Journal of Environmental Sciences Vol. 15, No. 2, pp. 199—204, 2003

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2003)02-0199-06 **CLC number**: Q149 **Document code**: A

Landscape pattern and its effect on ecosystem functions in Seoul Metropolitan area: Urban ecology on distribution of the naturalized plant species

Sun-Kee Hong[1], In-Ju Song[2], Hyun-Ok Kim[3], Eung-Kyong Lee[1]

(1. Environmental Planning Institute, Seoul National University, Seoul 151-742, Korea. E-mail: pinehong@soback.kornet.net; 2. Seoul Development Institute, Seoul 100-250, Korea; 3. Technical University Berlin, Germany)

Abstract: During land transformation process in the human history, naturalized plants were introduced to several land use patterns by the different ways of plant itself. Including some naturalized plants that had been contribute to land restoration, many naturalized plants have been invaded to original habitat or landscape for native plants. Once the plants were colonized, they extend their area and population size. Urban developed areas often give an important role of source habitat for naturalized plants and expanding their population size. In recent, this situation is appearing as one of environmental problems about the urban landscape management controlling the naturalized plants that invaded in the developed area and conserving the native vegetation. This paper is focusing on relationships between distribution of habitat of naturalized plants and landscape patch in urban area in Seoul. Gangdong-Gu, one of the administrative areas in Seoul was selected for this study. We examined the recent land use change using LANDSAT TM data and spreading of the representative naturalized plants (*Robinia pseudoacacia* and *Eupatorium rugosum*) by Seoul Biotope Mapping Project and field survey in 1999. As a result, these two species were often occurred in the same habitat and distributed in forest edge disturbed by man. Their distribution patterns were related to landscape indices (patch size and shape) in the forest edge.

Keywords: biotope mapping; ecosystem management; human impact; landscape pattern; naturalized plants; urban ecology

Introduction

The disturbance on land in urban and suburban area, which resulted from urbanization caused damage to the natural environment and rural landscape of traditional and stable quality in the perimeters of residential areas. Therefore it is necessary to seek a land use plan capable of preserving existing original landscape (Forman, 1995; Lee, 1998; Hong, 1999; 2001). However, the current land use plan in urban fringe and suburbs is based on the existing shaped cities and planning concepts, and in particular, open space planning is in the same situation. In Korea, since most of the rural areas are encircled by mountain-type natural open spaces or green belts, the process of urbanization have brought a lot of transformation of natural open space and damage, therefore causing the heterogeneity of landscape and stirring negative impacts in terms of landscape ecology. Landscape change in urban area is significantly related to landscape fragmentation and habitat isolation. According to Forman(Forman, 1995), the major man-influenced change of a landscape is the progressive division of large, comparatively homogeneous tracts of forest into a heterogeneous mixture of much smaller patches. Habitat loss for some plant and animal species, habitat creation for others, decreased connectivity of the remaining vegetation, decreased patch size, increased distance between patches, and an increase in edge at the expense of interior habitat (Hanssen, 1995; Reed, 1996).

Cause of landscape change of Korea is related to many various development projects with little consideration on the natural environment. Moreover, these development projects are consequent to population growth, expansion of industrial facilities, and various development activities caused serious imbalances in the natural environment. Consequently, these many causes are threatening ecosystems to the brink of permanent destruction. For example of recent change of forested landscape in Korea, total area of land covered by forest are decreasing 6597000 hm^2 in 1972, 6586000 hm^2 in 1980, and 6452000 hm^2 in 1995 (Ministry of Environment, 1997). Loss of forested areas is 8000 hm^2 by annual since the past five years. Decreasing green connectivity by industrialization and urbanization have created man-made barriers such as roads and railroads, which separate ecosystems, thereby threatening their richness and diversity (Ministry of Environment, 1997).

A study is focusing on the ecological effect of landscape patches on forest ecosystem in urban landscape. The first research object is on current landscape changes of Seoul Metropolitan area. Second object is about patch pattern's effect on ecosystem functions (especially in alien species invasion) in Seoul area. Spatio-temporal variations of structure of forest patches in urban landscape were quantified in Seoul from 1983 to 1999.

There are many definitions about "naturalized plant" (Groves, 1986; Song, 1999). According to

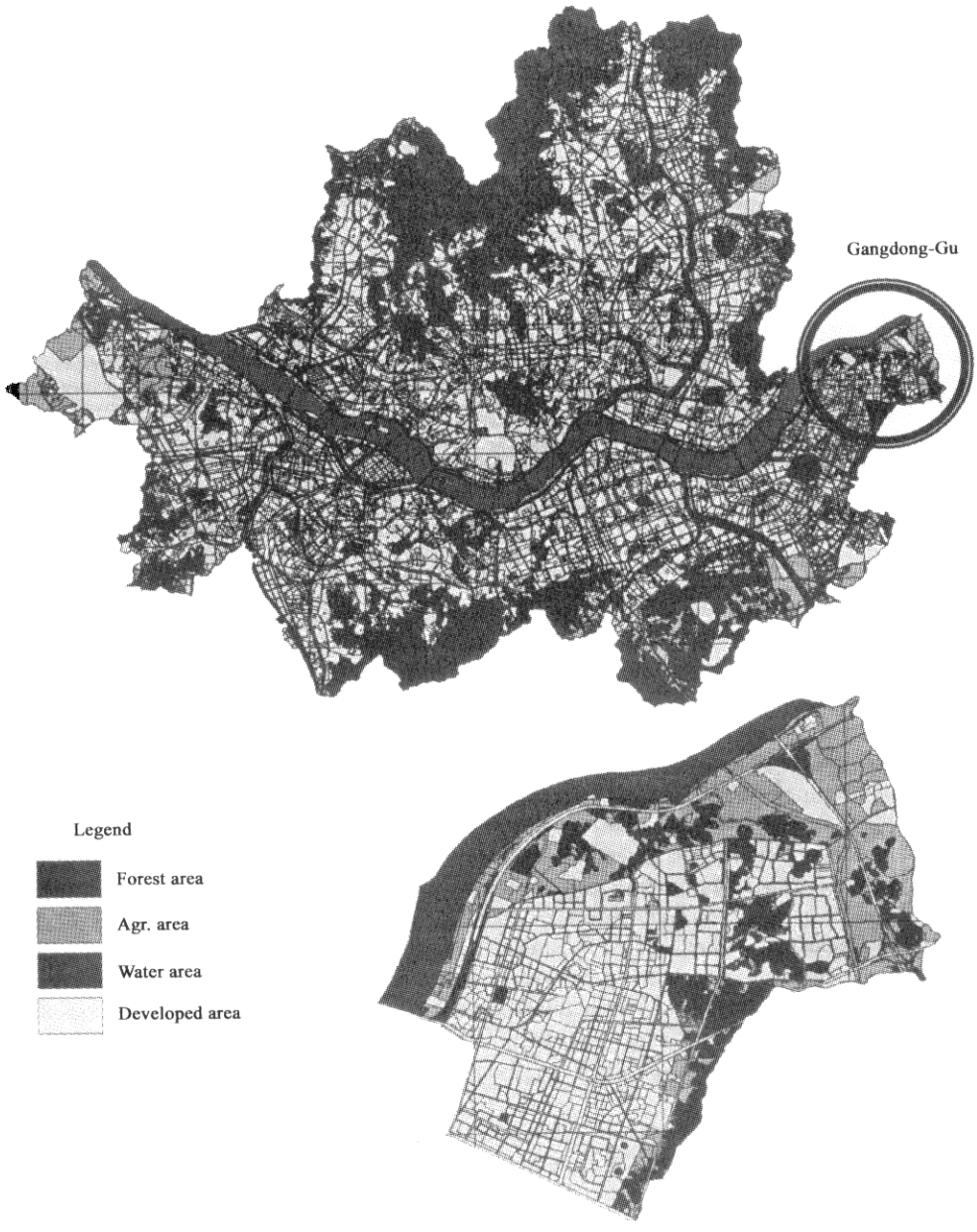

Fig. 1 Land use of Seoul and Gandong-Gu from Seoul Biotope Map (Seoul Metropolitan Government, 2000)

NIER (NIER, 1995; 1996), naturalized organism was defined as "non-native" species in Korea which have been introduced anthropogeneouly or naturally and can reproduce and survive in wild habitats by themselves. Disturbed area such as urban developed areas often gives an important role of source habitat for naturalized plants and expanding their population size (Forman, 1995). Invading of naturalized plants is significantly related to the processes of land transformation and ecosystem deterioration (Groves, 1986; de Wall, 1994). Invaded naturalized plants colonize an original habitat of native plants. Colonized plants expand their habitat area and population sizes (Kim, 2000). Developed areas give an important source habitat for the naturalized plants. Controlling the naturalized plants that invaded in the developed area is indispensable for conserving the native vegetation (NIER, 1996). Its distribution is expanding to the

developed area in central Korea. Study purposes are to examine the relationship between distribution characteristics of the naturalized plants and landscape structure, and also to get planning implement for urban vegetation restoration on the basis of landscape ecology (de Wall , 1994; Hanssen, 1995; Hong, 2001)

1 Analysis process

To do this research, previous quantification analysis of urban landscape of Seoul area is carried out. LANDSAT TM data during 1986 to 1999 was applied to the analysis of recent land use change. Spatial data of Biotope Mapping Project of Seoul Metropolitan Area(Seoul Metropolitan Government, 2001) also applied to manage for the research. Above all, we quantified landscape structure of total Seoul to understand the situation of urban ecological system. To compare the total landscape and surveyed area, we carefully selected one major developed area, Gangdong-Gu, from the total Seoul Metropolitan area (Fig. 1). Field survey on urban forest ecosystem carried out to identify the naturalized plants. Two naturalized plants are selected for this study. *Robinia pseudoacacia* is an introduced deciduous tree for landscape restoration from North America (Lee, 1993; Kim, 2000). Its aggressive root sucker is one of troubles for forest management. A White Snakeroot *Eupatorium rugosum* is perennial herb that firstly identified in urban forest, especially in Seoul since 1978 year (NIER, 1995; Park, 1995; Kim, 2000).

Quantification analysis of landscape of Gangdong-Gu was carried out (Fig. 2). Especially number and size of forest patch were measured by counting of spatial element identified by Arc View ver. 3.1. In order to know pattern of landscape patch, regression analysis between area and perimeter of patch was carried out. Patch shape index was applied to landscape of Gangdong-Gu. For all landscape patch, to quantify the disturbance intensity on patch boundary and evaluate the amount of edges, an index of the shape of patch edge based on area and perimeter of the patch was introduced (Forman, 1995). The circle has an index near 1.0, and it becomes larger with many irregularities and convolution of patch boundary. In the present paper, patch circularity that explaining convolution of patch edge was corresponded to shoreline development index (D).

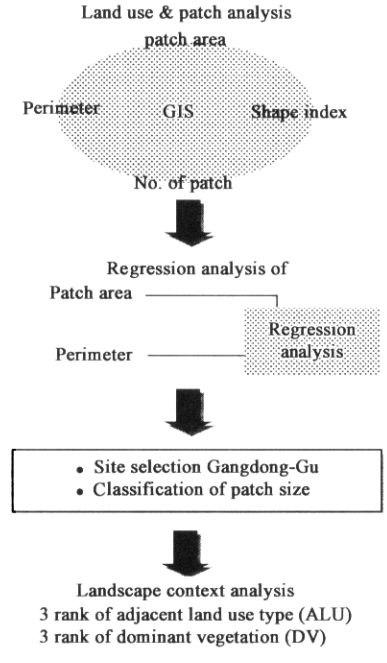

Fig.2 Analysis process for this research

2 Results and discussion

2.1 Structure and shape of landscape and patch of total area and experimental area of Seoul

Area of forest patches decreased during 1988-1999. Patch shape was became smaller and simpler. Developed area was extended to boundary of forest patches. Moreover, core area of inner forest was more decreased than total forest area. Total area of forest patches decreased during 1988—1996. Number of forest patches increased during the same period. Patch size was became smaller and patch shape became irregular form. According to Lee (Lee, 1998), heterogeneity of sizes of urban forest patch increased during 1983—1996. Variety of patch types around forest patches increased. Developed area was extended to inner boundary of forest patches. Core area of inner forest was more decreased than total forest area in greenbelt. In general, vegetation landscape around urban area has been fragmented since 1980's when large plan of land development had been extend to all area of Seoul (Hong, 2001).

According to analysis of Seoul Biotope Map shows current pattern of land use type of Total Seoul and Gangdong-Gu in 1999 (Seoul Metropolitan Government, 2000). More than 30% is occupied by resident area in Gandong-Gu. Agricultural field and natural forest also are major land use types in the area (15.2% in agricultural land, 11.7% in natural forest). According to these data, Gandong-Gu is emerged developing district in Seoul. Table 1 shows the changes of patch number of total Seoul from 1988 to 1999 years. Small patches less than 1 hm^2 are drastically disappeared during this period. Total area of vegetation in Seoul was also decreased. Table 2 is an analyzed data of Gangdong-Gu. Similar trends with Total Seoul were occurred in Gangdong-Gu. Although small patches less that 1 hm^2 are disappeared by development, a

number of patch sized 2—10 hm^2 was increased in Gangdong-Gu and total area of Seoul. Large patch (more than 100 hm^2) was dissected to small size since 1992. It is significantly related to new land use of southern part of Seoul since 1990.

Table 1 Changes of patch number in Seoul (1988—1999)

Patch size, hm^2	No. of patch					Total area		
	Sep. 1988	Sep. 1992	Sep. 1994	Sep. 1996	Sep. 1999	Sep. 1988	Sep. 1992	Sep. 1994
Less than 1	5039	4735	4338	6579	2759	1129.68	1028.43	962.64
1—2	362	318	252	384	467	511.38	457.11	366.66
2—5	253	218	202	256	401	792.54	669.15	627.12
5—10	89	104	85	86	151	625.50	733.14	595.26
10—50	93	72	82	91	149	2000.16	1622.70	1775.43
50—100	12	10	9	17	21	901.35	717.21	611.82
100—1000	17	20	20	19	28	4067.73	4668.21	5202.99
More than 1000	4	4	3	3	1	10233.36	9491.40	8752.23
Sum	5869	5481	4991	7435	3977	20261.70	19387.35	18894.15

Table 2 Changes of patch number in Gangdong-Gu (1988—1999)

Patch size, hm^2	No. of patch					Total area		
	Sep. 1988	Sep. 1992	Sep. 1994	Sep. 1996	Sep. 1999	Sep. 1988	Sep. 1992	Sep. 1994
Less than 1	285	279	234	365	178	65.89	56.77	50.85
1—2	25	23	13	28	32	35.21	32.49	19.62
2—5	19	16	16	16	29	58.95	47.66	48.28
5—10	6	5	6	7	10	42.93	36.09	40.41
10—50	11	5	10	8	15	219.42	110.70	233.31
50—100	2	3	3	4		135.82	225.63	193.38
100—1000	1	1	0	0	0	104.67	135.24	0.00
More than 1000	0	0	0	0	0	0.00	0.00	0.00
Sum	349	332	282	428	264	662.89	644.58	588.84

Length and shape of perimeter may give an ecological role of population distribution and migration route for animal and plant in and out of patch(Forman, 1995). To compare the pattern of patch boundary of the total Seoul and Gandong-Gu, regression analysis between patch area and perimeter was carried out. High correlation coefficients show that perimeter is dependent on patch size in total Seoul and Gandong-Gu ($R^2 = 0.9305$ in Total Seoul, $R^2 = 0.8503$ in Gangdong-Gu). It means perimeter length is significantly related to patch area. These two indices (perimeter and area) are related to patch shape (boundary shape) concerning edge effect on fauna and flora in the landscape.

In this study, large patch has a higher shape index than that of small patch in the Gangdong-Gu. Besides residential area like large apartment complex and school area usually shows simple shape such as rectangle, patch shape of remnant forest and small mountain surrounding those land use shows more complicated. In natural ecosystems, when a patch is disturbed, the early successional species (i.e. herbaceous plants) often colonize from outer boundary (edge) to inner part of patch (Forman, 1995). These ecological processes make patch boundary to develop. In the case of vegetation, roadside vegetation such as saum and mantle communities (Forman, 1986) occurred in the boundary of forest patch(de Wall, 1994). In this case of urban vegetation, remnant forest patch may make a suitable site for naturalized plants invaded from outside of the patch.

2.2 Distribution of naturalized plants in urban landscape

We classified forest patch to 5 class by patch size. Table 3 shows the occurred patch size of *Robinia pseudoacacia* and *Eupatorium rugosum* (in 5 patch size classes, I to V). Patch number and shape index of patch also measured according to this class. Patch numbers of Class I and II are larger than other group, however, total area is relatively small. Shape index is higher in Class V patch that has large area (3.08). It means that Class V has large perimeter of patch. *Robinia pseudoacacia* was often occurred in Class IV (21.3%) and V (26.8%), and *Eupatorium rugosum* was founded in the Class V (27.1%). Moreover, occurrence of *Eupatorium rugosum* was identified in the patches with high shape index. Both species were often occurred in the same vegetation patch with Class V (20.6%).

Table 4 shows the occurrence of two naturalized species according to adjacent land use types (ALU) and dominant vegetation (DV). Road, cultivated lands with greenhouse and apartment block around green

space (or forest patch) were major 3 adjacent land use types that two species are often occurred. This table also shows major 3 ranks of dominant vegetation types of *Robinia pseudoacacia*, *Castanea crenata* and *Pinus rigida*. These results indicate that distribution and occurrence of two species is related to adjacent land use types and vegetation types.

The distribution type of *Robinia pseudoacacia* forest shows patchy dispersed pattern around road and lowland of mountains. In the past, *Robinia pseudoacacia* forest in lowland was a planted type that almost introduced for revegetation and soil rehabilitation after landscape deterioration. In recent, its area was extended to inner forest consisting of native species. *Eupatorium rugosum* often occurred in *Robinia pseudoacacia* forest of a certain population size. In this study, two species were often coexisted in the same habitat and distributed in forest patch disturbed by human impact. This result shows very similar trend to the report of NIER (NIER, 1996). Their distribution patterns were related to some landscape indices such as size (Class V, 10—50 hm^2) and complexity of patch shape.

Table 3 Occurred patch size of *Robinia pseudoacacia* and *Eupatorium rugosum* (in 5 patch size classes, I—V).

Area class	Total	Area of Rp.	Area of Er.
I(less than 1hm^2)	54.86	2.14(3.89%)	0.88(1.60%)
II(1—2hm^2)	42.08	0.99(2.35%)	2.45(5.83%)
III(2—5hm^2)	81.63	7.12(8.72%)	3.36(4.12%)
IV(5—10hm^2)	68.30	14.56(21.31%)	2.67(3.91%)
V(10—50hm^2)	381.11	102.13(26.80%)	103.23(27.09%)

Table 4 Relationship of the occurrence of two species and adjacent land use types of Class V

Area class	Area(hm^2)	Perimeter(m)	Shape index	Area of Rp.	Area of Er.
V	10.25	2439.01	2.15	5.43	8.63
V	13.45	2412.22	1.86	0.00	0.00
V	14.17	3398.72	2.55	5.96	5.76
V	15.31	3576.42	2.58	0.00	0.00
V	15.84	6130.15	4.34	0.00	0.00
V	17.86	4537.50	3.03	3.62	1.09
V	22.48	4274.21	2.54	5.50	10.19
V	22.65	5589.57	3.31	14.04	17.55
V	25.61	5132.53	2.86	8.51	7.76
V	27.88	3814.13	3.63	12.91	0.87
V	30.74	8042.46	1.85	9.92	13.87
V	34.47	7557.06	2.58	17.45	20.42
V	38.52	8165.83	3.71	0.00	0.00
V	43.33	12046.04	5.16	18.80	17.08
V	48.56	5694.36	2.31	0.00	0.00

Area of Rp. & Er.	ALU 1st	ALU 2nd	ALU 3rd	DV 1st	DV 2nd	DV 3rd
5.43	Road	Cult.	–	Rp	Ah	nur.
0.00	Forest	Road	House	Field	–	–
5.76	Cult.	Burial	–	–	–	–
0.00	Grass	House	Const.	Idle	Field	
0.00	Cult.	Rail	Forest	Grass 1	–	–
0.50	Cult.	Field	House	Quercus	Qa	Pr
5.46	Road	Field	Apart	Pr	Rp	Pk
13.17	Apart	Road	Edu.	Rp	Pt	–
6.77	Road	Apart	Comm.	Cc	Rp	–
0.75	Road	Cult.	Field	Rp	Pt	nur.
9.52	Road	–	–	Rp	Plant	Pk
16.59	Road	Orch.	–	Rp	Ah	Qa
0.00	Water	Sports	Mili.	Grass 2	Grass 3	Grass 1
14.63	Cult.	Burial	Reser.	Rp	Cc	Pr
0.00	Road	Indu.	Grass	Field	Grass 1	–

Land use type code; cult: cultivated land with greenhouse, grass: grassland, House: housing lot, apart: apartment block, comm: commercial area, indu: industrial area, edu: education facility, sports: large sports facilities, rail: railroad, const: construction site, burial: burial area, orch: orchard, mili: military installation area, reser: reservoir, water: water area. Vegetation type code; idle: idle land, grass 1: grassland with naturalized plants, grass 2: indegenous moist grassland, grass 3: indegenous dry grassland, plant: alien tree plantation without stratification, nur: nursery, Quercus: mixed forest of Quercus spp. Pk: Pinus koraiensis; Pr: Pinus rigida, Rp: Robinia pseudo-acasia, Cc: Castanea crenata, Ah: Alnus hirsuta, Qa: Quercus accutissima, Pt: Populus tomentiglandulosa, Er: Eupatorium rugosum. ALU: Adjacent of land use, DV: Dominant of vegetation

According to NIER(NIER, 1996), the percent of naturalized plant species was found in industrial complexes(36.1%). It followed by riverside and around the apartment, which were 34.7% and 29.6% respectively. Therefore, distribution patterns of these plants are significantly related to human impact. Result of our research was coincident with the previous report of NIER. Naturalized plants have influence to man and ecosystem health (NIER, 1996; Sun, 1997; Song , 1999). It had been known that *Ambrosia artemisiifolia* var. *elatior* and *Solidago altissima* were detrimental to human health and *Eupatorium rugosum* had a negative impact on natural ecosystem. Although there are many methods for controlling naturalized plants and invasive plants (Dodd , 1994), it is difficult to apply to them because chemical and physical methods may cause the second pollution on soil and other ecosystem. Biological control method relating to application of competitors is reasonable. However, it will take a long-term to control the naturalized plants by these methods. It has been known that many naturalized plants have negative effect on ecosystem health. However, we can apply ecological characteristics of the naturalized plants to disturb area such as arid land and steep slope as restoration materials (Song, 1999).

The result indicated that the ecosystem change is intense during the past ten years. This research examines the ecosystem change in two vast study sites to further understanding of regional scale processes.

Acknowledgements: Our thanks are due to The Urban Planning Bureau of Seoul Metropolitan Government for giving the valuable data and information for this research. This research is supported by colleagues from Institute of Landscape Ecology, Management and Planning (LEMP). This paper was presented at the 2nd IALE Asia-Pacific Regional Conference on Landscape Ecology, 2001 in Lanzhou, China.

References:

De Wall L C, Child L E, Wade P M *et al*., 1994. Ecology and management of invasive riverside plants[M]. New York: John Wiley & Sons. 217.

Dodd F S, de Wall L C, Wade P M, 1994. Control and management of *Heracleum mantegazzianum* (Giant Hogweed). In: Ecology and management of invasive riverside plants (De Wall, L.C., Child, L.E., Wade P.M. and Brock, J.H. ed.)[M]. New York: John Wiley & Sons. 111—126.

Forman R T T, 1995. Land Mosaics: The ecology of regions and landscapes[M]. Cambridge University Press. 635.

Forman R T T, M Godron, 1986. Landscape Ecology[M]. New York: John Wiley & Sons. 619.

Groves R H, J J Burdon, 1986. Ecology of biological invasion[M]. Cambridge University Press.

Hanssen L, L Farig, G Merriam, 1995. Mosaic landscapes and ecological processes[M]. Chapman & Hall. 356.

Hong S-K, 1999. Cause and consequence of landscape fragmentation and changing disturbance by socio-economic development in mountain landscape system of South Korea[J]. Journal of Environmental Science, 11: 181—187.

Hong S-K, I-J Song, W-S Choi, 2001. Theoretical comparison of modern and traditional urban plan: From an Asian landscape ecological planning perspective. In: Development of European Landscape(U. Mander, A. Printsmann and H. Palang ed.)[M] Publicationes Instituti Geographici Universitatis Tartuensis Vol. 92. 209—213.

Kim J-M, Y-J Yim, E-S Chun, 2000. Naturalized plants of Korea[M]. Science books. Seoul. 281 (in Korean).

NIER, 1995. Survey for ecological impact by naturalized organisms (I). National Institute of Environmental Research (NIER) No. 95-02-446 [R]. 215 (in Korean).

NIER, 1996. Survey for ecological impact by naturalized organisms (II). National Institute of Environmental Research (NIER) No. 96-03-474 [R]. 230 (in Korean).

Lee C-B, 1993. Illustrated flora of Korea[M]. Hyangmunsa. 990 (in Korean).

Lee E-K, 1998. Trend of forest fragmentation in the lower region of the Han River Basin[D]. Thesis of Master of Science, Seoul National University.

Ministry of Environment of Korea, 1997. An environmental white paper [R](in Korean).

Park S-H, 1995. Colored illustrations of naturalized plants of Korea[M]. Ilchokak. 371(in Korean).

Reed R A, J Johnson-Barnard, W L Baker, 1996. Fragmentation of a forested Rocky Mountain landscape, 1950—1993[J]. Biological Conservation, 75:267—277.

Song J-S, S-H An, 1999. Synecological study of the naturalized plant communities in old Andong City[J]. Korean Journal of Ecology, 22: 169—179 (in Korean).

Seoul Metropolitan Government, 2000. Biotope mapping and guideline for establishment of ecopolice in Seoul. 245p. + Biotope Map on CD-ROM (Machine readable data files)[E].

Suh M-H, Y-M Lee, J-H. Kil *et al*., 1997. Characteristics and distribution pattern of *Eupatorium rugosum* at Mt. Namsan in Seoul[J]. Korean Journal of Ecology, 20:285—291(in Korean).