Korean J. Ecol., 24(6): 385~394, 2001

Landscape Structure in the Greenbelt Zone around the Seoul, the Metropolis of Korea

Lee, Chang-Seok[1]*, Sun-Kee Hong[2], Jeong-Suk Moon[1] and Young-Han You[2]

[1]*Faculty of Environment and Life Sciences, Seoul Women's University, Seoul 139-774, Korea*
[2]*Center for Ecological Research, Seoul Women's University, Seoul 139-774, Korea*

ABSTRACT : An attempt to clarify the landscape structure of urban areas was carried out in the greenbelt around Seoul, Korea's metropolis. By means of aerial photographs and a field survey, a vegetation map including land-use pattern was made. Landscape structure was described by analyzing this vegetation map and the results of phytosociological survey. Landscape element types identified were (1) secondary forest, (2) plantation, (3) cultivated field, (4) urbanized area, (5) graveyard, and (6) bare rock. Vegetation units, resulting from the phytosociological analysis, included *Quercus mongolica, Q. variabilis, Q. acutissima, Pinus densiflora, Q. aliena*, and *Alnus japonica* communities. Plantations were composed of *Robinia pseudoacacia, Populus tomentiglandulosa, P. rigida, Larix leptolepis, P. koraiensis*, and *Castanea crenata* stands. Patches near to human settlements in the lower zones of the mountains were fragmented and small but they became larger towards the higher mountain zones. On the other hand, the number of patches was fewer and their size was larger in Mt. Cheonggye more distant from the principal residential area, larger in size, and higher in elevation compared with the other 2 mountains, Mt. Daemo and Mt. Acha. Floristic composition of Mongolian oak (*Q. mongolica*) stand distributing in the upper part of each mountain, in which artificial interference is rare, showed a difference among those study areas different in parent rock and disturbance regime. But that of black locust (*R. pseudoacacia*) stand located in lowland of mountainous area, in which artificial interference is frequent was similar to each other. As the results of analyses on the frequency distribution of diameter classes of major species, dominant landscape elements, Mongolian oak forest showed different responses depending on artificial interference as continuous maintenance and retrogressive succession in the sites far from and near to the residential areas, respectively. On the other hand, black locust stands showed a probability to be restore to the native oak forest through progressive succession.

Key words: Greenbelt, Landscape element, Landscape structure, Urban forest, Vegetation map.

INTRODUCTION

Mankind has been continuously utilized forest around his living environment by traditional living methods and regulations since his birth on earth (Holzner *et al.* 1983). Forests around living environment of human in urban area have been utilized as locations to obtain timber, fuel, organic fertilizer, and feed of livestock as well as for land-use of diverse types. Therefore, even though a forest was recognized as homogenous pattern by aerial photograph, its internal structure is changed to heterogeneous one by artificial interference (Küchler and Zonneveld 1988, Nakagoshi and Rim 1988, Nakagoshi *et al.* 1992).

In a viewpoint of landscape ecology, a study on urban forest closely related to human life could contribute to understand cultural landscape including cultural background native to forest and human living there. Moreover, urban forest is not only a habitat of diverse species in a viewpoint of biodiversity conservation (Spellerberg *et al.* 1991, Hudson 1991, Saunders and Hobbs 1991), but also a forest for environmental protection with buffering function against environmental stresses occurring from urbanized area (Bradley 1995). Furthermore, the importance also getting increase by affording rural space for a plentiful urban life in both aspects of spirit and body (Adams and Dove 1989, Bradley 1995).

But the urban forest is losing its ecological functions by environmental pollution and is degraded without any economic value by desertion due to negligence in recent years. Therefore, an ecological alternative to restore its original ecological functions is required urgently. In fact, applied landscape ecological studies, such as ecological restoration of urban landscape and ecological management or utilization of urban forest are carried out actively on the basis of landscape ecological principle (Fuller and Warren 1993, Warren and Fuller 1993). In other words, interdisciplinary studies for recovery of ecological functions of urban forest have

* Author for correspondence; Phone: 82-2-970-5666, Fax: 82-2-970-5822, e-mail: leecs@mail2.swu.ac.kr

been vigorously executed on the basis of diverse landscape ecological principles. Furthermore, results of those studies are positively applied to prepare landscape planning and management system for sustainable and nature friendly land-use in a given area.

In this paper, firstly, we described the distribution of landscape elements in urban area of Seoul, metropolis of Korea. Secondly, we compared the landscape structures in terms of kinds, number, and size of patch in landscape, and discussed the characteristics of anthropogenic disturbance causing the structural differences in these landscapes. Thirdly, we compared landscape quality in study areas with different parent rock and disturbance regime. And finally, we deduced the future of major vegetation landscape elements by analyzing the population structure of dominant species of those elements.

STUDY AREA

Study area, Seoul (long. 126° 46′ 15″ - 127° 11′ 15″ E, lat. 37° 25′ 50″ - 37° 41′ 45″ N) covering 605.42km^2 is located on the central part of Korea as the metropolis of Korea (Fig. 1). The altitude of the study area ranges from 20 m to 605 m above sea level. Parent rock of mountainous areas in Seoul is consisted of gneiss and granite in Mts. Cheonggye (hereafter Mt. C) and Daemo (hereafter Mt. D), and Mt. Acha (hereafter Mt A), respectively. Soil of these areas is generally brown forest soil but immature soil is also found in ridge or peak parts of mountains, especially in Mt. A with granite as parent rock. The study area has the continental climate, making the weather very warm and rainy in the summer and cold and dry in the winter. Mean annual temperature and precipitation were 11.5°C and 1307mm, respectively (Korea Meteorological Administration 1990).

Potential natural vegetation of mountainous area around Seoul is estimated to consist of the following four communities (Lee 1997):

1) *Quercus mongolica* stand: deciduous broad-leaved forest on the upper slope.

2) *Carpinus laxiflora* stand: deciduous broad-leaved forest on the lower slope.

3) *Zelkova serrata* stand: deciduous broad-leaved forest on the mountain valley.

4) *Pinus densiflora* stand: evergreen needle-leaved forest on the exposed ridge or peak parts.

Due to human activity, substitute vegetation is predominant in this study area. Trees were intensively cut for domestic fuel, organic fertilizer, timber to construct houses, and so on. As a result, the forest vegetation became poor both in species richness and phytomass. After conversion of fuel, fertilizer, building materials, and so on from plant materials to fossil fuels, chemical fertilizer, cement or metal according to economic and industrial development since 1970s, dependence of people on plant materials in forest decreased. Moreover, development restriction areas called "greenbelt zone" were designated as one of the urban plans in 1971 to prevent indiscreet expansion of the city and to preserve the natural environment in suburbs of the city.

The landscape of Seoul is characterized by apartment complexes, which are arranged throughout the whole area. Apartment complex was restricted on the southern part of Seoul in the past but residential area of such type expanded into the entire area as most houses were transformed into apartment type in re-developmental process of old residential area. Consequently, apartment occupied the principal residential type in Seoul. As the population size and area of Seoul are about 10 millions and 605 km^2, respectively, population density amounts to 16,530/km^2. Residential area became, therefore, dominant

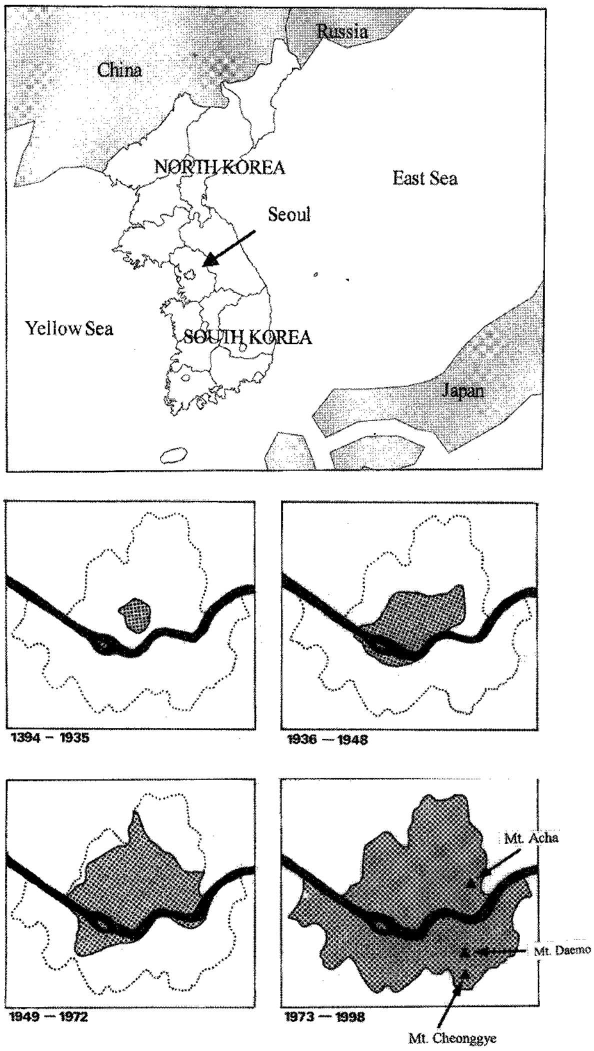

Fig 1. A key map indicates the study area. Maps of the lower part show changes of Seoul, the Metropolis of Korea and study sites.

landscape element type in this area.

Mountainous area of high elevation is distributed in the outskirts and central part is composed of flat plain of low altitude because Seoul is a basin topographically. Most flat areas had been paddy field, cropland or orchard before 1970's, when the massive housing reformation projects were begun except the northern part from the Han river, which formed the old Seoul. Agricultural landscape elements are remained as remnant patches on the foot of mountainous area, which is located on the outskirts of Seoul (Seoul city 1997, 1998). Otherwise, they are partially remained in streamside, open spaces with soil, and so on.

All the apartment complexes have urban parks and gardens, which are constructed artificially in a viewpoint of landscape architecture. But plants introduced there and arranging pattern of them are not harmonious with the natural condition of that place. Street trees are also planted in roadside, although most of them are exotic or non-local species.

In addition, streams including the Han river are channeled or covered with artificial framework for uses as road, parking lot, and so on. That is say, most areas below mountain foot even in mountainous area were occupied by urbanized area including residential area.

METHODS

A correct mapping expressing components of landscape element throughout the extensive area is a fundamental method of landscape ecology to evaluate the landscape structure (Küchler and Zonneveld 1988, Nakagoshi *et al.* 1992, Hong and Lee 1997). Because the vegetation and landscape structures of a region are altered as the land-use regimes of that region change, human activities in the past and the present can be reflected in the current structure of the landscape. In this viewpoint, actual vegetation map is very valuable tool to understand the effects of human activity on vegetation landscape (Kamada and Nakagoshi 1996).

Boundaries of landscape elements divided by vegetation landscapes and land-use patterns were certified by aerial photographs. In the present study, monochrome aerial photographs (1:5,000 and 1:7,000 scales) taken in winter of 1996 were used for recognizing vegetation types and landscape boundaries. The landscape attributes identified by aerial photographs were overlapped on topographical map of 1:25,000 scale. The smallest area of each patch (or landscape element) is 625 m^2: 25 m x 25 m. Patches smaller than 625 m^2 were neglected, because their size and shape would be uncertain on a topographical map at a scale of 1:25,000 (Nakagoshi *et al.* 1992). Vegetation map was completed by use of GIS (Geographic Information System) supported by ArcView (ESRI 1996). Vegetation patch and other land-use pattern identified as landscape element by aerial photograph were confirmed by field checks, and phytosociological procedure (Braun-Blanquet 1964) was applied in field survey and data processing.

Landscape analyses, such as measurement of the number, the area, and the boundary length of each patch were carried out by use of GIS supported by ArcView (ESRI 1996). In the present study, our results were focused on the components, number and distribution pattern of vegetation patches.

To compare the species composition of vegetation landscape elements under the different disturbance regime and natural conditions, DCA (detrended correspondence analysis, Hill 1979) ordination was carried out. Vegetation data for ordination were obtained from median value of cover class of the species showing frequency more than 10% in *Q. mongolica and Robinia pseudoacacia* stands, which are dominant elements among the landscape element types of secondary forest and of introduced plantations of 3 study areas, respectively.

Changes of landscape structure was estimated by analyzing the frequency distribution of diameter (mature tree: diameter at breast height, saplings and seedlings: diameter at ground surface) classes of major species composing dominant landscape elements.

RESULTS

Landscape pattern of study areas

The landscape element types identified from vegetation maps (Fig. 2) were summarized in Table 1. Landscape element types of Mt. C were identified as secondary forest occurred from natural succession after artificial disturbance, plantation introduced to rehabilitate the degraded forest ecosystem, agricultural element, and urbanized area (Table 1).

Secondary forest element was composed of *Q. mongolica*, *Q. variabilis*, *Q. acutissima*, *Q. aliena*, and *P. densiflora* stands. Dominant landscape element among them was *Q. mongolica stand* and *Q. acutissima* stand in upland and lowland, respectively. Introduced landscape element was composed of *R. pseudoacacia*, *Populus tomentiglandulosa*, *P. rigida*, *Larix leptolepis*, and *Castanea crenata* plantations. Dominant element among them was *R. pseudoacacia* plantation.

In addition, agricultural element composed of cropland and paddy field appeared and graveyard also appeared even though their area is small. Lowland below agricultural element was occupied by urbanized area including human settlements.

Landscape element types appeared in Mt. D and their distribution pattern was similar to those in Mt. C. *Alnus japonica* stand appeared newly and *Quercus aliena* stand did not appear in secondary forest element of Mt. D. In addition, bare rock also appeared newly in Mt. D.

Landscape element types and their distribution in Mt. A were

Table 1. The configuration of landscape element identified from vegetation maps of 3 mountains

Landscape element type	Mt. Cheonggye			Mt. Daemo			Mt. Acha		
	Number	Area	N/1,000ha	Number	Area	N/1,000ha	Number	Area	N/1,000ha
Secondary forest									
Pinus densiflora	17 (5.7)	131.3 (2.9)	129.5	3 (1.2)	12.8 (1.0)	235.3	10 (7.9)	218.1 (16.1)	45.9
Quercus mongolica	5 (1.7)	1,684.3 (37.9)	3.0	3 (1.2)	97.2 (7.5)	30.9	6 (4.7)	58.0 (4.3)	103.4
Q. variabilis	4 (1.3)	441.9 (37.6)	9.1	2 (0.8)	38.7 (3.0)	51.7	– –	– –	–
Q. aliena	1 (0.3)	1.2 (0.0)	847.5	– –	– –	–	– –	– –	–
Q. acutissima	27 (9.1)	412.7 (9.2)	65.4	24 (9.8)	268.4 (20.6)	89.4	20 (15.8)	72.1 (5.3)	277.5
Alnus japonica	– –	– –	–	1 (0.4)	2.3 (0.2)	431.0	1 (0.8)	1.0 (0.1)	1,030.9
Subtotal	54 (18.1)	2,671.3 (59.6)	20.2	32 (13.4)	419.3 (32.1)	76.3	37 (29.2)	349.1 (25.7)	106.0
Plantation									
Pinus rigida	16 (54)	100.4 (2.2)	159.3	60 (24.4)	139.3 (10.7)	430.6	4 (3.1)	99.7 (7.4)	40.1
P. koraiensis	8 (2.7)	16.5 (0.4)	485.4	11 (4.5)	6.3 (0.5)	1,751.6	7 (5.5)	13.3 (1.0)	525.9
Robinia pseudoacacia	35 (11.8)	439.6 (9.8)	79.6	40 (16.2)	202.9 (15.5)	187.1	21 (16.5)	343.2 (25.3)	61.2
Populus tomentiglandulosa	14 (4.7)	22.7 (0.5)	617.3	17 (6.9)	49.9 (3.8)	340.5	– –	– –	–
Larix leptolepsis	16 (5.4)	69.8 (1.6)	229.2	3 (1.2)	6.9 (0.5)	435.4	2 (1.6)	53 (0.4)	380.9
Castanea crenata	15 (5.0)	169.3 (3.8)	88.6	6 (2.4)	4.1 (0.3)	1,467.0	5 (3.9)	51.8 (3.8)	96.6
Subtotal	104 (35.0)	818.3 (18.3)	110.0	137 (55.6)	409.5 (31.4)	334.6	39 (30.6)	513.2 (37.8)	76.0
Agricultural field									
Orchard	– –	– –	–	– –	– –	–	9 (7.1)	50.4 (3.7)	178.6
Crop land	9 (3.1)	34.2 (0.8)	263.2	11 (4.5)	95.4 (7.3)	115.3	– –	– –	–
Paddy field	27 (9.1)	493.2 (0.8)	54.7	24 (9.8)	86.2 (6.6)	278.5	2 (1.6)	9.6 (0.7)	207.7
Subtotal	36 (12.1)	527.4 (11.8)	68.3	35 (14.3)	181.6 (13.9)	192.7	11 (8.7)	60.0 (4.4)	18.3
Graveyard	9 (3.1)	11.3 (0.3)	799.3	15 (6.1)	10.8 (0.8)	1,394.0	2 (1.6)	172.0 (12.7)	11.6
Urbanized area	58 (19.5)	449.4 (10.0)	129.1	23 (9.4)	282.4 (21.6)	81.4	17 (13.4)	233.3 (17.2)	72.9
Bare rock	– –	– –	–	3 (1.2)	2.4 (0.2)	1,265.8	21 (16.5)	29.2 (2.2)	719.4
Total	297 (100)	4,477.6 (100)	58.3	246 (100)	1,305.9 (100)	188.4	127 (100)	1,356.8 (100)	93.6

Values in parenthesis indicate percentage of number and size of patch.

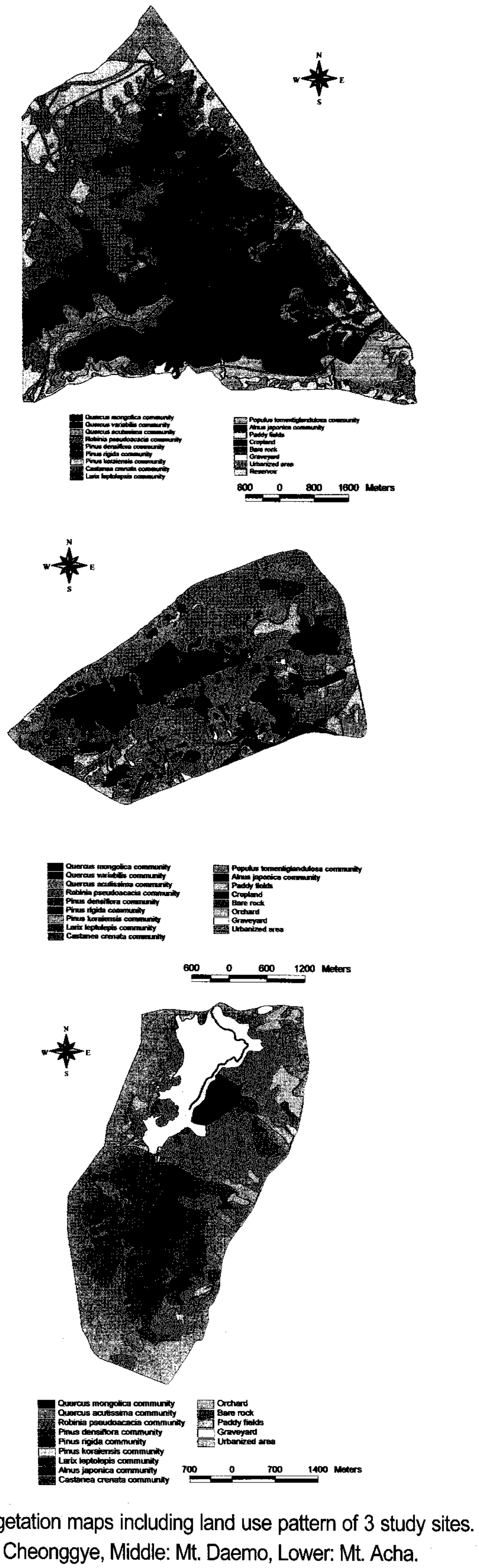

Fig. 2. Vegetation maps including land use pattern of 3 study sites. Upper: Mt. Cheonggye, Middle: Mt. Daemo, Lower: Mt. Acha.

some different from those of the other 2 areas. First of all, areas occupied by graveyard and *P. densiflora* stand were very large and orchard was included in agricultural element. In addition, several elements, such as *Q. variabilis, Q. aliena* and *P. tomentiglandulosa* stands did not appear.

The number and size of patches

Table 1 shows the configuration of landscape elements in 3 study areas. Total number of patches was the most in Mt. C with the largest dimension among 3 study areas. But the number of patches per unit area was the most in Mt. D with the smallest dimension. In Mt. C, the number of patches was the most in the introduced element and size of patches was the smallest in that element. In Mt. D, the number of patches was the most in the introduced element as the same as the case in Mt. C. Size of patches was the smallest in introduced plantation. In Mt. A, the number of patches was the most in the introduced element similarly to the case in the other 2 mountains. Size of patches was the smallest in agricultural element.

In all of the mountains, percentage of the introduced patches was more than that of secondary forest elements (Mt. C; 35.0:18.1%, Mt. D; 55.6:13.4%, Mt. A; 30.6:29.2%). The number of P. *rigida* and *R. pseudoacacia* patches, especially in Mt. D, which has higher percentage of introduced element, occupied 24.4% and 16.2% of total patches, respectively. Area of these 2 patches were also larger than those of the other patches composing introduced landscape element as 10.7% and 15.5% of total area, respectively.

Comparison of floristic composition among study areas

As a result of ordination on stands composing *Q. mongolica* stand, dominant element of secondary forest, stands tended to be arranged in the following order of Mt. C, Mt. D, and Mt. A on Axis I (Fig. 3a). In the result, Mt. C and Mt. D showed similar species composition but Mt. A was somewhat different in its species composition from those of the other two mountains.

In the result on *R. pseudoacacia* stands, stands were tended to be concentrated on one spot except several outlier stands (Fig. 3b). That is, difference of floristic composition among stands was not obvious.

Vegetation succession

Vegetation succession was analyzed from frequency distribution diagrams of size classes of major woody plants composing Mongolian oak stands (Fig. 4) and black locust stands (Fig. 5). Mongolian oak stands of Mt. C distant from the principal residential area (Fig. 4a) and of Mt. A (Fig. 4d) had many young Mongolian oaks in low diameter classes. But Mongolian oak stands of Mt. C near to the residential area (Fig. 4b) and of Mt. D (Fig. 4c) held many young individuals of *Sorbus alnifolia* in low diameter classes.

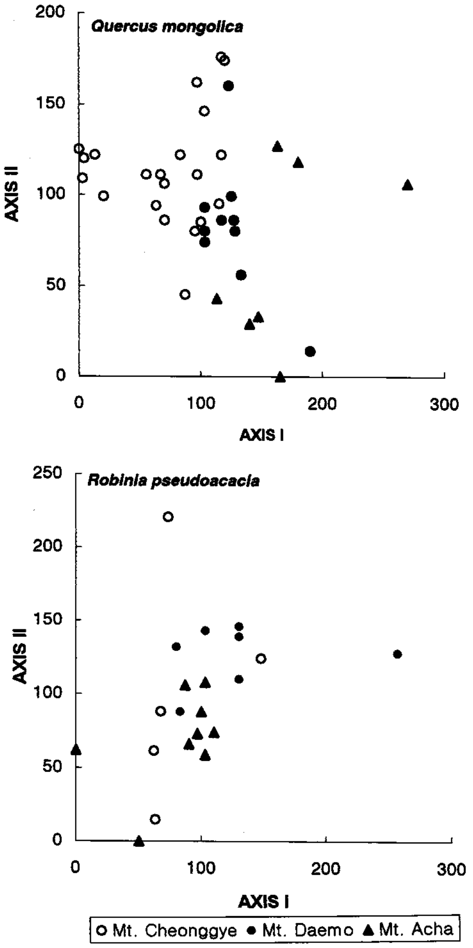

Fig. 3. Ordination of *Quercus mongolica* and *Robinia pseudoacacia* stands of 3 mountains different in parent rock and disturbance regime.

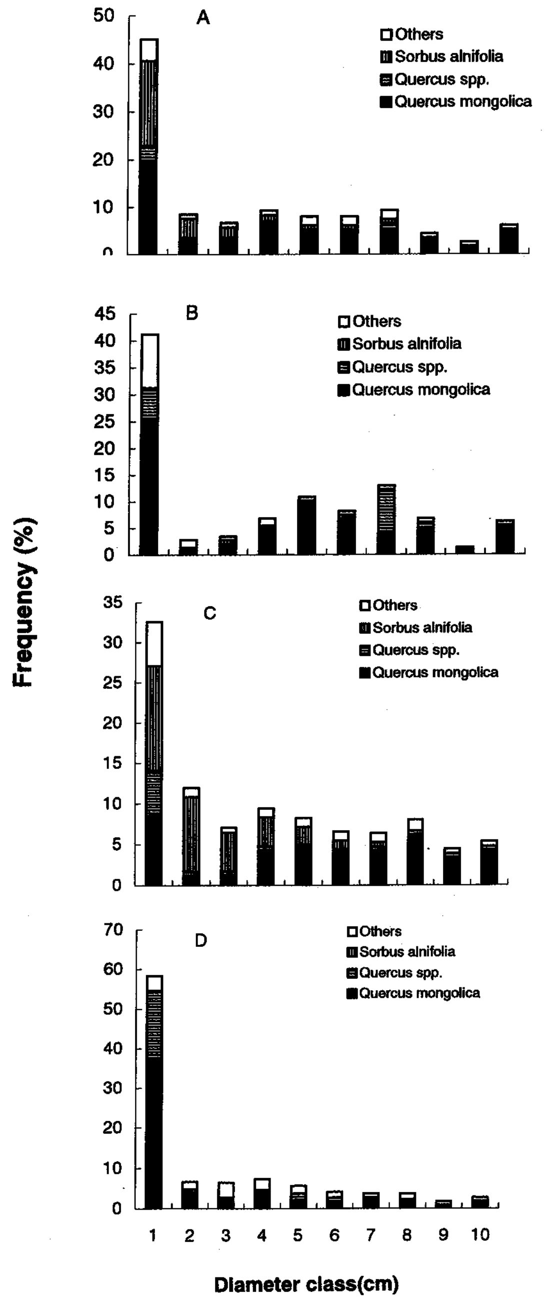

Fig. 4. Size distribution diagrams of major woody plants in *Quercus mongolica* stand of 3 mountains. A: site near to the principal residential area in Nt. Cheonggye, B: site distant from the principal residential area in Mt. Cheonggye, C: Mt. Daemo, D: Mt. Acha.

Many young oak individuals appeared in low diameter classes in diagram of *R. pseudoacacia* stand (Fig. 5). That is, plantation afforested by introducing exotic plant, *R. pseudoacacia* showed a probability to be succeeded by oaks native to Korea.

DISCUSSION

Context of different landscape pattern

Landscape pattern of 3 study areas was similar to each other but showed a difference in several aspects. In particular, Mt. A showed somewhat remarkable difference from the other 2 mountains as the area holds wide pine stands and orchard. The first difference is originated from coarse soil particle and shallow soil depth, typical soil characteristics of area with granite as a parent rock. A causal factor of the other difference can be found in changing process of landscape in Seoul. Seoul had been the Capital of Chosun Dynasty from 1392 to 1945 and has been maintaining as the Capital of Korea since 1945 (Fig. 1). In a process of urbanization, enlargement of urbanized area toward the south from the urban center of Seoul was more rapid than that toward the other directions. Especially, enlargement toward the south since 1970s was very rapidly progressed in accordance with rapid economic growth and population increase. In

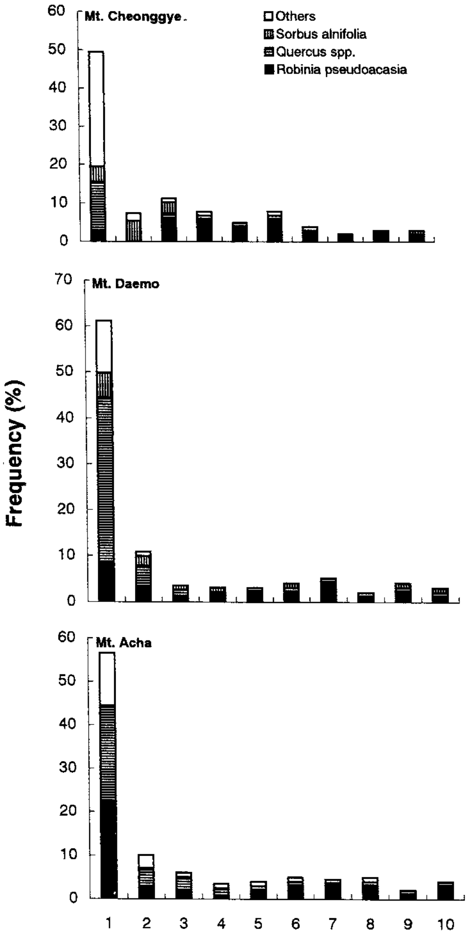

Fig. 5. Size distribution diagrams of major woody plants in *Robinia pseudoacacia* stand of 3 mountains.

this process of rapid urbanization, orchard of large area usually located in hillock or lowland of mountainous area was incorporated to urbanized area including human settlements (Lee *et al.* 1998).

Cause of fragmentation

The number and size of patches reflect the intensity of disturbances caused by both nature and human in the human-influenced landscape, and hence they can be used as indices reflecting the intensity of disturbance (Turner 1989, Forman and Godron 1986, Raedeke and Raedeke 1995).

As was shown in above-mentioned results, plantation with many patches of small scale was an important factor causing fragmentation of vegetation patch in all study areas. Considering the fact that plantation was introduced to rehabilitate the forest devastated by excessive artificial interference, the source of landscape fragmentation can be found in human impact.

On the other hand, urbanized area in Mts. C and D and secondary forest in Mt. A appeared also in important causal factors of landscape fragmentation. The result in the former two mountains would be related to the developmental projects, which is in progress even in recent years. That of the latter can be explained in relation to parent rock of the area. That is to say, bare rock appeared in a causal factor of vegetation fragmentation in Mt. A. Landscape patches located in the upland of the mountain due to bare rock (16.5%). Bare rocks do not permit the establishment of vegetation near them and consequently induced different vegetation type from those in sites distant from them. As is shown in such example, the number of patches also reflects vegetation boundaries caused by topographical and geological features (Zonneveld 1995).

On the other hand, the number of landscape patches decreased toward the top of mountains, and moreover, most patches, including the introduced patch like plantation, were concentrated around the urbanized and agricultural fields, which are located in the lowland below the mountain foot. Those elements were restricted in sites easy to manage as low topographical condition. *Larix leptolepsis*, however, was planted in the small valley of upper part of Mt. C.

Cause of different species composition among study areas

In the result of ordination on the Mongolian oak stands investigated in three study areas, a cause of difference in species composition of between Mt. A and the other two mountains can be found in soil characteristics. Parent rock of Mt. C and Mt. D was gneiss and that of Mt. A was granite (Table 2). Weathering of gneiss is more rapidly progressed than that of granite. In addition, particle of soil from gneiss is finer than that of soil from granite. Differences of those soil characteristics related to parent rock in Mt. A, might induce floristic composition different from the other two mountains.

On the other hand, difference between Mt. C and Mt. D would be related to artificial interference. That is to say, Mt. C is located more far from the principal residential area, in which apartment complexes are concentrated than Mt. D is (Table 2). Moreover, Mt. C was larger in area and higher in elevation as compared with those of Mt. D (Table 2). Those environmental conditions

Table 2. Comparison of natural and artificial environments among three study areas

	Total area (ha)	Elevation (m)	Distance from the principal residential area (km)	Parent rock
Mt. Cheonggye	4,477.6	605.3	4.5	Gneiss
Mt. Daemo	1,305.5	305.5	0.7	Gneiss
Mt. Acha	1,356.8	303.8	0.8	Granite

might influence on the intensity of artificial interference, such as hiking, recreation, and non-ecological forest management and those effects would cause different floristic composition.

On the other hand, similarity of species composition of black locust stands would be related to their habitat in each area. In other words, main habitat of the black locust stand, is restricted in the mountain foot. Therefore, such sites would be under frequent human impact in all the three study areas and such an effect might lead to similar floristic composition to each other.

Consequently, the secondary forest (e.g. *Q. mongolica* stand), which is distributed mainly in the upland of mountainous area under mild artificial interference showed different species composition according to parent rock, and size, elevation, and distance from the principal residential area related to accessibility of visitors to each area. But introduced vegetation, which are located near to the urbanized or agricultural landscape elements showed similar species composition in all the three areas due to frequent human disturbance.

Effects of anthropogenic disturbance on urban landscape pattern

Considering that all the three study areas investigated are located around the urban area, they necessarily might be influenced by human disturbance. In the perspectives of landscape structure and fragmentation of patch, Mt. D was the most severely disturbed among three areas. Vegetation patch in Mt. C far from the principal residential area was significantly different from those of the other two mountains in the number and distribution pattern of patch. Landscape structure and species composition at mountain foot was similar to each other. However, distribution pattern and species composition of landscape elements above mid-slope of mountain were different from those of Mts. A and D.

Landscape element types from lowland toward the upland in Mt. C were distributed in the order of urbanized area, agricultural fields, introduced vegetation, and secondary forest landscape elements (Fig. 2). Distribution pattern of landscape elements in Mt. C that introduced elements hardly appeared within matrix of secondary forest was different from that in the other two mountains. Distribution pattern of landscape element types in Mt. D was similar to that of Mt. C. But patches of introduced element frequently appeared in matrix of secondary forest. In addition, introduced elements, especially black locust and pitch pine, which were restricted in lowland in Mt. C were also distributed above mid-slope. Considering that those patches were introduced as measures to rehabilitate the forest devastated by excessive human impact, we could interpret that those differences were originated from excessive artificial interference. Distribution pattern of landscape element types in Mt. A was similar to the other two mountains. But dominant element in secondary forest was *P. densiflora* stand differently from the other two mountains. Such a difference would be caused due to parent rock composed of granite, which is slow in weathering and coarse in particle as was above mentioned. On the other hand, distribution pattern of landscape element types in Mt. A was similar to that of Mt. D in respect that introduced element, especially patches of black locust and pitch pine plantations appeared above mid-slope. Such a similarity was related to that both Mt. D and Mt A are located closely to the principal residential area, smaller in size, lower in elevation than Mt. C is (Table 2).

CONCLUSION

Landscape features, such as component, size, number and distribution pattern of vegetation patch, and matrix reflect the effects of anthropogenic and natural disturbances in the urban landscape system (Forman 1995). Management of forest and land-use patterns in and around mountainous area influence on the forest vegetation. Natural succession of forest vegetation in urban areas was, therefore, partly retarded by those human activities. Moreover, soil properties changed by disturbances, and geomorphologic features may also affect the size and distribution of patches and matrices in landscape established in a given area (Forman and Godron 1986, Zonneveld 1995).

The effects of type and intensity of disturbance on urban landscape, therefore, can be indirectly clarified through the analysis on vegetation patches (Bradley 1995, Forman 1995). Landscape composition, such as natural landscape patch, remnant patch in large matrix (viz. relict stand, see Muller-Dombois and Ellenberg 1974), introduced patch, and emergent patch appearing from the environmental changes such as fire, land-slide, and flooding mirrored the complex of human-nature disturbance. In the present study, Mt. C having fewer patches shows anthropogenic disturbance of lower intensity than that of the other two mountains. Such results are due to long distance from the principal residential area, high elevation, and large size. Mt. D near to the residential area are accessible easily by people, and thereby vegetation landscape was split to small patches. In the case of Mt. A, patches due to geomorphologic conditions such as bare rock and steep slope were added to the vegetation patch, while characteristics of parent rock less susceptible to human impact mitigated differentiation of patch.

On the other hand, many small patches of *P. densiflora* were found within the matrix of *Q. mongolica*, dominant secondary forest element in Mt. C. Such small patches were not included in the number of patches because patchy elements smaller than 625m^2 were neglected in vegetation map. Existence of those remnant patches of pine stand in large matrix of *Q. mongolica* suggests that a change of vegetation landscape is occurring at this mountainous area. In most forest ecosystems conserved well in Korea, natural pine stands restricted on some limited sites, such as outcrops of ridge or peak parts (Lee 1995a, 1995b). Such sites can not be found in these study areas excluding Mt. A composed of rocky mountain. Most pine stands that appeared in these study areas would be, therefore originated from artificial interference. These relict communities left as the remnant patches in this study area will be replaced by large matrix of surrounding vegetation types with the progress of succession (Agee 1995). During the period of traditional agriculture, woody plants within the pine forest were used as fuels for cooking and heating system of houses like Ondol (Hong and Nakagoshi 1996). Herbaceous plants and litter on the forest floor were collected and used as compost for paddy fields and croplands, and as fodder for working cows. Management system of pine forest, however, has abandoned according to switch of energy and fertilizer since 1970s. Secondary vegetation including pine forest is, consequently, changing to oak forest dominated by *Q. mongolica* or the other deciduous forests of late succession stage (Lee *et al.* 1998b). In other words, the total landscape system including vegetation has been changing rapidly in mountainous areas around Seoul.

ACKNOWLEDGEMENTS

This study was partly supported from research fund of Seoul City and was accomplished with Post-Doc. Fellowship Program under Korea Research Foundation (1997) of the Ministry of Education, Korea of Dr. S.K. Hong.

LITERATURE CITED

Adams, L. W. and L. E. Dove. 1989. Wildlife reserves and corridors in the urban environment. A guide to ecological landscape planning and resource conservation. National Institute for Urban wildlife, Columbia, MD. 91p.

Agee, J. K. (1995) Management of Greenbelts and forest remnants in urban forest landscapes. In: Bradley GA (ed.), Urban Forest Landscapes, Integrating Multidisciplinary Perspectives. University of Washington Press. pp. 128-138.

Bradley, G. A. 1995. Urban Forest Landscapes, Integrating Multidisciplinary Perspectives. University of Washington Press. 224p.

Braun-Blanquet, J. 1964. Pflanzensoziologie. Grundze der Vegetaionskunde. Springer-Verlag. Wien. 865p.

Environmental System Research Institute. 1996. ArcView GIS. Environmental System Research Institute, Inc. New York. 350p.

Forman, R. T. T. and M. Godron. 1986. Landscape Ecology. John Wiley, New York. 620p.

Forman, R. T. T. 1995. Land Mosaic: The ecology of landscapes and regions. Cambridge University Press. 632p.

Fuller, R. J. and M. S. Warren. 1993. Coppiced woodlands: their management for wildlife. Nature Conservancy Council, Peterborough.

Hill, M. O. 1979. DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University Ithaca, New York. 52p.

Holzner, W., Werger, M. J. A. and I. Ikushima. 1983. Man's impact on vegetation. Dr. W. Junk, The Hague. 370p.

Hong, S. K. and C. S. Lee. 1997. Development and roles of landscape ecology as an emerging opportunity for ecology. Korean J. Ecol. 20: 217-227. (In Korean with English abstract).

Hong, S. K. and N. Nakagoshi. 1996. Biomass changes of a human-influenced pine forest and forest management in agricultural landscape system. Korean J. Ecol. 19:305-320.

Hudson, W. E. 1991. Landscape linkages and biodiversity. Island Press, Washington DC. 194p.

Kamada, M. and N. Nakagoshi. 1996. Landscape structure and the disturbance regime at three rural regions in Hiroshima Prefecture, Japan. Landscape Ecology 11: 15-25.

Korea Meteorological Administration. 1990. Annual climatological report. Korea Meteorological administration, Seoul. (In Korean).

Küchler, A. W. and I. S. Zonneveld. 1988. Vegetation mapping. Kluwer Academic Publishers, Dordrecht. 635p.

Lee, C. S. 1995a. Disturbance regime of the *Pinus densiflora* forest in Korea. Korean J. Ecol. 18: 179-188. (In Korean with English abstract).

Lee, C. S. 1995b. Regeneration process after disturbance of the *Pinus densiflora* forest in Korea. Korean J. Ecol. 18: 189-201. (In Korean with English abstract).

Lee, C. S. 1997. Synergistic effects of air pollution and soil acidification on water stress of plant. Proc. Sym. Ecol. Soc. Kor. 1997. pp. 48-68. (In Korean).

Lee, C. S., S. K. Hong and Y. H. You. 1998. Landscape ecological studies on green-belt zone in the Metropolitan area of Seoul, Korea. The 1st landscape ecology forum "Landscape ecology: principle, concept, and application" Proceedings. pp. 9-25.

Lee, E. B. 1998. Actual vegetation and potential vegetation of Pukhansan national park, mid-western Korea. Korean J. Ecol. 20: 439-445.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. Wiley, New York. 547p.

Nakagoshi, N., M. Kamada and S. K. Hong. 1992. Map of actual vegetation map in Miwa-cho, Hiroshima Prefecture. Bull. Biol. Soc. Hiroshima Univ. 58: 3-6 + Map.

Nakagoshi, N. and Y. D. Rim. 1988. Landscape ecology in the greenbelt area in Korea. Munstersche Geogr. Arb. 29:247-250.

Raedeke, M. A. M. and K. J. Raedeke. 1995. Wildlife habitat design in urban forest landscapes. In G.A. Bradley (ed.), Urban Forest Landscapes, integrating multidisciplinary perspectives. University of Washington Press. pp. 139-149.

Saunders, D. A. and R. J. Hobbs. 1991. Nature Conservation 2: The Role of Corridors. Surrey Beatty, Chipping Norton.

Seoul city. 1997. A research report of detailed survey on the forest ecosystem of Seoul (The Ist Year). Seoul city, Seoul. 492p. (In Korean).

Seoul city. 1997. A research report of detailed survey on the forest ecosystem of Seoul (The Ind Year). Seoul city, Seoul. 445p. (In Korean).

Spellerberg, I. F., F. B. Goldsmith and M. G. Morris. 1991. The Scientific Management of Temperate Communities for Conservation. Blackwell, London. 566p.

Turner, M. G. 1989. Landscape ecology: The effect of pattern on process. Ann. Rev. Ecol. Syst. 20: 241-251.

Warren, M. S. and R. J. Fuller. 1993. Woodland ridges and glades: their management for wildlife. Nature Conservancy Council, Peterborough.

Zonneveld, I. S. 1995. Land Ecology - An Introduction to Landscape Ecology as a base for Land Evaluation, Land Management and Conservation. SPB Academic Publishing, Amsterdam, 199p.

(*Received November 27, 2001, Accepted December 17, 2001*)