

<table>
<thead>
<tr>
<th>Priority Conservation Forest</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>54</td>
<td>144,858 ha</td>
<td>72.4%</td>
</tr>
<tr>
<td>Moderate Conservation Forest</td>
<td>360</td>
<td>36,391 ha</td>
<td>18.2%</td>
</tr>
<tr>
<td>Buffering Forest</td>
<td>2231</td>
<td>18,695 ha</td>
<td>9.4%</td>
</tr>
</tbody>
</table>

Table 3-2. Patch Number, Area, and Proportion of the Conservation Classes of the Alternative I

<table>
<thead>
<tr>
<th>Priority Conservation Forest</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>86,329 ha</td>
<td>43.2%</td>
</tr>
<tr>
<td>Moderate Conservation Forest</td>
<td>59</td>
<td>75,542 ha</td>
<td>37.8%</td>
</tr>
<tr>
<td>Buffering Forest</td>
<td>2572</td>
<td>38,074 ha</td>
<td>29.0%</td>
</tr>
</tbody>
</table>

Table 3-3. Patch Number, Area, and Proportion of the Conservation Classes of the Alternative II

<table>
<thead>
<tr>
<th>Priority Conservation Forest</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>103,581 ha</td>
<td>51.8%</td>
</tr>
<tr>
<td>Moderate Conservation Forest</td>
<td>244</td>
<td>77,081 ha</td>
<td>38.6%</td>
</tr>
<tr>
<td>Buffering Forest</td>
<td>2381</td>
<td>19,283 ha</td>
<td>9.6%</td>
</tr>
</tbody>
</table>
Table 3-4. Patch Number, Area, and Proportion of Priority Conservation Forest of the Selected Alternative: County Basis

<table>
<thead>
<tr>
<th>Admin.</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>YeonKi</td>
<td>39</td>
<td>10,275</td>
<td>7.1</td>
</tr>
<tr>
<td>JeungPyoung</td>
<td>8</td>
<td>3,270</td>
<td>2.3</td>
</tr>
<tr>
<td>JinChon</td>
<td>20</td>
<td>19,632</td>
<td>13.6</td>
</tr>
<tr>
<td>ChungWon</td>
<td>55</td>
<td>30,988</td>
<td>21.4</td>
</tr>
<tr>
<td>KongJu</td>
<td>52</td>
<td>44,758</td>
<td>30.9</td>
</tr>
<tr>
<td>ChungJu</td>
<td>13</td>
<td>1,827</td>
<td>1.3</td>
</tr>
<tr>
<td>ChonAn</td>
<td>90</td>
<td>11,990</td>
<td>8.3</td>
</tr>
<tr>
<td>KyeRyoung</td>
<td>2</td>
<td>2,782</td>
<td>1.9</td>
</tr>
<tr>
<td>TaeJeon</td>
<td>13</td>
<td>19,335</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Table 3-5. Patch Number, Area, and Proportion of Moderate Conservation Forest of the Selected Alternative: County Basis

<table>
<thead>
<tr>
<th>Admin.</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>YeonKi</td>
<td>65</td>
<td>5,035</td>
<td>13.8</td>
</tr>
<tr>
<td>JeungPyoung</td>
<td>17</td>
<td>368</td>
<td>1.0</td>
</tr>
<tr>
<td>JinChon</td>
<td>48</td>
<td>2,565</td>
<td>7.0</td>
</tr>
<tr>
<td>ChungWon</td>
<td>194</td>
<td>9,339</td>
<td>25.7</td>
</tr>
<tr>
<td>KongJu</td>
<td>38</td>
<td>10,304</td>
<td>28.3</td>
</tr>
<tr>
<td>ChungJu</td>
<td>65</td>
<td>1,615</td>
<td>4.4</td>
</tr>
<tr>
<td>ChonAn</td>
<td>63</td>
<td>1,977</td>
<td>5.4</td>
</tr>
<tr>
<td>KyeRyoung</td>
<td>4</td>
<td>1,089</td>
<td>3.0</td>
</tr>
<tr>
<td>TaeJeon</td>
<td>37</td>
<td>4,099</td>
<td>11.3</td>
</tr>
</tbody>
</table>
Table 3-6. Patch Number, Area, and Proportion of Buffering Forest of the Selected Alternative: County Basis

<table>
<thead>
<tr>
<th>Admin.</th>
<th>Patch Number</th>
<th>Area</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>YeonKi</td>
<td>261</td>
<td>2,615</td>
<td>14.0</td>
</tr>
<tr>
<td>JeungPyoung</td>
<td>65</td>
<td>250</td>
<td>1.3</td>
</tr>
<tr>
<td>JinChon</td>
<td>297</td>
<td>1,355</td>
<td>7.2</td>
</tr>
<tr>
<td>ChungWon</td>
<td>463</td>
<td>3,275</td>
<td>17.5</td>
</tr>
<tr>
<td>KongJu</td>
<td>415</td>
<td>5,132</td>
<td>27.5</td>
</tr>
<tr>
<td>ChungJu</td>
<td>227</td>
<td>711</td>
<td>3.8</td>
</tr>
<tr>
<td>ChonAn</td>
<td>144</td>
<td>740</td>
<td>4.0</td>
</tr>
<tr>
<td>KyeRyoung</td>
<td>25</td>
<td>286</td>
<td>1.5</td>
</tr>
<tr>
<td>TaeJeon</td>
<td>408</td>
<td>4,332</td>
<td>23.2</td>
</tr>
</tbody>
</table>
Table 3-7. FRAGSTATS Connectance of the entire forest patches (2km threshold)

<table>
<thead>
<tr>
<th>Selected Alternative</th>
<th>FRAGSTATS Connectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>0.958</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>0.918</td>
</tr>
</tbody>
</table>

Table 3-8. FRAGSTATS Connectance of Priority Conservation Forest patches (2km threshold)

<table>
<thead>
<tr>
<th>Selected Alternative</th>
<th>FRAGSTATS Connectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>0.917</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>0.901</td>
</tr>
</tbody>
</table>

Table 3-9. FRAGSTATS Connectance of Moderate Conservation Forest patches (2km threshold)

<table>
<thead>
<tr>
<th>Selected Alternative</th>
<th>FRAGSTATS Connectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>5.929</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>7.246</td>
</tr>
</tbody>
</table>

Table 3-10. FRAGSTATS Connectance of Buffering Forest patches (2km threshold)

<table>
<thead>
<tr>
<th>Selected Alternative</th>
<th>FRAGSTATS Connectance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>2.417</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>2.475</td>
</tr>
</tbody>
</table>
Table 3-11. Landscape Connectivity and Fragmentation of Selected Alternative

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Connectivity</th>
<th>Fragmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Alternative</td>
<td>26</td>
<td>3.395</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>22</td>
<td>4.763</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>24</td>
<td>4.309</td>
</tr>
</tbody>
</table>

Figure 3-6. Comparison of Priority Conservation Forest of Selected Alternative, Alternative 1 and Alternative 2
Figure 3-7. Comparison of Moderate Conservation Forest of Selected Alternative, Alternative 1 and Alternative 2

Table 3-12. Landscape Connectivity and Fragmentation of Alternative 1

<table>
<thead>
<tr>
<th></th>
<th>Connectivity</th>
<th>Fragmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Alternative</td>
<td>38</td>
<td>3.070</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>25</td>
<td>3.445</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>40</td>
<td>2.791</td>
</tr>
</tbody>
</table>
Figure 3-8. Comparison of Buffering Forest of Selected Alternative, Alternative 1 and Alternative 2

Table 3-13. Landscape Connectivity and Fragmentation of Alternative 2

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Connectivity</th>
<th>Fragmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected Alternative</td>
<td>26</td>
<td>3.395</td>
</tr>
<tr>
<td>Alternative 1</td>
<td>22</td>
<td>4.763</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>24</td>
<td>4.309</td>
</tr>
</tbody>
</table>
Figure 3-9. Landscape Green Axis based on the Selected Alternative
Chapter IV. Policy Implications of Landscape Connectivity Analysis

1. Evaluation of the Land Use Planning Alternatives

PERS/EIA of new urban development should evaluate the broad-scale environmental impact, but is not easy because of the vast landscape scale and the many environmental factors to consider. To abate these problems and consider a broad-scale ecological process, it is required to apply landscape ecological methodologies to evaluate the environmental impacts of urban development. Among many landscape ecological indices to be analyzed, the area, quality, and connectivity of forest patches are one of the most important landscape ecological features and are easily analyzed from preexisting land cover maps.

In PERS/EIA of the land use plan, a few alternatives, usually three, are arranged and compared to select the alternative with least environmental impacts. The sample study shown in the previous chapter clearly demonstrates the feasibility of the application of landscape ecological methodology in evaluating the alternatives of the forest conservation plan. The sample study considers important landscape ecological features in forest patch analysis and alternative arrangements and then evaluates the alternatives quantitatively by using landscape ecological indices, Connectivity, and Fragmentation.

Although the sample study compares alternatives by using landscape connectivity and fragmentation, the quantitative comparison of alternatives are further refined by using additional landscape indices in order to consider other landscape ecological aspects. The quantitative landscape ecological analysis is not actively applied in PERS/EIA and not actively adopted during the land use planning process. As demonstrated in the sample study, the quantitative analysis of broad-
scale landscape connectivity and fragmentation makes it much easier to compare land use plans in PERS/EIA and, when it is integrated into the planning process, the landscape ecological methodology is expected to help make a better ecologically favored land use plan.

2. Regional Planning of Landscape Connectivity

There are many different concepts of landscape connectivity: greenway, biotope network, and green axis. The concept of a green axis is based on landscape patterns, so it can be defined and analyzed by using land cover GIS data. By defining a green axis based on landscape ecological indices, some small forest patches that must be neglected unless the landscape connectivity is considered might turn out to be essential patches for regional landscape connectivity and should be classified as priority conservation forest.

As landscape ecological indices provide important information regarding landscape patterns, the land use planning process should integrate landscape ecological concepts and use landscape ecological indices to build more ecologically favored land use plans. The integration of landscape ecological methodology into land use planning is similar to the concept of Strategic Environment Assessment (SEA), so it means that it is possible to consider landscape ecological concepts at the beginning of land use policy making.
Chapter V. Conclusion

The importance of this research is to demonstrate the applicability of the landscape ecological analysis of forest patch and landscape connectivity in PERS/EIA with little problem and the feasibility of the quantitative comparison of the alternatives of land use planning in terms of landscape ecological aspect.

Currently, PERS/EIA evaluates the environmental impact of the development plan on the target area and its neighborhood based on field-sampled data from the restricted area. Although the development takes place over a small area, the environmental effect of any development is not limited to the developed area. Thus it is important to evaluate the broad-scale environmental effect of the development plan. However, due to data limitations and time-/labor-intensive processes, it is extremely difficult to do. From an ecological point of view, the broad-scale ecological effect is effectively assessed by landscape ecological methodology, but landscape ecological methodologies are not actively adopted during the PERS/EIA process. By providing additional landscape ecological indices, such as the shape and the spatial distribution pattern of forest patches, the environmental effects of the development plan would be assessed more completely at the local and regional scales.

The important landscape ecological features of forest patch, such as area, quality, and proximity, are easily analyzed from land cover GIS data and then used to grade forest patches and assign different conservation priorities in order to arrange alternative forest conservation plans. The alternatives are compared quantitatively by using landscape ecological indices, connectivity, and fragmentation. It means that it is feasible to evaluate the alternatives of spatial land use planning in PERS/EIA quantitatively. As there are too many landscape ecological indices and methodologies, the most appropriate landscape ecological index and methodology for analysis purposes should be chosen carefully. As shown in the previous chapter, while FRAGSTATS's
'Connectance' is affected by the patch number, USDA DigitalVision’s ‘Connectivity’ shows no problem, so FRAGSTAT is not appropriate to compare the landscape connectivity of each class of alternatives with different patch number.