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Distribution and Characteristics of Native and Exotic Plants on Cut Slopes and Rest Areas along Korean Highway Lines

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Vegetation surveys were performed at 45 plots along 10 highways cut slopes in South Korea. Total floral inventory, species richness and exotic plant percentage were obtained within each plot. Life history and life form of each species appeared were analyzed. Community types were classified using hierarchical cluster analysis and detrended correspondence analysis and non-metric multidimensional scaling were conducted from vegetation matrix. 292 species of vascular plants were discovered and the number of natives and exotics were 226 and 66, respectively. There were no significant differences of species richness and exotic plant percentage between cut slopes and rest areas. Hierarchical cluster analysis indicated five clear vegetation associations in cut slopes and rest areas. Detrended correspondence analysis indicated that species composition of total and native plants were similar along the highway cut slopes whereas exotic plants were distributed differentially along the highway cut slopes. In non-metric multidimensional scaling, the studied sites were more separated from each other on the basis of their species composition than the results of detrended correspondence analysis with respect to total, native and exotic plants. The both ordination represented that exotic plants have not been made uniform yet on cut slopes and rest areas by highway corridor in spite of diverse chronosequences after highway construction termination (1 to 22 years). This study showed that the distribution of species composition in exotic plants was different and localized on cut slopes and rest areas of highway in this representative peninsula area of North East Asia and the invasion of exotic plants can retard the process of plant species homogenization.

Key Words : Cut slope, Detrended correspondence analysis, Exotic plant, Highway, Non-metric multidimensional scaling

1. Introduction

The cut slope is a very common landscape along highway lines in South Korea. This artificial landform has been increased by highway expansion since urban and industrial development. Indiscreet and linear-favored highway constructions have destroyed many edge regions in mountainous areas. As a result, these lead to two facing cut slopes. These fragments have characteristic floristic layers and artificial revegetation, including spraying seed mixture, has contributed to this floral trend. The cut slopes belong to roadsides that are intensively managed strip adjacent to roads.

Natural plant communities are usually recognizable in roadsides[1]. It is an ever-increasing theme whether natural communities are degraded or not on highway cut slopes of a representative peninsula.

Exotic plant dispersal from this artificial seed bank has made surrounding vegetation change. Recently, many exotic plants also have invaded into these fragments. It is presumed that anthropochory through transportation vehicles plays an important role in colonization of these cut slopes by exotic plants and these areas have a function as biological pollution source into adjacent other areas[2]. Nonindigenous species including exotic plants go through transitions (transportation, release, establishment and spread) in invasion process. Previous publications on exotic plants have concentrated on the later transitions whereas the early transitions are the most important for management and policy towards exotic plants because they are the stages where exotic plants can be prevented[3]. Once exotic plants colonize highway cut slopes, the plants

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can spread along the highway by vehicles[2]. Hence, highway cut slopes can be ideal places for studying transport and release of exotic plants. Many papers related to highway have treated the measurements of heavy metals in soils and vegetation, so far[4~6].

Ruderal urban vegetation can include new invading species or allergen species, as well as vectors of disease, or insect host species that can cause damage to cultivated plants[7]. Many exotic plants on highway cut slopes with ruderal urban vegetation may have bad effects on public health due to allergies and scarce aesthetic values. Many literatures confirm that exotic species have an unpredictable impact on human health and ecosystems[8]. However, there are few studies about vegetation distribution on highway lines.

The spread along highways or roads is an important factor on the arrival and establishment of exotic species. Peninsulas provide a valuable environment for testing the importance of roads in the spread of exotics, because they provide discrete, bounded areas into which roads can act as corridors[9]. Tikka *et al.* found that grassland plants use road and railway corridors for dispersal in central Finland[10]. It is hypothesized that if the spread of exotics along highways arose and expanded, species composition of highway cut slopes should form a spatially homogeneous pattern. Rest areas are places where drivers can park for refreshment. Rest areas have generally spaces with grasses and trees. In Korea, rest areas are connected linearly with cut slopes and they may reflect on spread processes between cut slopes. Therefore, highway managers and urban ecologists are interested in comparing rest areas and cut slopes.

The goal of this study is to compare floral difference among cut slopes and rest areas on Korean peninsula, examine whether the spatial patterns of native and exotic species are different on this representative peninsula and test the hypothesis that species composition of highway cut slopes is more varied by native and exotic species spread through highway corridor or not.

2. Materials and Methods

2.1. Sites

The study areas are on southern Korean peninsula and located in middle latitudes of the Northern Hemisphere (between 38°21'N, 126°11'E and 33°12'N, 129°52'E; Fig. 1). The cut slope is defined as the sloped mountainous areas beyond the highway road that are sectioned by highway constructions. The rest areas are defined as parking lots and around open lands for highway users. I selected the cut slopes for studies along 10 highway lines: Kyoungboo, Joongboo, the second Kyoungin, Gooma, Honam, Yangsan-Goopo, Joongang, 88, Joungdong and Donghae (Fig. 1). The second Kyoungin, 88 and Joungdong highway are perpendicular to north to south direction of Korean peninsula. Other seven highways parallel north to south direction of Korean peninsula. All cut slopes studied were 39 sites (Table 1). The characteristics of cut slopes were given in Table 1.

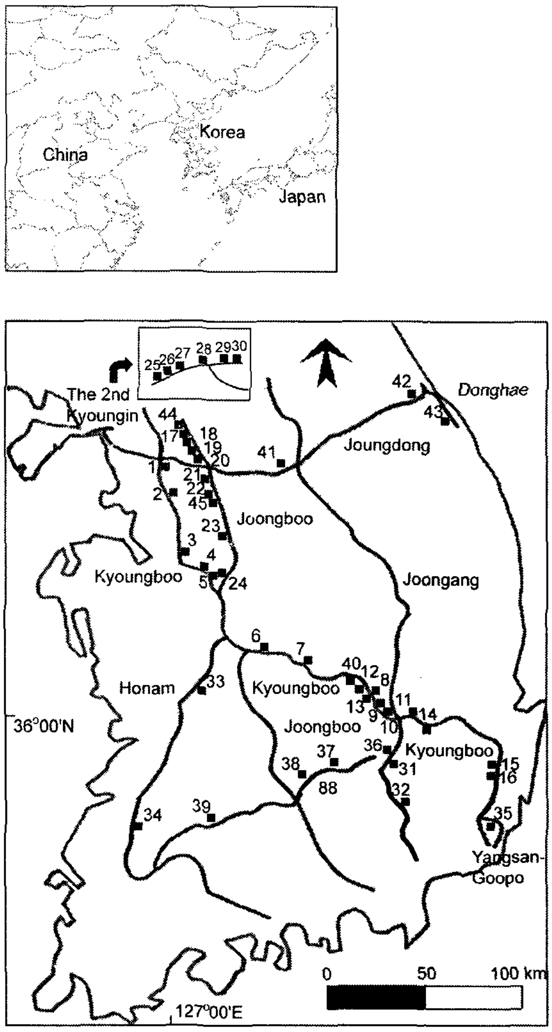

Fig. 1. Location map of plots. Numerals correspond to the number of cut slope stations in Table 1.

Table 1. Characteristics of cut slopes and rest areas studied

# of cut slope stations or rest areas	Name of highway line	Direction to Korean peninsula/ name of rest areas*	City of starting point	Distance from starting point (km)	Construction completion year
1	Kyoungboo	north-south	Seoul	34.0	1970
2	Kyoungboo	north-south	Seoul	69.0	1970
3	Kyoungboo	south-east	Seoul	98.0	1970
4	Kyoungboo	southeast-northwest	Seoul	115.5	1970
5	Kyoungboo	north-south	Seoul	123.0	1970
6	Kyoungboo	south-east	Seoul	168.0	1970
7	Kyoungboo	south-east	Seoul	186.0	1970
8	Kyoungboo	south-east	Seoul	237.2	1970
9	Kyoungboo	south-east	Seoul	259.2	1970
10	Kyoungboo	south-east	Seoul	272.0	1970
11	Kyoungboo	southeast-northwest	Seoul	311.0	1970
12	Kyoungboo	east-west	Seoul	230.0	1970
13	Kyoungboo	north-south	Seoul	257.0	1970
14	Kyoungboo	north-east	Seoul	318.0	1970
15	Kyoungboo	south-west	Seoul	371.0	1970
16	Kyoungboo	south-west	Seoul	380.0	1970
17	Joongboo	south-east	Hanam	18.0	1987
18	Joongboo	south-east	Hanam	25.0	1987
19	Joongboo	south-east	Hanam	28.0	1987
20	Joongboo	south-east	Hanam	37.5	1987
21	Joongboo	north-south	Hanam	46.2	1987
22	Joongboo	south-east	Hanam	65.1	1987
23	Joongboo	south-east	Hanam	91.0	1987
24	Joongboo	north-south	Hanam	111.0	1987
25	The 2nd Kyoungin	south-east	Incheon	2.0	1994
26	The 2nd Kyoungin	east-west	Incheon	3.2	1994
27	The 2nd Kyoungin	east-west	Incheon	5.2	1994
28	The 2nd Kyoungin	east-west	Incheon	13.3	1994
29	The 2nd Kyoungin	south-east	Incheon	23.5	1994
30	The 2nd Kyoungin	south-east	Incheon	29.5	1994
31	Gooma	south-east	Daegu	24.0	1977
32	Gooma	south-west	Daegu	52.5	1977
33	Honam	southwest-northeast	Daejun	44.5	1973
34	Honam	south-north	Daejun	143.5	1973
35	Yangsan-Goopo	south-west	Yangsan	10.0	1996
36	Joongang	north-east	Daegu	25.8	2001
37	88	south-west	Daegu	36.0	1984
38	88	south-west	Daegu	57.0	1984
39	88	south-west	Daegu	174.5	1984
40	Kyoungboo	Chupoongryung*	Seoul	214.0	1970
41	Joungdong	Moonmag*	Suwon	72.0	1975
42	Joungdong	Daegwanryoung*	Youngin	181.0	1975
43	Donghae	Donghae*	Kangreung	36.1	1975
44	Joongboo	Dongeseoul*	Hanam	0.2	1987
45	Joongboo	Joongboo*	Hanam	65.2	1987

*Rest areas are from 40 to 45.

All cut slopes were approximately 139 m wide and 26 m long adjacent to each highway and were above the highway. Yearly vehicular traffic on Kyoungboo highway line, Joongboo highway line, the second Kyoungin highway line, Gooma highway line, Honam highway line, Joongang highway line, 88 highway line, Joungdong highway line and Donghae highway line during 2002 were 273,603,000, 60,982,000, 21,641,000, 21,592, 000, 51,374,000, 32,449,000 (2001 year), 14,554,000 (2001 year), 151,877,000 and 17,659,000, respectively[11]. Chupoongryung, Moonmag, Daegwanryoung, Donghae, Dongseoul and Joongboo, six rest areas between inter-highways, were surveyed for control plots (Table 1). These areas are sometimes mown, burnt or subject to selective weeding at irregular intervals.

2.2. Vegetation analysis

Vegetation surveys were conducted at 39 highway cut slopes and 6 rest areas. I selected the sites by driving along the highways in both bounds directions and stopping to find the locations where the vegetation extended about 70 m from the highway. The distances between sites were not considered due to the sparsity of study sites. The distance from starting point about each location was measured by highway kilometrage markers. A total of 45 locations were chosen on a subjectively selected, uniform vegetation stand parallel to the highway from highway curb (Fig. 1). At each location, I established a transect perpendicular to the highway, along which a vegetation survey was performed as close to mid-slope as possible at distance of about 35 m from the highway edge to minimize the influence of disturbed conditions prevailing at the upper and lower ends of each cut slope. The upper ends of highway cut slopes were easily identified from alterations in vegetation cover and height and from tree canopy presence[12]. Two or three plots were established along a transect running parallel to the highway to suit the varied width of each site. Plot sizes were fixed at 16 m^2 (4 m × 4 m) for grassland and 100 m^2 (25 m × 4 m) for woody vegetation in accordance with Bredenkamp and Theron[13]. The vegetation data from two or three plots of each location were averaged. The sampling was performed three times in spring, summer and fall periods (March to October) when the vegetation reached at the peaks from 1999 to 2003. All species of vascular plants in plots were recorded. Taxa names conformed to those of Lee[14] and Park[15,16]. Phytosociological units followed the system of Kim et al.[17].

The presence of all grass species, including trees and shrubs, was recorded to collect total flora inventories in each plot by random walking along edge line and diagonal axis repeatedly. I stopped searching when I had not found any more new species. Species richness was defined as the total species number found in each plot. All plants were classified into native and exotic species. Exotic species were defined as not indigenous in Korea, introduced intentionally or unintentionally, and having their origins outside of Korea[18]. Exotic species were further divided into those that have invaded and those that have been deliberately introduced. Exotic plant percentage was calculated as the ratio of the number of exotic species to the total number of species within each plot. Life history of each species was also categorized into three groups: annual, biennial and perennial. The ratio of the number of annual, biennial and perennial species to the total number of species in the vegetation plot (1 m^2) was calculated as follows:

Ratio of annual, biennial or perennial species number to total species number = (species number of annual, biennial or perennial) / (total species number)

Life form of each species was classified by the following according to Raunkiaer methods : Megaphanerophyte and Mesophanerophyte(MM), Microphanerophyte (M), Nanophanerophyte (N), Chamaephyte (Ch), Hemicryptophyte (H), Geophyte (G), Therophyte (Th), Helophyte (He) and Epiphyte (E)[19].

2.3. Data analysis

Wilcoxon two sample tests were employed to compare the differences of species richness and exotic plant percentage between plots of cut slopes and rest areas and among plots of cut slopes because the distribution was not normalized. Wilcoxon two sample tests were carried out using SAS program Ver. 8.02.

2.4. Community classification

I chose a hierarchical, agglomerative technique to produce dendrograms using Ward's method for classifying plots[20]. Plot classification began with the construction of a plot-by-plot matrix using dissimilarity measures. Ward's method is advocated as a general-purpose linkage method that minimizes distortions in the clustering space[21]. The forty-five plots were described by the presence/absence of the 291 species recorded in study sites. Plant communities were named after dominant species, followed by subdominant species, in plots[22]. The domination degree of species was estimated from the extent of their frequency on the plots.

2.5. Ordination analysis

Ordination is defined as a method that arranges site points based on similarities in species composition in a continuum such that points that are close together correspond to sites that are similar in species composition, and points that are far apart correspond to sites that are dissimilar[23]. The floristic similarity of the plots along cut slopes and rest areas was investigated by means of detrended correspondence analysis and non-metric multidimensional scaling[24,25]. The two ordination analyses were compared to show the variation degree of species diversity change from plot to plot of the cut slopes and rest areas along Korean highway lines. These both analyses were based on species frequencies in the plots and an original matrix was made. The species composition variations of natives, exotics and total plants (natives and exotics) were also analyzed separately by DCA to test whether the vegetation type varied along the highway lines. Detrended correspondence analysis summarizes the variability of the data by producing a two-dimensional ordination space in which similar plots are close together and dissimilar entities are far apart. Non-metric multidimensional scaling (NMDS) can successfully recover gradients of high beta diversity as inter-habitat diversity[26]. Non-metric multidimensional scaling (NMDS) was based on Sorensen (Bray-Curtis) similarity index from the original matrix. Stress is a measure that reflects the degree of deviation of NMDS distances from original matrix distances. The stress values were reported. The NMDS scree plots were examined to select for the final number of dimensions in the NMDS run. The data set was performed using PC-ORD program[21]. In both analyses, default settings were used[21]. Biplot scores of each plot calculated by PC-ORD were used to produce plot scatter diagrams.

3. Results

3.1. Total flora and exotic plants

The flora included 292 species of vascular plants; the number of natives and exotics were 226 and 66, respectively. Exotic plant species accounted for 29% of cut slope flora on Korean highway lines. Exotic species that have been deliberately introduced were seven: *Amorpha fruticosa* L., *Dactylis glomerata* L., *Eragrostis curvula* Nees, *Festuca arundinacea* Schreb., *Lolium perenne* L., *Trifolium hybridum* L., *Trifolium repens* L. The seven species covered 11% of total number of exotic species. *Artemisia princes* var. *orientalis* (Pampan.) Hara, a native plant,appeared most frequently as 97% through all the plots. It was the most dominant species in cut slopes and rest areas (Table 2). *Oenothera biennis* L., *Erigeron annuus* (L.) Pers., *Lactuca indica* var. *laciniata* (O. Kuntze) Hara, *Miscanthus sinensis* Anderss., *Setaria viridis* (L.) Beauv., *Conyza canadensis* (L.) Cronq. and *Chenopodium ficifolium* Smith appeared on the decreasing frequency order with the value of over 50% (Table 2). Many species showed low frequency: 84% of the total number of species represented less than 20% frequency.

3.2. Species richness and exotic plant percentage

The mean species richness of cut slopes and rest areas were 19.9 and 31.0, respectively. From the result of Wilcoxon two sample tests, species richness of rest areas was significantly greater than that of highway cut slopes ($P < 0.05$). Species richness among cut slopes was not significantly different each other (Wilcoxon two sample tests; $P > 0.05$). The mean exotic plant percentages of cut slopes and rest areas were 23.3 and 10.5, respectively. Exotic plant percentage of highway cut slopes was significantly greater than that of rest areas ($P < 0.05$). The exotic plant percentage of cut slopes on Kyoungboo line was significantly greater than that of cut slopes on the 2nd Kyoungin line (Wilcoxon two sample test; $P < 0.05$). The exotic plant percentage of cut slopes on Joongboo line was significantly greater than that of cut slopes on the 2nd Kyoungin line ($P < 0.05$). Exotic plant percentages among any other cut slopes were not significantly different ($P > 0.05$).

3.3. Life history and life form types

As analysis results of life history pattern in all species recorded, percentage of annual, biennial and perennial were 27.1, 11.6 and 37.0%, respectively. Percentage of tree and vine among all species appeared was 22.3 and 2.1%, respectively. The ratio of the annual spe-

Table 2. Species that appeared at more than 20% of relative frequency between plots

Scientific name	Relative frequency (%)	Life form	Life history
Artemisia princes var. *orientalis*	97	H[c]	p[j]
Oenothera biennia[a]	80	H	b[k]
Erigeron annuus	73	H	b
Lactic indica var. *laciniata*	73	H	b
Miscanthus sinensis	60	H	p
Setaria viridis	57	H	b
Conyza canadensis[a]	53	H	b
Chenopodium ficifolium[a]	51	Th[d]	a[l]
Robinia pseudoacacia[a]	48	MM[e]	tree
Persicaria blumei	48	Th	a
Taraxacum officinale[a]	44	H	p
Humulus japonicus	44	Th	a
Eragrostis curvula[b]	42	H	p
Ambrosia artemisiaefolia[a]	40	Th	a
Digitaria sanguinalis	40	Th	a
Pueraria thunbergiana	40	E[f]	vine
Rumex crispus[a]	37	H	p
Lepidium virginicum[a]	37	H	b
Artemisia capillaries	35	H	p
Stellaria aquatica	35	H	p
Conyza bonariensis[a]	33	H	b
Kummerowia striata	31	Th	a
Bidens frondosa[a]	28	Th	a
Trifolium repens[b]	28	H	p
Echinochloa crusgalli	28	Th	a
Aster yomena	28	H	p
Amorpha fruticosa	26	M[g]	tree
Commelina communis	26	Th	a
Bidens bipinnata	26	Th	a
Rubus parvifolius	26	H	tree
Lespedeza bicolor	26	M	tree
Populus tomentiglandulosa	26	MM	tree
Rubus crataegifolius	24	H	tree
Plantago asiatica	24	H	p
Oxalis corniculata	22	G[h]	p
Chrysanthemum boreale	22	H	p
Themeda triandra var. *japonica*	22	H	p
Viola mandshurica	22	H	p
Cyperus microiria	20	Th	a
Clematis apiifolia	20	E	vine
Portulaca oleracea	20	Th	a
Melica onoei	20	H	p
Pinus densiflora	20	MM	tree
Rosa multiflora	20	N[i]	tree

[a]Exotic species invaded; [b]Exotic species deliberately introduced; [c]Hemicryptophyte;
[d]Therophyte; [e]Megaphanerophyte and Mesophanerophyte; [f]Epiphyte;
[g]Microphanerophyte; [h]Geophyte; [i]Nanophanerophyte; [j]Perrennial; [k]Biennial; [l]Annual.

cies number to the total species number of highway cut slopes was not significantly different with that of rest areas (Wilcoxon two sample test; $P > 0.05$). The ratio of the biennial and perennial species numbers to the total species number of highway cut slopes was not significantly different with those of rest areas ($P > 0.05$). The ratio of the annual, biennial and perennial species numbers to the total species number among highway cut slopes did not generally tend to show significant differences. However, the ratio of the annual species number to the total species number between Kyoungboo and the 2nd Kyoungin highway line and the ratio of the perennial species number to the total species number between Joongboo and the 2nd Kyoungin highway line were significantly different ($P < 0.05$).

Hemicryptophytes of life form types were largest when all species occurred were pooled (45%) and therophytes were the second largest type of life form (26%). In case of exotic plants, hemicryptophyte and therophyte accounted for 52 and 42%, respectively, of all exotic plants recorded. Hemicryptophyte, therophyte and mega-and mesophanerophyte covered 43, 22 and 10%, respectively, relating to all native plants.

3.4. Community classification

Ward's clustering was used to produce classification dendrograms. Five major species group were distinct from hierarchical cluster analysis. These groups represented clear five communities at the 18.7 level of similarity (Fig. 2). These groups represented this following: (i) *Robinia pseudoacacia-Artemisia princeps* var. *orientalis* (group 1), (ii) *Rubus parvifolius- Artemisia princeps* var. *orientalis* (group 2), (iii) *Artemisia princeps* var. *orientalis-Erigeron annuus* (group 3), (iv) *Artemisia princeps* var. *orientalis-Lactuca indica* var. *laciniata* (group 4), (v) *Lespedeza bicolor-Eragrostis curvula* (group 5) (Fig. 2). *A. princeps* var. *orientalis* appeared in all five groups. *Robinia pseudoacacia* L. and *Lespedeza bicolor* Turcz were representative tree species on cut slopes and rest areas as classified in groups. *E. annuus* and *E. curvula*, exotic plants, appeared in group names. Plots of rest areas corresponded to group 3 and group 4 (Fig. 2).

3.5. Ordination

Detrended correspondence analysis (DCA) of total plants including native and exotic plants showed that

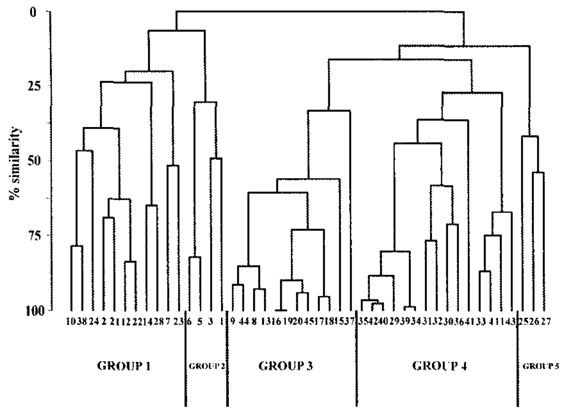

Fig. 2. Dendrograms using presence/absence species data for every plot and Ward's clustering technique. Five vegetation groups are as follows: Group 1 (*Robinia pseudoacacia-Artemisia princeps* var. *orientalis*), Group 2 (*Rubus parvifolius- Artemisia princeps* var. *orientalis*), Group 3 (*Artemisia princeps* var. *orientalis-Erigeron annuus*), Group 4 (*Artemisia princeps* var. *orientalis-Lactuca indica* var. *laciniata*), Group 5 (*Lespedeza bicolor-Eragrostis curvula*). Numerals on the first axis correspond to the number of cut slope stations in Table 1.

the composition of plants in highway cut slopes was similar whereas it was different from the composition of plants in rest areas (Fig. 3a). When all plots were ordered on Axis I, group 4 of hierarchical cluster analysis was segregated on the upper and right corner from all the others (Figs. 2 and 3a). In the case of DCA of native plants, the vegetation composition of highway cut slopes was analogous and it was dissimilar to the vegetation composition of rest areas except Dongseoul and Joongboo rest areas (Fig. 3b). The ordination of exotic plants indicated that the species composition of plots is highly variated in the ordination space (Fig. 3c).

A solution with two dimensions was achieved with non-metric multidimensional scaling (NMDS) ordination. The results of non-metric multidimensional scaling showed more segregated patterns than those of DCA (Figs. 3 and 4). The studied plots with only exotic plants by NMDS were more spread than those by DCA (Figs.3c and 4c).

The two ordinations showed that the species composition of highway cut slopes were significantly different from that of rest areas but the exotic species composition was diverse throughout the highway cut slopes and rest areas.

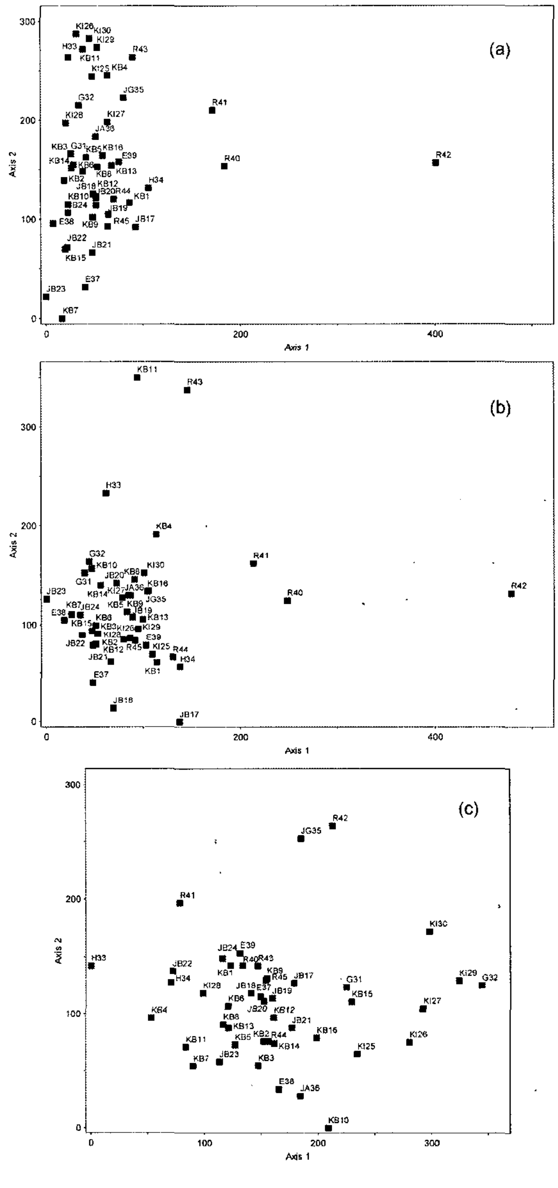

Fig. 3. Scatter diagram of the 45 plots with total plants (a), native plants (b) and exotic plants (c) according to the first two axes of a detrended correspondence analysis. KB1- KB16: plots of Kyoungboo highway line; JB17-JB24: plots of Joongboo highway lines; KI25-KI30: plots of the 2nd Kyoungin highway line; G31-G32: plots of Gooma highway line; H33-H34: plots of Honam highway line; JG35: a plot of Yangsan-Goopo highway line; JA36: a plot of Joongang highway line; E37-E39: plots of 88 highway line; R40-R45: plots of rest areas.

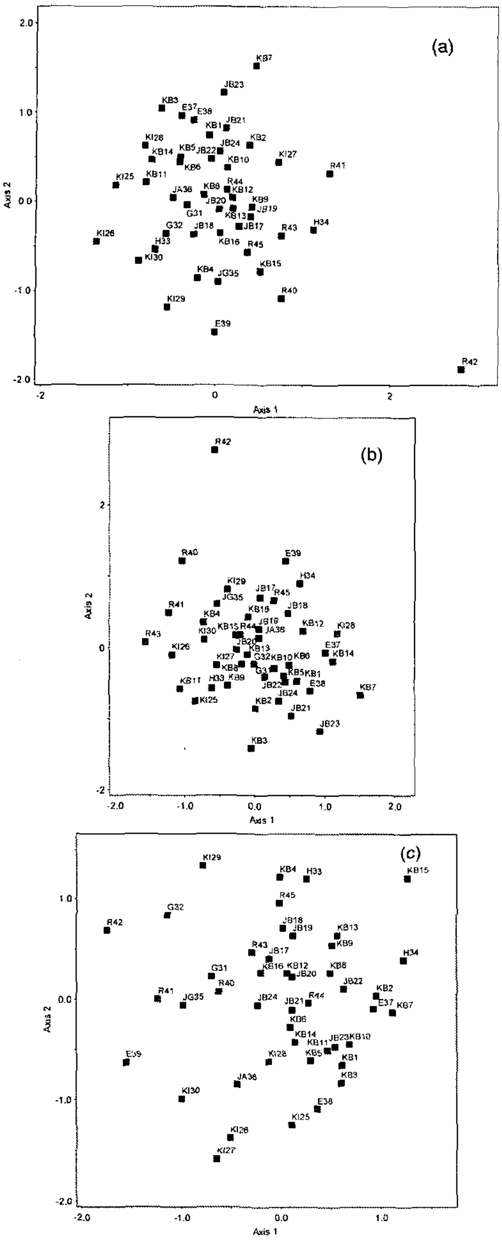

Fig. 4. Scatter diagram of the 45 plots with total plants (a), native plants (b) and exotic plants (c) according to the first two axes of a non-metric multidimensional scaling. The raw values of site scores are used in this scaling. Stress level: (a) 27.1, (b) 26.0, (c) 27.2. KB1- KB16: plots of Kyoungboo highway line; JB17-JB24: plots of Joongboo highway lines; KI25-KI30: plots of the 2nd Kyoungin highway line; G31-G32: plots of Gooma highway line; H33-H34: plots of Honam highway line; JG35: a plot of Yangsan-Goopo highway line; JA36: a plot of Joongang highway line; E37-E39: plots of 88 highway line; R40-R45: plots of rest areas.

4. Discussion

Approximately 8% (292/3657) of the plant species recorded in all over South Korea were found in this inventory on cut slopes of highway lines. Thus, cut slopes of highway lines are supposed to provide diverse habitats in South Korea. The structure of landscape surrounding the cut slopes consisted of mainly mountains and hills. The greater vegetation diversity on slopes above roads reflects great variety of microhabitats where strike and dip of the rock outcrops, rates of weathering and the presence of seepage strongly influence plant distribution[27]. The highway cut slopes have been revegetated with the introduced species. These introduced species are generally exotic species that are not indigenous in Korea, introduced intentionally or unintentionally, and have their origins outside of Korea as a previous definition. The deliberately introduced species for revegetation measures are mostly *F. arundinacea*, *E. curvula*, *L. perenne*, *D. glomerata*, and *Poa pratensis* L[28]. They produced a dense sward in study sites. Four species of these were recorded on the present study at the relative frequency of 17%, 42%, 4%, and 15%, respectively whereas *P. pratensis* did not appeared (Table 2). Only *E. curvula*of the introduced species is native to South Africa but other three species (*F. arundinacea*, *L. perenne* and *D. glomerata*) are native to Europe. Highway cut slopes are very scarce in moisture due to openness to light. Therefore, *E. curvula*, a warm season grass, seems to grow better and frequently on cut slopes of highway lines. The number of exotic plants recorded in Korea is 281 taxa until 2002[29]. About 22% (64/281) of the exotic species of plants found in South Korea was found on these cut slopes of highway lines.

Species richness of rest areas was significantly higher than that of highway cut slopes. Much dispersal of plants by human visiting to rest areas may cause species richness to increase. *A. princeps* var. *orientalis* appeared in all groups from hierarchical cluster analysis. This species is known to grow well in disturbed areas and is presumed to be a keystone species to stabilize the cut slopes on the highway lines.

The results of this study support that the distribution of annual, biennial and perennial on highway cut slopes and rest areas are statistically similar. This phenomenon can be explained by approximate succession on highway surrounding ecosystem. Excessive disturbances and management on highway slopes might make slow vegetation development. This study demonstrated that hemicryptophytes and therophytes predominate on highway cut slopes. Despite therophytes are typical of disturbance sites[30], this study supports that hemicryptophytes contribute strongly to plant establishment on highway cut slopes. The ratio of therophytes to hemicryptophytes of Korean highway cut slopes (0.58) was less than that of European urban flora (0.93 to 2.95)[31]. Hemicryptophytes are generally herbaceous perennials. It is presumed that herbaceous perennials have been increased on highway cut slopes through corridor pathways. Although Ullmann and Heindl found that most of the roadside plant groups in temperate Europe lacked definite associations,[32] this study showed that in spite of polluted and disturbed condition of highway cut slopes, plant species on highway cut slopes of a representative peninsula can form distinctive plant communities.

The major damage causing factors of elements associated with vegetation development along highway lines are deicing salt and biotic factors such insects and fungi[33]. Mowing, commonly used as a management technique in highway cut slopes, could have impacts on vegetation development. Mowing, automobile accident, construction and emergency stops may cause roadside plants to bolt earlier, which results in a temporally unpredictable environment to plants[34]. Vehicles on highways contribute to plant species dispersal and consequently affect the biogeography and species composition[35]. Thus, another factors correlated with vegetation development along highways lines as biological pollutions are exotic plant invasion as this study. In particular, controlling exotic flora along highway cut slopes is very important, especially where highways border areas that are vulnerable to invasion by exotic plants.

Detrended correspondence analysis using only exotic plants showed that all plots were clearly dispersed in ordination space because their species composition were highly divergent (Fig. 3c). The fact illustrates species variability of exotic plant distribution on the cut slopes of highway lines. This also represents that exotic plants invade through diverse routes and they have been not made uniform yet on cut slopes and rest areas by highway corridor. Furthermore, non-metric multidimensional scaling gave more separated results of highway cut slopes with exotic plants. The results reflect more variation in exotic species composition. The local physiographic changes are reported to prevent migration along highway corridor from being a long-distance process[36]. Few species are known to have successfully spread over 1 km because of roads[2]. The distribution of peninsula flora is supposed to be different, compared to continent flora[37]. The result of this study does not support to the idea that highways act as corridors for the flow of exotic plants on the typical peninsula as the study of Harrison et al.[9] while the clustering of native plants in the ordination space of this study shows function of highway corridors. Ruderal vegetation becomes increasingly uniform from decrease in species diversity[38]. It is supposed that it needs to take a longer time for exotic plants to be in an even distribution like native plants in this study, so that distribution of exotic plants may increase with time. The dissimilar spatial pattern of exotic plants on highway cut slopes is not due to variation in the diversity or quality of habitats because environment of cut slopes on the Korean highways are very similar. From this study, it is recommended that management of exotic plants on highway cut slopes of this representative peninsula be conducted for the focus of specific exotic species on a local scale, not on the basis of whole exotic species.

The roles of highway vegetation are utility, safety, and beauty. The vegetation structure of cut slopes could also stabilize highway slopes. Highway verges including slopes can be favorable places to bird communities if they complement habitats similar to habitats adjacent habitats[39]. Species diversification and removal of exotic plants are necessary measures for highway cut slopes. Many appropriate measures such as minimizing the soil depth of highway cut slopes, using coarse, infertile soil as cut slope fills to create a poor seedbed for exotic species and reestablishing native vegetation along highway cut slopes after construction[12]. It is desirable that the scenery of the roadsides is in harmony with landscape around as well as emphasizing the regional characteristics, also giving friendly and comfortable image to drivers and nearby residents[40]. The use of native plant materials results in lower water and maintenance requirements[41]. Thus, native plant should be used as restoring highway cut slopes with control of exotic plants and the potential use of native plants should be planned in conservation programs of highway cut slopes. Planting native trees adaptable to these cut slopes after mowing exotic weeds is considered to be an effective measure.

5. Conclusions

The exotic plants have been monitored nationally up to now in Korea[42]. However, the specific research and assessment of exotic plants according to kinds of ecosystem are rare. This study demonstrated that plant species clearly made up plant communities on these disturbed area but exotic plants invaded on highway cut slopes of representative peninsula ecosystem in Korea. Both detrended correspondence analysis and non-metric multidimensional scaling showed that exotic plants were distributed diversely and locally on spatial scale of the peninsula. From conservation viewpoints of habitats on highway slopes, it is recommended that removal measures of exotic plants be conducted differentially on regional scale, relating to exotic species.

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References

1) Forman R. T. T., Sperling D., Bissonette J. A., Clevenger A. P., Cutshall C. D., Dale V. H., Fahrig L., France R., Goldman C. R., Heanue K., Jones J. A., Swanson F. J., Turrentine T. C., 2003, Road ecology: Science and solutions, Island Press, 424pp.
2) Forman R. T. T., Alexander L. E., 1998, Roads and their major ecological effects, Annu. Rev. Ecol. S., 29, 207-231.
3) Kolar C. S., Lodge D. M., 2001, Progress in invasion biology: predicting invaders. Trends Ecol. Evol., 16, 199-204.
4) Ward N. I., Reeves R. D., Brooks R. R., 1975, Lead in soil and vegetation along a New Zealand state highway with low traffic volume, Environ. Pollut., 9, 243-251.
5) Robel R. J., Howard C. A., Udevitz M. S., Curnutte B. Jr., 1981, Lead contamination in vegetation, cattle dung, and dung beetle near an interstate highway, Kansas, Environ. Entomol., 10, 262-263.
6) Gratani L., Taglioni S., Crescente M. F., 1992, The accumulation of lead in agricultural soil and vegetation along a highway, Chemosphere, 24, 941-949.
7) Franceschi E. A., 1996, The ruderal vegetation of Rosario City, Argentina, Landscape Urban Plan., 34, 11-18.
8) Pimentel D., 2002, Biological invasions:Economic and environmental costs of alien plant, animal, and microbe species, CRC Press, 384pp.
9) Harrison S., Hohn C., Ratay S., 2002, Distribution of exotic plants along roads in a peninsular nature reserve, Biol. Invasions, 4, 425-430.
10) Tikka P. M., Hgmander H., Koski P. S., 2001, Road and railway verges serve as dispersal corridors for grassland plants, Landsc. Ecol., 16, 659-666.
11) KHC (Korea Highway Corporation), 2004, Korean highway statistics. Korea Highway Corporation, 20pp.
12) Gelbard J. L., Belnap J., 2003, Roads as conduits for exotic plant invasions in a semiarid landscape, Conserv. Biol., 17, 420-432.
13) Bredenkamp G. J., Theron G. K., 1978, A synecological account of the Suikerbosrand Nature Reserve. I. the phytosociology of the Witwatersrand geological system, Bothalia, 12, 513-529.
14) Lee T. B., 1985, Illustrated flora of Korea, Hyangmunsa, 990pp.
15) Park S. H., 1995, Colored illustrations of naturalized plants of Korea, Ilchokak, 371pp.
16) Park S. H., 2001, Colored illustrations of naturalized plants of Korea. Appendix, Ilchokak, 178pp.
17) Kim J. M., Kim C. S., Park B. G., 1987, Survey method of vegetation. Ilshinsa, 170pp.
18) Kim K. D., 2005, Invasive plants on disturbed Korean sand dunes. Estuar. Coast. Shelf Sci., 62, 353-364.

19) Raunkiaer C., 1934, The life forms of plants and statistical plant geography, Clarendon Press, 632pp.
20) van Tongeren O. F. R., 1995, Cluster analysis. In Data analysis in community and landscape ecology (Jongman R. H. G., ter Braak C. J. F., van Tongeren O. F. R., eds.). Cambridge University Press, pp. 174-212.
21) McCune B., Mefford M. J., 1999, Multivariate analysis of ecological data. version 4.27, MjM Software, 237pp.
22) Kim K. D., Lee E. J., Cho K. H., 2004, The plant community of Nanjido, a representative nonsanitary landfill in South Korea: Implications for restoration alternatives, Water Air Soil Poll., 154, 67-185.
23) Jongman R. H. G., ter Braak C. J. F., van Tongeren O. F. R., 1995, Data analysis in community and landscape ecology, Cambridge University Press, 299pp.
24) Hill M. O., 1979, DECORANA-A FORTRAN program for detrended correspondence analysis and reciprocal averaging, Cornell University Press, 52pp.
25) Kenkel N. C., Orloci L., 1986, Applying metric and nonmetric multidimensional scaling to ecological studies: some new results, Ecology, 67, 919-928.
26) Minchin P. R., 1987, An evaluation of the relative robustness of techniques for ecological ordination, Vegetatio, 69, 89-107.
27) Greller A. M., 1974, Vegetation of roadcut slopes in the Tundra of Rocky Mountain National Park, Colorado, Biol. Conserv., 6, 84-93.
28) Woo B. M., Kim B. Y., Cho Y. C., Jeon G. S., 1996, Analysis of growth characteristics of he introduced species revegetated on the highway cut-slopes, Korea Inst. Landsc. Architect, 26, 12-20.
29) Kil J. H., Shim K. C., Park S. H., Koh K. S., Suh M. H., Ku Y. B., Suh S. U., Oh H. K., Kong H. Y., 2004, Distribution of naturalized alien plants in South Korea, Weed Technol., 18, 1493-1495.
30) Armesto J. J., Pickett S. T. A., 1985, Experiments on disturbance in old-field plant communities: Impact on species richness and abundance, Ecology, 66, 230-240.
31) Grapow L. C., Blasi C., 1998, A comparison of the urban flora of different phytoclimatic regions in Italy, Glob. Ecol. Biogeogr., 7, 367-378.
32) Ullmann I., Heindl B., 1989, Geographical and ecological differentiation of roadside vegetation in temperate Europe, Bot. Acta, 102, 261-269.
33) Palaniyandi R., Leiser A. T., Paul J. L., 1978, Factors associated with vegetation decline along Sierran highway corridors, HortScience, 13, 377.
34) Rothfels C. J., Beaton L. L., Dudley S. A., 2002, The effects of salt, manganese, and density on life history traits in *Hesperis matronalis* L. from old-field and roadside populations, Can. J. Bot., 80, 131-139.
35) Spellerberg I. F., 2002, Ecological effects of roads, Science Publishers, 251pp.
36) Wilcox D. A., 1989, Migration and control of Purple Loosestrife (*Lythrum salicaria* L.) along highway corridors, Environ. Manage., 13, 365-370.
37) Crisp M. D., Laffan S., Linder H. P., Monro A., 2001, Endemism in the Australian flora, J. Biogeogr., 28, 183-198.
38) Pysek P., Chocholouskova Z., Pysek A., Jarosik V., Chytry M., Tichy L., 2004,Trends in species diversity and composition of urban vegetation over three decades, J. Veg. Sci., 15, 781-788.
39) Meunier F. D., Verheyden C., Jouventin P., 1999, Bird communities of highway verges: Influence of adjacent habitat and roadside management, Acta Oecol., 21, 1-13.
40) Lee H. T., 1996, A study on the landscaping of the slope in highway, Korea Inst. Landsc. Architect., 24, 1-12.
41) Anonymous, 1995, Natural vegetation cuts costs on expressway, Am. City County, 110, 48.
42) Kil J. H., Park S. H., Koh K. S., Suh M. H., Ku Y. B., Suh S. H., Oh H. K., Kong H. Y., 2006, Alien Plants in Korea. May 22th. Available on-line: http://alienplant.nier.go.kr/eng/index.html.