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Landscape Structure and Ecological Restoration of Mt. Hwangryung in Pusan, Korea

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부산시 황령산의 경관구조와 생태적 복원

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ABSTRACT

An attempt to clarify the landscape structure of urban areas was carried out on Mt. Hwangryung located in the center of Pusan, southern Korea. By means of aerial photographs and field survey, a vegetation map including land-use pattern was made. Landscape structure was described by analyzing the vegetation map. Landscape element types were classified into secondary forest, introduced plantation, and other elements including urbanized area. *Alnus firma* and *Pinus thunbergii* communities, introduced plantation elements, formed matrix and some secondary forest elements and the other artificial plantations of small scale tended to distribute as small patches in such matrix. The number of patches per unit area in secondary forest elements was more than that in introduced plantation element. The result on patch size was vice versa. As the results of landscape ecological analyses, it was estimated that differentiation of patches recognized in community level would be related to artificial interference and those in sub-communities levels to natural process such as progression of succession. On the other hand, restoration plans in viewpoints of restoration and landscape ecology were suggested to improve ecological quality of Mt. Hwangryung.

Key words: Landscape structure, Aerial photograph, Vegetation map, Land-use pattern, Restoration.

INTRODUCTION

Landscape ecology was emerged as a fusion of the spatial approach of geographers and the functional approach of ecologists (Forman and Godron 1986, Forman 1995). The latter focused on ecosystems as homogeneous units in space, with input and output of energy and matter to and from the undefined surroundings (Hong and Lee 1997). Geographers considered the heterogeneous pattern of the surface of the earth, on various levels of spatial scale, and described the changes in that pattern due to human land-use (Vos and Opdam 1993). A more thorough study on the functioning of such heterogeneous systems, called landscapes, became urgent with the growing significance of spatial planning (Hong and Lee 1997). Growing awareness of the deterioration of landscapes and a loss of natural diversity coincided with a high population density and an intensifying land use (Lee *et al.* 1998a).

Landscape ecology becomes an important basic science for nature conservation and management, and a basis for spatially integrating conservation aims in urban and agricultural spaces. Landscape ecology was also developed as an applied science, aiming at solving problems arising from spatial interactions between land units with contrasting functions, e.g. urban or agricultural areas and nature reserves (Vos and Opdam 1993, Primack 1995, Farina 1998). Landscape ecological research plays different roles in various stages of problem solving. In an early stage, problems are detected and brought to the attention of policy makers, spatial planners and nature conservationists. Next measures to solve the problem have to be detected and indicated (Vos and Opdam 1993).

Landscape ecological principles provide the important information for the protection of biological diversity because many species are not confined to a single habitat but move between habitats or live on borders where two habitats meet (Primack 1995). When a given area is managed excessively, the result lead to an area transformed into a mass of edges, where transition zones abound. Disturbed habitats like this contain a large number of species because wandering species that depend on human disturbance increase but lack species with high ecological value as a species requiring undisturbed large habitat.

To remedy such problems, a habitat needs to be managed on the regional landscape level, at which the size of the landscape units more closely approximates the natural units prior to human disturbance (Grumbine 1994, Noss and Cooperrider 1994). Green network to create larger habitat by linking all habitats in an area as a regional plan is contrived, which would contribute to protect rare species that are not able to tolerate human disturbance (Primack 1995, Lee *et al.* 1998b).

In this study, firstly, we described the landscape structure in terms of kinds, number, and size of patch in vegetation landscape on Mt. Hwangryung fragmented into a number of small patches by excessive artificial interference. Secondly, we discussed restoration plans to improve the ecological quality of Mt. Hwangryung in viewpoints of restoration and landscape ecological principles. The former focused on improving the ecological quality of each landscape element and the latter on creating green network to link Mt. Hwangryung and its surroundings to improve Mt. Hwangryung as a habitat with higher ecological quality.

STUDY AREA AND METHODS

This study was carried out on Mt. Hwangryung located in the center of Pusan, southern Korea. This area was depicted in an actual vegetation map as vegetation units classified into community or lower communities of group and subgroup (Cho and Lee 1998). This study was accomplished on the bases of the results obtained from them.

Assessments on patterns of landscape structure and function are based on spatio-temporally distributing ecological data, which are necessarily recorded at a variety of spatial and temporal scales (i.e. Hong *et al.* 1995). Landscape analyses, such as measurement of the number and area of vegetation patches were carried out by LANDCADD (LANDCADD International 1992) as one of GIS supported by AutoCAD. In the present study, our results on landscape structure focused on the components, number and distribution pattern of vegetation patches. On the other hand, restoration plans to improve the ecological quality of Mt. Hwangryung were discussed on the bases of restoration and landscape ecological principles.

RESULTS AND DISCUSSION

A perspective of vegetation landscape

Dimension of total area shown in detailed vegetation map was 816.0ha. Area of *A. firma* plantation was the largest as 268.8ha and followed by *P. thunbergii* plantation of 255.9ha. Area of secondary forest occupied was 8.6% of that of plantation. That is, this study area was mainly composed of artificial plantation. The other artificial plantations of small scale and secondary forests tend to distribute as small patches in matrix of *A. firma* and *P. thunberii* plantations. But a number of native species consisting potential natural vegetation is established in substratum of artificial forest existing as huge matrix. From this result, we could predict change of landscape with the progression of succession (Lee and Hong 1998). And *Quercus serrata* community, dominant secondary forest element, exists as a remnant patch in valleys of the lower area or in small valleys of the upper area including circumference of Maha temple being conserved as temple forest. Patches of them shown in spreading landscape element suggest extension of their dimension (Forman and Godron 1986, Forman 1995).

Landscape structure

The landscape element types identified from the vegetation map are summarized in Table 1. Landscape element types of Mt. Hwnagryung were identified as secondary forest occurred from natural succession, introduced plantation element for rehabilitation of degraded forest ecosystem, and other elements including residential area, road, facilities of diverse types, and so on (Table 1, refer to Cho and Lee 1998). Secondary forest element was composed of *Q. serrata* community, *Q. dentata* community, *Q. acutissima* community, *Platycarya strobilacea* community, *Prunus sargentii* community, and *Pinus densiflora* community. Dominant landscape element among them was *Q. serrata* community.

Introduced plantation element was composed of *Alnus firma* community, *P. thunbergii* community, *P. rigida* community, *Robinia pseudoacacia* community, *Chamaecyparis obtusa* community, *Castanea crenata* community, *Populus tomentiglandulosa* community, *Cedrus deodara* community. Dominant elements among them were *A. firma* and *P. thunbergii* communities. *A. firma* is a typical introduced plant species in southern Korea. It was introduced from Japan for rehabilitation of devastated forest in the 1960's. It is a typical early successional species and hence we can easily find dying individuals which surpassed their longevity in *A. firma* stands.

P. thunbergii community introduced as a measure to rehabilitate the burned area exists as young stands

Table 1. The configuration of landscape elements identified from vegetation map of Mt. Hwangryeong

Landscape element type	Number	Area	No. /100ha
Sceondary forest element	25 (5.2)	28.5 (3.5)	88
Quercus serrata community	7 (1.5)	7.0 (0.9)	100
Q. dentata community	12 (2.5)	17.2 (2.1)	70
Q. acutissima community	5 (1.0)	7.0 (0.9)	71
Platycarya strobilacea community	4 (0.8)	3.9 (0.5)	103
Prunus sargentii community	1 (0.2)	0.6 (0.1)	167
Pinus densiflora community	54 (11.2)	64.2 (8.0)	84
Introduced element	132 (27.4)	266.6 (32.7)	50
Alnus firma community	115 (23.9)	248.2 (30.4)	46
Pinus thunbergii community	15 (3.1)	29.2 (3.2)	51
P. rigida community	53 (11.0)	49.4 (6.1)	107
Robinia pseudoacacia community	22 (4.6)	51.1 (6.3)	43
Chamaecyparis obtusa community	3 (0.6)	2.1 (0.3)	143
Castanea crenata community	5 (1.0)	3.8 (0.5)	132
Populus tomentiglandulosa community	1 (0.2)	1.4 (0.2)	71
Cedrus dendara community	346 (71.8)	651.8 (80.1)	53
Others	82 (17.0)	99.2 (12.2)	83

Values in parentheses indicate percentage.

on southern slope dominated by frequent fire events.

Other elements including residential area, military facilities, road, graveyard, burned area, incised land, etc. are distributed throughout the study area but are concentrated on the lower or the top parts of mountainous area and roadside.

On the other hand, urbanized area centered on residential area is mostly restricted on the lower parts of mountainous area.

The number and size of patches

The number and size of patches reflect the intensity of disturbances caused by both nature and man in the human-influenced landscape, and hence they become indices reflecting the intensity of disturbance (Turner 1989, Forman and Godron 1986, Hong *et al.* 1995, Raedeke and Raedeke 1995).

Percentage occupied by the introduced patches among the total number of patches (71.8%) was far higher than that of secondary forest elements (11.2 %). The number of *A. firma*, *P. thunbergii*, and *R. pseudoacacia* patches was particularly numerous and occupied 27.4%, 23.9%, and 11.0% of total number of patches, respectively.

Causal factors of patch differentiation, viz. landscape fragmentation can be recognized by comparing the number of patches per unit area of each landscape element (Lee *et al.* 1998a). When the number of patches per unit area between secondary forest elements and introduced ones is compared, mean number of patches of the former was higher as 84 than that of the latter of 53. Secondary forest patches are remnant patches or emerged patches with the progression of succession in this study area (Forman 1995). From these results, we knew that causal factor of landscape fragmentation would be related to remnant patches and development of succession process. Such result did not coincide with that obtained from Seoul and its surroundings, in which excessive artificial interference were causal factors of landscape fragmentation (Lee *et al.* 1998a).

On the other hand, this study area is a Green Island, in which all area below the mountain foot was urbanized. We, therefore, compared differentiation of patches in each area divided into near, intermediate and distant areas with the distance from the urbanized area by assuming the present study area with such environmental condition as an ellipse. The number of patches per unit area (100ha) recognized at community level in near, intermediate, and distant areas was shown in 49, 42, and 43, respectively. That is, the number of patches in the lower part of mountainous area near to the urbanized area was more than those in the mid-slope and the upper parts distant from the urbanized area. From this result we could know that differentiation of patches at community level in isolated areas like the present study area was dependent on artificial interference.

But the results compared on the basis of the number of patches identified at the level of lower communities, group or subgroup showed some different ones from those at community level. The number of patches per unit area (100ha) in near, intermediate, and distant areas was 58, 60, and 63, respectively. That is, the number of patches decreased as approaching to the urbanized area. Such results would be related to the causal factors of differentiation of patches at sub-community level. Most patches at sub-community level seem to be originated from the natural process like progression of succession considering that vegetation of this study area, especially artificially planted ones under mild artificial interference were succeeding to natural vegetation (Cho and Lee 1998). In fact, the fact that the number of patches at sub-community level in distant sites from the urban area, in which artificial interference was mild, was more than that in near sites from that area under severe artificial interference prove such speculation.

From these results, we could judge that patches at community level recognized as homogeneous pattern by aerial photograph were mainly introduced elements and those at sub-community level were mainly regenerated ones originated from natural process of succession. In fact, the human have continuously utilized forests around their living environment by traditional living methods and regulations since their birth on earth (Holzner *et al.* 1983). Therefore, even though a forest was recognized as homogenous pattern by aerial photograph, its internal structure is changed to heterogeneous one by artificial interference or natural recovery after disturbances of diverse types (Küchler and Zonneveld 1988, Nakagoshi and Rim 1988, Nakagoshi *et al.* 1992, Forman 1995, Zonneveld 1995).

Ecological restoration

To diagnose the ecological state of each vegetation unit, species composition, stratification, and successional tendency of vegetation were analyzed. Synthesizing the results from the present study area (Cho and Lee 1998) and other studies carried out in the vicinal areas (Yoon 1994, Joo *et al.* 1995), *Q. serrata* community was recognized as potential natural vegetation of this area. *Q. serrata* community was established restrictedly in valley of the lower area or in small valley of the upper area now (Cho and Lee 1998). But succession tendency of vegetation units appeared in this study areas showed, in general, the possibility to be succeeded by *Q. serrata* community except for the vegetation in some sites disturbed by excessive artificial interference. Restoration plan in this study was focused on inducing succession of substituted vegetation to natural vegetation.

Aronson *et al.* (1993) classified restoration into 3 levels according to the degree of recovery of degraded ecosystem: restoration seeks a complete or near-complete return of a degraded site to a pre-existing state, rehabilitation seeks a return to possible alternative steady states or a synthetic "simplified ecosystem" as an intermediate step in their long-term goals, and reallocation aims at creating new ecosystem by supplying ongoing energy-subsidies that does not necessarily bear an intrinsic relationship with the pre-disturbance ecosystem's structure or function. Both restoration and rehabilitation projects attempt to adopt the indigenous ecosystem's structure and function, while huge plantation of exotic plants are examples of reallocation. Afforestation of exotic species such as *A. firma*, *R. pseudoacacia*, *P. rigida*, etc. could be thought as a reallocation considering that exotic plants are introduced and diverse energy subsidies were applied. But it can be understood as a significant example in terms of restoration ecology that species composition of those afforested stands was recovered to state similar to that of natural vegetation (Cho and Lee 1998).

But in cases of stands located closely to the residential area or hiking trail among stands composing those communities, progression of succession was inhibited by excessive artificial interference. In addition, *P. tomentiglandulosa*, *C. obtusa*, and *C. deodara* communities showed also retardation of succession by excessive interference. Excessive artificial interference cause flourishing of undesirable plants such as *Styrax japonica*, *Stephanadra incisa*, *Oplismenus undulatifolius*, *Phytolacca americana*, *Ambrosia artemisiifolia*, *Paederia scandens*, and so on. Moreover, they inhibit the progression of succession by preventing the establishment of plants composing natural vegetation of this area. Therefore, restoration of unstable vegetation in this area does not require any special management except for exclusion of excessive artificial interference. However, protective planting applicable as supplemental measure of forest edge vegetation to prevent the expansion of the effect of excessive artificial interference would be contributed to stabilization of the disturbed vegetation.

On the other hand, as was above mentioned, this area is an isolated Green Island surrounded by the urbanized area. Restoration at landscape level based on land-use patterns of Mt. Hwangryung and its surrounding area is, therefore, preferentially required to improve ecological quality of the area as an ecological park. Green network as a plan to progress the ecological quality of Mt. Hwangryung can be designed by linking Mt. Hwangryung to Mt. Baekyang and Mt. Jang. But spaces between those mountains are occupied by urban area composed of biotopes with low ecological quality. Therefore, green network has to be created to construct the ecological connectivity of those mountains. Construction of green network in this urban area can be achieved by restoring or creating biotop (Primack 1995, Farina 1998). But biotop mapping has to be preferentially accomplished prior to restoration and creation of biotop. Roadside, riverside, open space, and so on can be considered as influential places for restoration and creation of biotop (Lee *et al.* 1998b).

적 요

부산시의 중심부에 위치하고 있는 황령산을 대상으로 도시지역의 경관구조를 밝히기 위한 연구가 수행되었다. 항공사진 분석과 야외조사를 통하여 토지이용 유형이 포함된 식생도가 작성되었다. 경관요소유형은 이차림요소, 인공림요소, 도시화지역을 비롯한 기타 요소로 구분되었다. 인공림 요소인 사방오리군락과 곰솔군락이 기질을 형성하였고, 이차림요소와 소규모의 기타 인공림 요소들은 그러한 기질내에 작은 patch로 분포하는 경향이었다. 단위면적당 patch의 수는 인공림 요소에서보다 이차림 요소에서 더 많았다. Patch의 크기에 대한 결과는 이와 반대 경향을 나타내었다. 경관생태학적 분석 결과, 군락수준으로 인식되는 patch의 분화는 인위적 간섭과 관계되고, 아군락 수준에서 인식되는 patch는 천이와 같은 자연적 과정과 관련이 있는 것으로 판단되었다. 한편, 황령산의 생태적 질을 개선하기 위한 복원 계획이 복원생태학 및 경관생태학적 관점에서 제시되었다.

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