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Restoration effects influenced by plant species and landscape context in Young-il region, Southeast Korea: Structural and compositional assessment on restored forest

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Abstract

Despite it has been mentioned that the successful restoration in landscape level was achieved in the Young-il soil erosion control project, quantitative evaluation of restored plant communities (*Alnus firma* as introduced species and *Pinus thunbergii* as native species) was hardly founded. Light availability, litter and woody debris cover, and forest structure and composition were determined for 500 m^2 band-quadrat in three forest types. Abiotic factors of *Q. serrata* stands, as reference forest, and *A. firma* stands were similar but not for *P. thunbergii* stands. There were no significant difference on mean stem density (stems ha^{-1}, $H = 3.6$, $p = 0.162$), and the mean basal area of each stand had marginal significance (m^2 ha^{-1}, $H = 5.7$, $p = 0.058$) among stands as total basal area was higher with the order of *A. firma* (21.4 m^2 ha^{-1}), *P. thunbergii* (19.8 m^2 ha^{-1}) and *Q. serrata* (16.2 m^2 ha^{-1}). Restoration of vegetation structure was more effective in fast-growing and N-fixing *A. firma*, as introduced species plantation. However, result of MRPP, NMS ordination and ISPAN for herbaceous layer, not for tree and shrub species composition, indicated that restoration of ground vegetation was likely influenced highly from local environment. Propagule availability from landscape context such as connectedness to natural vegetation and management practices in restored isolated stands are available explanations for restoration effects and gaps between restored plantations and secondary oak forest.

Keywords: *Alnus firma*, landscape context, *Pinus thunbergii*, plantation, restoration, soil erosion, Young-il

INTRODUCTION

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (Society for Ecological Restoration International Science & Policy Working Group 2004) and starts with the desire to improve such deteriorated landscapes or ecosystems (del Moral et al. 2007). In the past, most forest restoration projects aimed to rehabilitate abiotic functions and the Young-il soil erosion control project also aimed primarily to prevent the spread of secondary damage from forest soil erosion into aquatic, agricultural and human systems over the region. Recently, the project has been noted as successful landscape level restoration model to environmental managers and ecologists (Cho 2005, Lee and Suh 2005).

Forest landscape degraded can be rehabilitated to secondary forest through artificial modification such as

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plantation and soil erosion control facilities for deteriorated sites. So, landscape change or restoration exhibited by both the natural processes and the artificial assists including management practices and policies. Human dominated landscapes or region as like Korea, the artificial disturbance rules the change and configuration of the landscape (Cho 2009). As this point, the structural and compositional effect of introduced (*Alnus firma*) and native (*Pinus thunbergii*) plantations on the restoration of secondary forest is rarely studied in Young-il district (Cho 2005), although the most of pre-barrens of Young-il district have been rehabilitated by coupling of human assistances and natural processes (Cho 2009). Plantations have been recommended to foster regeneration of native species and forest, and hence promote biodiversity (Chapman and Chapman 1996, Haggar et al. 1997, Lugo 1997, Oberhauser 1997, Powers et al. 1997, Lamb 1998, Otsamo 2000, Carnevale and Montagnini 2002, Cusack and Montagnini 2004, Arévalo and Fernández-Palacios 2005, Igarashi and Kiyono 2008) and decrease soil erosion problem in degraded area (Chirino et al. 2006). Several studies addressed that plantations of exotic species have facilitated forest succession where disturbances obscured establishment of native species (Parrotta 1995, Fimbel and Fimbel 1996, Loumeto and Huttel 1997).

Partly, several studies tested differences in species composition and diversity between or among vegetation types, as Ito et al. (2004) on previous land use, plantation and secondary, Graae et al. (2003) on landscape context, isolated or not, and Graae and Heskjær (1997) on management history, unmanaged and managed. Synthetically results of those investigations revealed that seed disposal, seed bank and abiotic conditions, such as nutrients, soil water content, landscape context and so on, were attributed to the gap of vegetation types tested. For those results, there are fundamental differences on the starting point with absence and presence of initial floristics of vegetation development of Young-il restoration project and on the suffering active restoration treatment. Of particular important is the recognition that some ecosystems may occur in a number of alternative states, which may be contingent on the disturbance history, human intervention and so on (Beisner et al. 2003, Suding et al. 2004, Hobbs 2007).

Despite it has been mentioned that the successful restoration in landscape level was achieved in the Young-il district (Cho 2009), quantitative and functional evaluation of restored plant communities natural secondary (*Quercus serrata* dominated) forest were hardly founded except for Cho (2005), in which he reported phytosociological characteristics and successional pattern of restored stands in Young-il erosion control district. Followings are the objectives of this study: 1) to compare the abiotic and biotic (vegetation structure and composition) variables among restored continuous and isolated forests with natural forest, and 2) to clarify the vegetation restoration effects with planted species and landscape context.

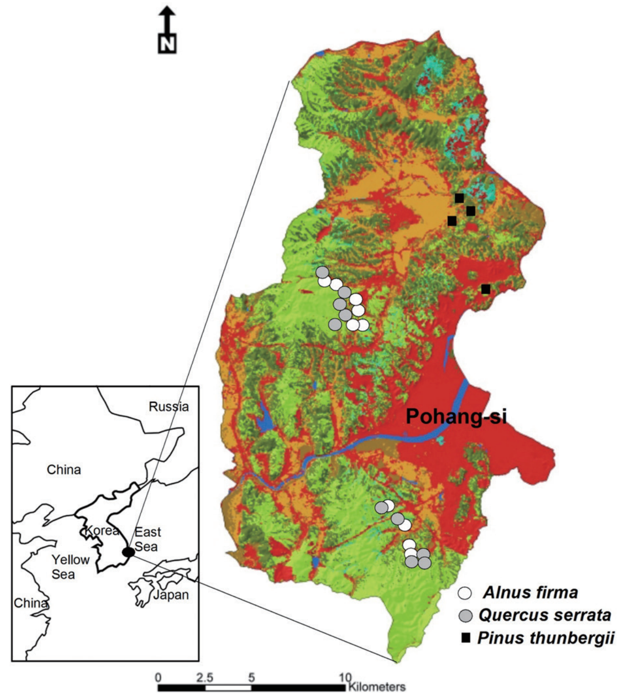

Fig. 1. Study area and location of restored forests, *Alnus firma* and *Pinus thunbergii*, and natural secondary *Quercus serrata* forest. In the map, green color area mean broadleaved summergreen vegetation and dark green area is evergreen coniferous vegetation.

MATERIALS AND METHODS

Study area

This study area was conducted in plantation forests, *A. fima* and *P. thunbergii,* restored by Young-il soil erosion control project in 1970s and adjacent natural secondary oak forest, *Q. serrata*, Pohang-si, southeastern Korea (Fig. 1). Korean alder (*A. firma*) and *Q. serrata* forests were located in mountainous habitat that connected with core forest vegetation of the study area and Korean black pine (*P. thubergii*) plantation was in isolated hilly patches surrounded by paddy fields and residential area. The altitudinal distribution of study area is below 200 m above sea level. The Young-il region was classified into warm-temperate summergreen broad-leaved forest area (Kim and Lee 2006) and annual precipitation and temperature (1971 ~ 2011) at Pohang weather station, the closest appropriate climate station, average 1,166.8 mm and 14.0°C, respectively.

In the early of 1970s, remained natural vegetation of Young-il area was composed of *P. densiflora* as dominant and several oak species as co-dominant with high frequencies (Ri et al. 1977). Based on aerial photograph interpretation taken in early 1970s, secondary broadleaved forest were rarely founded and restricted from middle to higher elevation of the region but remained with bared ground in young state, as coppice, with pines in low area. Thus secondary broadleaved forest as a reference stands of our study in lowland (dominated by *Q. serrata*) has been developed from initially existing vegetation. Planted vegetation *A. firma* and *P. thunbergii* stands, however, have been from bare ground through human assistances such as planting and fertilizing and relatively limited initial floristics, especially for Korean black pine stands as isolated patches in the landscape.

During the restoration project, various introduced, representatively *A. firma*, *A. sibirica*, *P. rigida* and *Robinia pseudoacacia,* and native, *P. thunbergii,* tree species, shrub, *Lespedeza bicolor,* and herbaceous plants, *Arundinella hirta*, *Themeda triandra* and *Cymbopogon tortilis,* were planted or sowed on stabilized slopes by terracing and fertilization was practiced continuously after plantation at three year intervals (Gyeongsangbuk-do 1999). While planted or sowed shrub and herbaceous species decreased rapidly, dominance of introduced tree species increased along years after the project and frequency of native oaks and pines were also increased (Hong 1982).

Hong (1982) and Cho (2005) reported that potential natural vegetation was oak dominated forest in lowland of Young-il erosion control district. Various plantations in study area were converted to oak dominate or co-dominate forest by natural succession (Cho 2005). While, for the *P. thunbergii* plantation mostly distributed in lower mountainous area and hilly isolated patches in study area, succession by natural processes after the project was likely obstructed by low availability of seed and seedling banks of potential dominant and forest species as shade tolerant, *Q. serrata* (frequency at 2.5% of 40 sampling points) in isolated forest patches. The characteristics of isolated habitats in the study area were with low understory cover and growth rate of tree species (Cho et al. 2009), or by management activities.

Field survey

For restored forest, total of 14 stands were selected in *A. firma* (10 stands) and *P. thunbergii* (4 stands) plantation and 10 secondary forests dominated by *Q. serrata* as reference stands. After field exploration, we verified that the sites selected were very low and young vegetation or devastated state in early 1970s through checking orthogonal images taken in early 1970s by visual.

Vegetation sampling was conducted from 25 August to 12 September 2008 and 2009. Total of 24 with 10m × 50 m (500 m^2) plots, a wide band for forest structure and composition of tree species, were established parallel with the contour and was > 30 m from all stand edges and road. The band consisted of 10 microplots (1 m^2) for ground vegetation spaced at 5 m intervals, 5 subplots (25 m^2) for shrub vegetation spaced at 5 m intervals and 2 ~ 5 plots (100 m^2) for tree species composition. Within each sub (1.5 m ~ 2.5 m in height) and microplots (< 1.5 m in height), cover (%) of all vascular plants were recorded. Litter and coarse woody debris coverage (%) were also determined in microplots. Diameter at ground 0.3m height of all tree species was measured in a band. Age of each stand was estimated by counting tree rings from increment cores for the largest tree species in the plot. Mean age of *Q. serrata*, Korean alder and Korean black pine was 36, 34 and 32, respectively.

To estimate light availability and canopy openness (%), we took digital hemispherical photographs at the center and four corners of bands from a height of 1.8 m using Nikkon D80 digital camera with Sigma 4.5mm F2.8 EX DC Circular Fisheye HSM lens. Pictures were taken on uniformly overcast days to avoid direct sunlight. Total transmitted light or PPFD (Photosynthetic Photon Flux Density) (mol m^{-1} day^{-1}) averaged over the year was calculated with Gap Light Analyzer 2.0 employing the standard overcast sky model (Frazer et al. 1999).

Statistical analyses

Stand-level means of *Q. serrate* (*n =10*), *A. firma* (*n =10*) and *P. thunbergii* (*n =4*) were calculated for basal area (m^2 ha^{-1}), density (stems ha^{-1}) and average cover of species and litter and CWD cover also computed for the sampling bands. We used Nonmetric Multidimensional Scaling (NMS) (Kruskal 1964) ordination to examine differences in species composition of samples between natural and restored two forest types. Separate analyses were also conducted to plot and sub and microplot samples. Importance value (Barbour et al. 1999), as sum of relative stem density and basal area, of each tree species in plots and percent cover of subplots and microplots were fed in a matrix for NMS ordination. NMS was performed using Søresen's distance measure and we used the "slow and thorough" autopilot of PC-ORD version 4.0 (McCune and Mefford 1999) conducting 40 runs that yield one to six dimensional solutions. A Monte Carlo test was performed to compare stress of randomized data (McCune et al. 2002).

In addition to NMS, multiresponse permutation procedures (MRPP) (Biondini et al. 1988) to test whether species composition differed between natural and restored stands were applied. MRPP is a nonparametric procedure that avoids distributional assumptions of normality and homogeneity of variance, which are not commonly met in ecological data. It produces A-statistics (the chance-corrected within-group agreement) with probability of statistical significance (McCune et al. 2002).

For compare species attributes as habitat affinity, indicator species for each stands were identified with ISPAN (indicator species analysis; Dufrêne and Legendre 1997, McCune and Mefford 1999). The indicator values (IV) as a result of ISAPN range from 0 to 100 and 100 as perfect indication means that presence of a species points to a particular group without error (McCune et al. 2002). For yielded indicator species, habitat affinity of forest, transitional and ruderal was classified by applying field professionality of the authors. Kruskal-Wallis test, a non-parametric analysis of variance, was used to compare the difference in mean basal area and stem density, PPFD, and canopy openness among forest types. An alpha level of 0.05 was used as the criteria for statistical significance. SPSS ver. 12.0 (SPSS Inc. 2003) and PC-ORD ver. 4.0 (McCune and Mefford 1999) were applied to univariate, means of abiotic and biotic variables such as cover of litter and CWD, BHA and stem density, and multivariate analyses, compositional analysis, respectively.

RESULTS

Abiotic variables

Mean canopy openness ($H = 43.6$, $p < 0.0001$) and light availability ($H = 43.9$, $p < 0.0001$) of Korean black pine stand (*P. thunbergii*; 24.5% and 12.7 mol m^{-2} d^{-1}) was higher than *Q. serrta* (10.5% and 4.3 mol m^{-2} d^{-1}) and *A. firma* (9.3% and 3.7 mol m^{-2} d^{-1}) stands (Fig. 2). Difference in mean percent covers of litter ($H = 40.6$, $p < 0.0001$) and coarse woody debris (CWD, $H = 53.5$, $p < 0.001$) among types also was significant (Table 1). The mean values of litter cover were in the order of *P. thunbergii* (96.4%), *Q. serrata* (78.2%), and *A. firma* (73.5%), and the mean values of CWD cover were in the order of *Q. serrata* (8.8%), *A. firma* (7.4%), and *P. thunbergii* (2.9%).

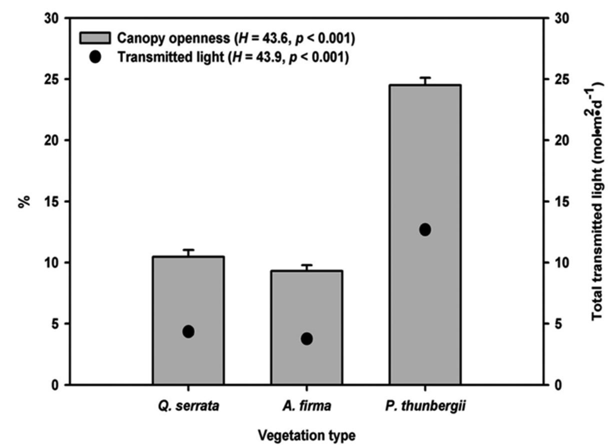

Fig. 2. Comparisons in mean canopy openness and transmitted light among stand types. Vertical bars in diagram indicate ± SE (standard error).

Stand structure

There was no significant difference on mean stem density (stems / ha, $H = 3.6$, $p = 0.162$), and the mean basal area of each stand had marginal significance (m^2 ha^{-1}, $H = 5.7$, $p = 0.058$) among stands (Table 2). The mean values of total basal area were in the order of *A. firma* (21.4 m^2 ha^{-1}), *P. thunbergii* (19.8 m^2 ha^{-1}), and *Q. serrata* (16.2 m^2 ha^{-1}), and the mean values of total density were in the order of *P. thunbergii* (1,141 stems ha^{-1}), *A. firma* (1,140 stems ha^{-1}), and *Q. serrata* (1,104 stems ha^{-1}). In oak and Korean alder forest, the mean basal area of *Q. serrata* (6.2 m^2 ha^{-1} in *Q. serrata* stands and 6.0 m^2 ha^{-1} in *A. firma* stands) was the highest, and it of *P. thunbergii* (19.4 m^2 ha^{-1}) was the highest among its own stands.

Species composition

All tested MRPP exhibited significant but low differences among and between groups (Table 3). In tests among three forest types, the values of size difference were in the

Table 1. Mean and standard errors (± SD) for litter and CWD cover of studied forest types at forest floor

Forest types	Litter cover (%)	CWD cover (%)
Quercus serrata	78.2 ± 3.5	8.8 ± 0.6
Alnus firma	73.5 ± 3.3	7.4 ± 0.8
Pinus thunbergii	96.4 ± 1.1	2.9 ± 0.7

Table 2. Mean basal area (m^2 ha^{-1}) and stem density (stems ha^{-1}) for woody species greater than 5cm diameter at ground height (0.3 m) among studied stands. All values are presented with mean value and ± SE, and SE means standard error for mean. Differences in mean values of basal area ($H = 5.7$, $p = 0.058$) and stem density ($H = 3.6$, $p = 0.162$) by Kruskal-Wallis tests were not significant at 0.05 level

Species	*Quercu serrata* stand		*Alnus firma* stand		*Pinus thunbergii* stand	
	Basal area	Stem density	Basal area	Stem density	Basal area	Stem density
Quercus serrata	6.2 ± 1.3	352 ± 78	6.0 ± 0.6	432 ± 137	-	-
Quercus variabilis	2.2 ± 0.8	112 ± 29	0.4 ± 0.3	12 ± 4	-	-
Pinus densiflora	< 0.1 ± <0.1	36 ± 19	0.5 ± 0.4	< 0.1 ± < 0.1	-	-
Quercus mongolica	1.2 ± 0.4	96 ± 31	2.0 ± 0.9	132 ± 42	-	-
Prunus sp.	0.1 ± 0.1	44 ± 13	0.3 ± 0.3	12 ± 4	< 0.1 ± < 0.1	10 ± 10
Platycarya strobilacea	1.4 ± 0.8	52 ± 24	< 0.1 ± <0.1	12 ± 4	< 0.1 ± < 0.1	10 ± 10
Carpinus laxiflora	< 0.1 ± <0.1	24 ± 11	< 0.1 ± <0.1	152 ± 48	-	-
Zelkova serrata	0.9 ± 0.4	16 ± 16	0.3 ± 0.2	-	-	-
Styrax obassia	0.6 ± 0.4	72 ± 28	4.6 ± 1.3	16 ± 5	-	-
Sorbus alnifolia	0.1 ± 0.0	36 ± 16	0.1 ± < 0.1	4 ± 1	-	-
Quercus acutissima	0.2 ± 0.1	4 ± 4	0.1 ± 0.1	8 ± 3	-	-
Carpinus tschonoskii	0.1 ± 0.1	12 ± 6	0.7 ± 0.4	4 ± 1	-	-
Styrax japonicus	0.4 ± 0.2	72 ± 42	0.1 ± 0.1	92 ± 29	-	-
Acer pseudosieboldianum	0.3 ± 0.2	76 ± 33	0.4 ± 0.2	12 ± 4	-	-
Castanea crenata	0.4 ± 0.2	8 ± 8	0.1 ± 0.1	28 ± 9	< 0.1 ± < 0.1	40 ± 16
Lindera erythrocarpa	0.8 ± 0.4	20 ± 16	0.4 ± 0.3	-	-	-
Rhus tricocarpa	0.4 ± 0.2	32 ± 17	< 0.1 ± < 0.1	36 ± 11	< 0.1 ± < 0.1	10 ± 10
Meliosma myriantha	0.1 ± 0.1	12 ± 9	< 0.1 ± < 0.1	12 ± 4	-	-
Quercus dentata	0.4 ± 0.4	8 ± 8	0.2 ± 0.1	24 ± 8	-	-
Fraxinus rhynchophylla	0.1 ± 0.1	4 ± 4	0.1 ± 0.1	< 0.1 ± < 0.1	-	-
Fraxinus sieboldiana	0.5 ± 0.5	16 ± 9	< 0.1 ± < 0.1	16 ± 5	-	-
Quercus aliena	-	-	< 0.1 ± < 0.1	28 ± 9	-	-
Alnus firma	-	-	4.7 ± 1.6	96 ± 30	-	-
Alnus sibirica	-	-	< 0.1 ± < 0.1	8 ± 3	-	-
Tilia amurensis	-	-	0.1 ± 0.1	4 ± 1	-	-
Pinus thunbergii	-	-	-	-	19.4 ± 1.8	1,210 ± 123
Robinia pseudoacacia	-	-	-	-	0.2 ± 0.1	100 ± 58
Albizia julibrissin	-	-	-	-	0.1 ± 0.0	30 ± 19
Total	16.2 ± 1.4	1,104 ± 75	21.4 ± 1.5	1,140 ± 360	19.8 ± 1.7	1,141 ± 60

Table 3. Result of the multiple response permutation procedures (MRPP) testing the differences in species composition among stand types. Samples of each group for MRPP were selected only in unmanaged sites to eliminate management noise but not for *Pinus thunbergii*

Test	Compared group[a]	*T*	*A*	*p*
Tree species composition	*QS, AF, PT*	-33.038	0.283	< 0.001
	QS, AF	-6.079	0.033	< 0.001
	QS, PT	-29.067	0.349	< 0.001
	AF, PT	-28.926	0.331	< 0.001
Shrub layer composition	*QS*[a], *AF, PT*	-19.850	0.117	< 0.001
	QS, AF	-4.045	0.027	0.003
	QS, PT	-19.394	0.139	< 0.001
	AF, PT	-18.219	0.111	< 0.001
Herbaceous layer composition	*QS, AF, PT*	-54.436	0.106	< 0.001
	QS, AF	-27.833	0.053	< 0.001
	QS, PT	-45.895	0.130	< 0.001
	AF, PT	-33.653	0.067	< 0.001

Note: *T* is the test statistics and refers to the separation between the groups, *A* is an estimate of effect size, and *p* is the probability of significances among groups.
[a]Species codes: *QS*, *Quercus serrata*; *AF*, *Alnus firma*; *PT*, *Pinus thunbergii*.

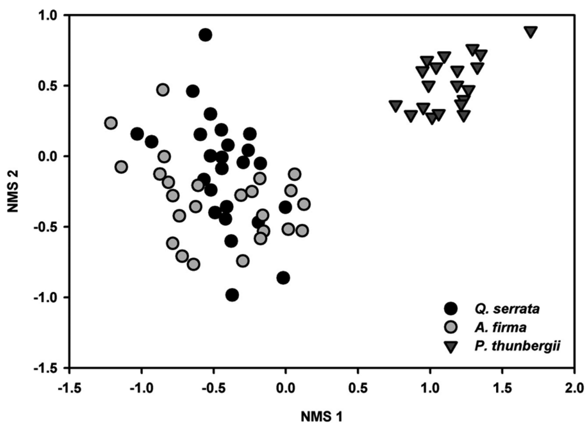

Fig. 3. NMS ordinations of tree species compositions. NMS 1 and NMS 2 accounted for 55.1 % and 10.5% of variation of woody species composition, respectively, resulting in a cumulative 65.6 % variation of woody composition by the first two NMS axes.

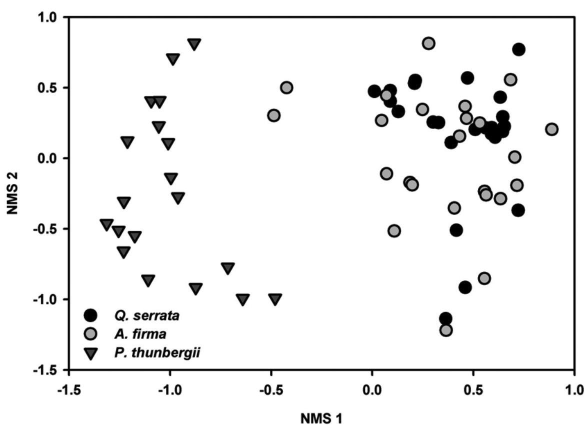

Fig. 4. NMS ordination of shrub layer compositions. NMS 1 and NMS 2 accounted for 36.4 % and 19 % of variation of woody species composition, respectively, resulting in a cumulative 55.5 % variation of shrub layer composition by the first two NMS axes.

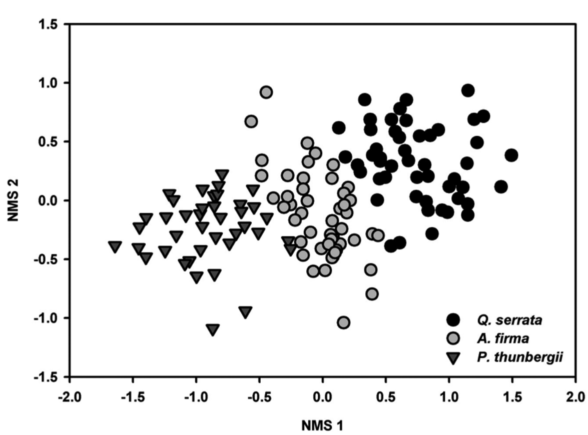

Fig. 5. NMS ordination of herbaceous layer compositions. NMS 1 and NMS 2 accounted for 39.8 % and 11.4 % of variation of woody species composition, respectively, resulting in a cumulative 51.3 % variation of herbaceous layer composition by the first two NMS axes.

order of tree species composition (*A = 0.283*), shrub layer (*A = 0.117*), and ground vegetation (*A* = 0.106). In paired test, the size difference (*A*) was low between *Q. serrata* and *A. firma* stand (tree composition, *A* = 0.033; shrub layer, *A* = 0.027; ground vegetation, *A* = 0.053), and high between *Q. serrata* and *P. thunbergii* (tree composition, *A* = 0.349; shrub layer, *A* = 0.139; ground vegetation, A = 0.13).

Results of NMS ordinations based on the importance values of tree species and percent cover of shrub and herbaceous layer vegetation well supported the results of MRPP (Figs. 3, 4, and 5). The compositions of tree species and shrub layer of *Q. serrata* and *A. firma* were largely overlapped. On the NMS 1, samples of *P. thunbergii* were separated from the samples of *Q. serrata* and *A. firma*.

In ground layer, indicator species analysis (ISPAN) yielded 32 taxa showing positive associations with specific stand types (Table 4). Compared to *Q. serrata* forest as natural secondary vegetation, the habitat affinities of ground species were different, and there were no forest species in restored plantation forests. Five forest species and four transitionals were associated with *Q. serrata* forest, four transitionals and two ruderals associated with *A. firma* stand, and 11 ruderals, four transitionals and two forest species related to *P. thunbergii* forest.

Floristic composition

Overally, total of 171 species with 67 families, 121 genera, 129 species, 2 subspecies, 35 varieties and 5 forms were occurred in studied 24 sampling bands (10 m x 50 m). For each stand types, total of 110 species with 51 families, 80 genera, 84 species, 1 subspecies, 22 varieties and 3 forms were occurred in *Q. serrata* stands, total of 104 species with 48 families, 78 genera, 77 species, 2 subspecies, 20 varieties and 5 forms were occurred in *A. firma* stands, and total of 65 species with 33 families, 53 genera, 49 species, 1 subspecies, 14 varieties and 1 forms were occurred in *P. thunbergii* stands. Among tree species, *Quercus* spp. (*Q. mongilica, Q. serrata, Q. variabilis, Q. aliena and Q. dentata*) and *Carpinus laxiflora* were evenly appeared in three stand types, but *Miscanthus sinensis*, as representatively disturbance related and shade-intolerant species, was only occurred in restored two forests.

DISCUSSION

Natural vegetation is the results of many contingent and stochastic factors (del Moral et al. 2007). During the assembly of vegetation, conditions that filters, moisture, nutrients, light and biotic pressures, immigrants change, leading to a different set of new colonist (Fattorini and Halle 2004). Therefore, a complete replica of the pre-disturbance ecosystem is not realistic and limited because much of the damages in our environment are irreversible (Choi 2004, Choi et al. 2008).

Local environmental effects on forest restoration

There were little differences in environmental variables and community structures between broadleaved forests of *Q. serrta* and *A. firma*, but not for *P. thunbergii* plantations, which had higher values of abiotic variables of canopy openness and light availability and litter cover, and lower in CWD cover and floristic diversity. Nearly even scores of environmental variables of oak and planted Korean alder forests may be usually originated from higher similarity in structure (Table 2). Those different forest attributes between restored vegetation may due to landscape context and difference in management history. As mentioned earlier, Korean black pine stands studied were located in isolated patches and surrounded by agricultural and residential patches in the study area. Thus there were likely limited local species pool and especially forest understory species (e.g. *Disporum smilacinum and Ainsliaea acerifolia*). As pointed by Prach et al (2007), vegetation development is substantially affected by the local species pool whether the sere was initiated naturally or assisted.

Relatively higher differences of composition including floristic composition were detected between secondary oak and planted black pine forests. Propagule availability from landscape context such as connectedness to natural stands (Graae et al. 2003), and continuous management practices, thinning and understory removal (Graae and

Table 4. Understory species exhibiting significant associations ($p < 0.05$) with a particular group of stand types, based on indicator species analysis (ISPAN). Codes for habitat affinity are forest (f), transitional (t) and ruderal (r)

Species	Max group	Habitat affinity	IV_{max}	*p*
Disporum smilacinum	*Quercus serrata*	f	60.0	0.001
Viburnum erosum	*Quercus serrata*	f	58.0	0.001
Carex gifuensis	*Quercus serrata*	t	56.0	0.001
Lindera erythrocarpa	*Quercus serrata*	f	48.0	0.001
Ainsliaea acerifolia	*Quercus serrata*	f	42.8	0.001
Fraxinus sieboldiana	*Quercus serrata*	t	29.8	0.001
Rhododendron schlippenbachii	*Quercus serrata*	t	29.1	0.001
Lindera obtusiloba	*Quercus serrata*	f	28.3	0.001
Carex ciliatomarginata	*Quercus serrata*	t	9.9	0.033
Viola albida	*Alnus firma*	t	31.2	0.001
Parthenocissus tricuspidata	*Alnus firma*	t	18.3	0.001
Persicaria posumbu	*Alnus firma*	t	14.6	0.001
Smilax sieboldii	*Alnus firma*	r	14.6	0.004
Styrax japonicus	*Alnus firma*	t	13.6	0.011
Persicaria filiformis	*Alnus firma*	r	10.4	0.008
Oplismenus undulatifolius	*Pinus thunbergii*	r	81.1	0.001
Smilax china	*Pinus thunbergii*	r	62.2	0.001
Spodiopogon sibiricus	*Pinus thunbergii*	t	62.1	0.001
Arundinella hirta	*Pinus thunbergii*	r	52.5	0.001
Lespedeza maritima	*Pinus thunbergii*	t	52.4	0.001
Miscanthus sinensis	*Pinus thunbergii*	r	45.0	0.001
Cocculus trilobus	*Pinus thunbergii*	r	27.5	0.001
Pinus thunbergii	*Pinus thunbergii*	r	25.0	0.001
Isodon inflexus	*Pinus thunbergii*	f	20.9	0.001
Rosa multiflora	*Pinus thunbergii*	r	17.5	0.001
Pteridium aquilinum	*Pinus thunbergii*	r	16.5	0.001
Rhus avanica	*Pinus thunbergii*	t	15.0	0.001
Dendranthema zawadskii	*Pinus thunbergii*	r	13.2	0.008
Calamagrostis arundinacea	*Pinus thunbergii*	t	13.1	0.012
Carex lanceolata	*Pinus thunbergii*	r	10.0	0.009
Dryopteris chinensis	*Pinus thunbergii*	f	9.6	0.046
Robinia pseudoacacia	*Pinus thunbergii*	r	7.5	0.024

Heskjær 1997) in Korean black pine stands are available explanations for gaps between secondary and restored Korean alder plantations. Lee et al. (2005) also noted that native species establishment could be poor on sites isolated from natural seed sources in reforested pre-degraded forest habitat.

Stem release activities applied to black pine stands exhibited brighter environment in forest floor. Higher ground litter cover is related to higher litter production and lower decomposition rate of pine species (Mun and Joo 1994), but the effect of structural factors, stem density and stand age, was unclear because of absence of reference data on natural black pine stands. Dense and thick pine litter coverage in planted *P. thubergii* stands likely to restrict establishment of additional plant species by forming unstable substrate and environments for seed germination. Allelopathic effect of the pine species is also considerable (Kim et al. 2002). Those limiting effects and low quality of restored Korean black pine plantation on understory composition and forest species recruitment draw further challenges for forest management and restoration.

Structural and compositional restoration with tree plantation

Plantation produce positive effects in landscape level and also revealed significant restorative consequences on structure and composition in pre-degraded forest land (Lugo 1992). Successive reforestation of fast-growing and N-fixing exotic *A. firma* and native *P. thunbergii* species on degraded forested land would have affected to improvement of degraded habitat by control surface runoff (Cho 2009). Furthermore, as passed about 30 years after planting, in *A. firma* plantations, *Q. serrata* as the representative dominant tree species was emerged as a codominant species, and low and no significant differences in species composition of woody and shrub vegetation compared with natural oak stands.

Restoration of vegetation structure was more effective in fast-growing and N-fixing *A. firma*, as introduced species plantation. However, result of MRPP, NMS ordination and ISPAN for herbaceous layer indicated that reforested communities had a different species composition in comparison to secondary stands. Representative understory species of secondary forest such as *Disporum smilacinum* and *Ainsliaea acerifolia* are rarely found and showed very lower cover in plantations. Those results suggest that difference in starting point, presence or absence of initial floristics and species pool, of vegetation likely to affect compositional aspect of restoration activities. Occurrence of ruderal and invasive, include native and alien species such as *Miscanthus sinensis*, *Oplismenus undulatifolius*, *Persicaria filiformis* and *Robinia pseudoacacia*, supports those explanations. In *A. firma* plantation, residual *A. firma* as pioneer species shows dim leaf density and earlier litter fall, which can affect micro habitat level light intensity and quality of interior of stand, as they have been reached ecological life span. Duration of ruderal species such as big grass *M. sinensis*, may be related to those characteristics of *A. firma* stands.

Introduction of species to degraded land is to restore ecosystem structure and function rather than to establish of species own. Compared with fully restored structural aspect of mean basal area and stem density of rehabilitated *A. firma* forest, recover of compositional aspect was relatively lower in understory vegetation. These results suggested that recovery of detailed species composition is limited by restoration. In comparative, local natural vegetation could be reference for restoration and monitoring, but not a detailed copy model (del Moral et al. 2007). Improving from this point, future-oriented restoration should focus on ecosystem functions through reconstructing structure rather than recomposition of species or the cosmetics of landscape surface (Choi 2004, Choi et al. 2008).

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