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Dynamics and Conservation of the Gwangneung National Forest in Central Korea: A National Model for Forest Restoration

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Forests in Gwangneung National Arboretum District (GNAD) have been protected since the 15th century. Consequently, these forests support more than 20% of all plant species in Korea. We constructed vegetation maps for landscape analysis, and forest dynamics, species diversity, and sustainable management were discussed. Secondary forests compose 51.0% of the whole vegetation, while plantations compose 45.2%. *Quercus serrata* dominates the forest, and the plantations are comprised mainly of *Pinus koraiensis*. Although dominated by plantations and human installations, the presence of a rare riparian hardwood forest, composed primarily of *Q. aliena*, was notable. Species diversity of the riparian ($H' = 3.38$) was significantly ($p<0.0001$) higher than the upland ($H' = 1.56$). Species turnover rate as a spatial heterogeneity was also higher. Such high species diversity and heterogeneity are justification to conserve the riparian and lowland forests in GNAD. Extensive recruitments of their own seedlings and saplings suggest a sustainable regeneration of *Q. serrata* and *Q. aliena* stands in the lower elevations, and the opposite is true for the *Q. mongolica* and *P. rigida* stands in higher elevations. GNAD contains diverse natural landscape elements that range from riparian to upland vegetation, which may well serve as a national model for forest restoration.

Keywords: conservation, diversity, forests, landscape, riparian, upland

Reforestation is a top priority for natural resource management in South Korea, particularly since the Korean War ended in 1953. The reforestation programs led by the South Korean government during the past five decades are often cited as an "exemplary model" for success around the world (Lamb and Gilmour, 2003). The main goals of these reforestation programs, however, were to prevent soil erosion and establish plantations for economic interests. These reforestation programs, which lacked a focus on restoring native ecosystems, resulted in a massive introduction of foreign species, a simplification of structure with even-aged monoculture plantations, and a poorly functioning ecosystem as evidenced by pest infestations and weedy species invasions (Northeast Asian Forest Forum, 2000). Establishment of native forests, including conversion of plantations to native forests through induced succession, could restore native structures and functions of Korean forest ecosystems, thus alleviating many of the monoculture and even-aged problems (Lee et al., 2004b).

Natural sciences are currently challenged with the task of managing and protecting ecological integrity, a requirement that includes maintenance of biological diversity and landscape and/or ecosystem diversity. To this end, controls and reference ecosystems and stands are essential to achieve environmentally sound and sustainable management. The development of ecological applications and practices are necessary and based essentially on ecological information, such as landscape pattern, vegetation structure, diversity, biomass, nutrient cycling, abiotic conditions (such as soil properties), etc. (Frelich et al., 2005; SER, 2002).

Gwangneung National Arboretum District (GNAD), a well-preserved forest since the 15th century (Lim et al., 2003), is a prime candidate as a model for forest conservation and restoration. The forests in GNAD have drawn extensive attention from numerous ecologists. Some of these researchers include Oh (1958), Yim and Kim (1985), and Lee et al. (1990, 1992) on community structure, succession and regeneration; Cho (1992), You et al. (1995), You et al. (1996) on succession and regeneration, litter decomposition and nutrient cycle; Son et al. (1995), Kim (1998), You et al. (2000), Kim and Jeong (2001), Kim et al. (2003) on litter decomposition and nutrient cycles; Lim et al. (2003) on carbon budget; and Kim et al. (1996) on species diversity.

These previous investigations focused on the upland at a local scale, and little attention was paid to riparian forests. A better understanding of bottomland, including the riparian forest, is particularly important for conservation and restoration planning because these areas are frequently disturbed by nature (e.g., flash floods) and various human activities (e.g., agriculture and building) (Naiman et al., 1998). The dynamics of riparian and upland forests can be better understood in a landscape scale that integrates both nature and human elements. This approach is critical to draw a comprehensive picture of nature/human interactions for a meaningful conservation and restoration plan (Hobbs, 1997).

This paper presents: (1) comprehensive vegetation maps, including both upland and riparian zones; (2) mechanisms of forest dynamics, species composition, and diversity including exotic species; (3) support for the conservation of riparian forests; and (4) recommendations for sustainable management and restoration of forest resources in GNAD and nation wide.

MATERIALS AND METHODS

Study Area

The forest surrounding Gwangneung National Arboretum was annexed to a royal tomb, called "Gwangneung", in

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which the seventh king of the Joseon Dynasty, "Sejo", was buried approximately 600 years ago. The forest was designated as a "royal court forest" and preserved completely until 1913, when Japanese conquerors transformed a section into experimental forest. The experimental system continues to date. The remaining forest has been well conserved and is recognized as the representative old-growth forest in central Korea (Lim et al., 2003).

GNAD, classified as a cool temperate forest, is in the central Korean Peninsula (37° 42′ 36″-47′ 41″ N and 127° 8′ 20″-11′ 58″ E) at 40 m to 620 m above sea level. Mean annual precipitation is 136.5 cm, and temperature is 11.3°C (Forest Practice Research Center, internal data file). This 2,526.5-ha (<0.03% of total land area of South Korea) preserve supports approximately 20% (904 species) of the entire plant species (4,400 species) found in South Korea (Korea National Arboretum, 2004).

Vegetation Map and Analyses

Based on aerial photographs, taken in October 2003, we constructed two vegetation maps (whole and riparian) within the GNAD boundary (Figs. 1 and 2). The vegetation

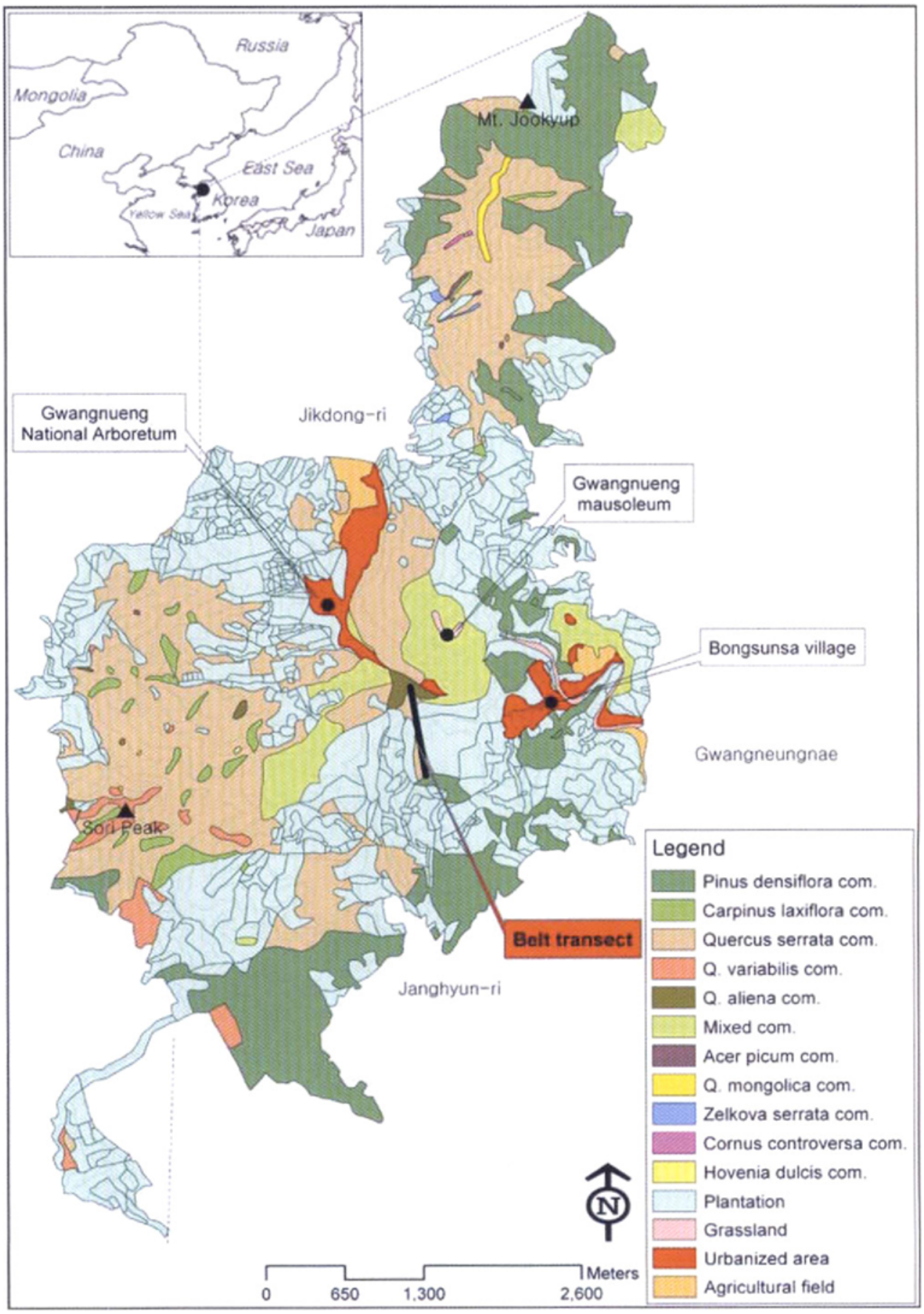

Figure 1. Geographic location, major vegetation types, and land uses in GNAD.

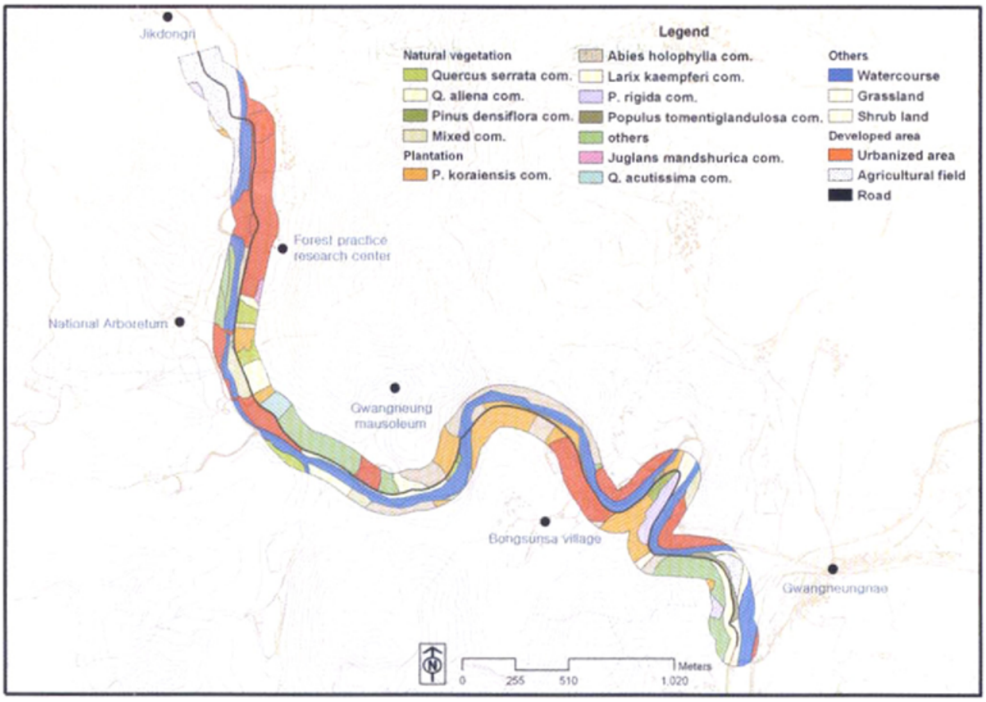

Figure 2. Major vegetation types and land uses in the riparian zone of GNAD.

map of the riparian zone, which lies within 100 m of local roads that run along the Bongseonsa stream, was also constructed in a detailed map of 1:5,000 in scale.

Vegetation patches (natural and plantation) were characterized with two landscape indices of shape index and edge density. Shape index (≥ 1) was calculated by dividing patch perimeter by the minimum perimeter, and it overcomes size-dependence by comparing the perimeter:area ratios to a standard shape, such as a square or circle (O'Neill, 1988; Mcgarigal and Marks, 1995). Patch shape has important considerations in regard to species dispersal, prey, nutrient flow, etc. (Forman and Godron, 1986). Edge density was obtained by adding the lengths (m) of all edge segments in the landscape, dividing by the total landscape area (m^2), and multiplying by 10,000 (Mcgarigal and Marks, 1995). In general, natural landscape elements have higher complexity and edge density (Forman and Godron, 1986).

Vegetation Sampling

A field vegetation survey was conducted from July to October 2004 in 157 plots (99 in the upland and 58 in the riparian). The size of each plot was either 10 m × 10 m in narrow valleys or 20 m × 20 m elsewhere. All plant species growing in each plot were identified, following Lee (1985), Park (1995), and the Korean Plant Names Index (2003). Stem diameters (at breast height for mature trees or at stem base for seedlings and saplings) of major tree species (*Q. mongolica* Fisch. ex Ledeb, *Q. serrata* Thunb. ex Murray, *Q. aliena* Blume, and *Pinus rigida* Mill.) were measured and sorted by diameter classes.

The vegetation survey was conducted by the relevé method (Barbour et al., 1999). Dominance of each species in each plot was estimated by ordinal scale (1 for <5% to 5 for >75%), and each ordinal scale was converted to the median value of percent cover range in each cover class. The importance value of each species was then calculated by sum of relative frequency and relative coverage (Curtis and McIntosh, 1951). Relative frequency is the frequency of one species as a percentage of total frequency, and relative coverage was determined by multiplying 100 to the fraction of each species cover to the summed cover of all species in each plot. Finally, a matrix of importance values for all species in all plots was constructed.

Statistical Analyses

The differences in shape index and edge density for natural and plantation patches were compared using the Wicoxon rank sum test. Ordination analyses were conducted by Multi Variate Statistical Package (MVSP, 2002). For matrix of importance values, relativization by species column was done, and it was fed to Detrended Correspondence Analysis (DCA) for ordination (Hill, 1979).

As a measure of species diversity, Shannon Wiener's Diversity Index (*H'*) and species richness, as the number of species per a single plot, were calculated for each quadrat (Magurran, 2003). We also measured species turnover rate by Wilson and Shmida's index (β_W) of beta diversity (Wilson and Shmida, 1986) with species presence-absence data along the belt transect from the riparian area (40m) to the adjacent mountain peak (260 m) (Fig. 1). Twenty-nine plots were established for beta diversity measurements, and the size of all plots was 20 m × 20 m. Percentages of native and alien species to endemic species were also determined for each stand type.

Analysis of variance (ANOVA) was used to test the differences in mean species diversity (*H'*) and richness for forest types ($n \geq 3$). *F*-statistics were calculated for species diversity and richness. The Tukey-Kramer procedure was used to compare means of forest types. In all statistical analyses, the level of significance was at least $p=0.05$. SAS version 9.1 (SAS, 2002) was used for all statistical analyses.

RESULTS

Spatial Distribution and Landscape Characteristics

Eleven upland and 12 riparian forest types were identified, and each type was named after the dominant species in its canopy layer. Secondary forest (1,225.8 ha in 126 patches) comprised 51.0% of the upland area, and 45.2% was plantation (1,084.6 ha in 622 patches) (Table 1, and Figs. 1A and 1B). *Q. serrata* (583.5 ha), followed by *Pinus densiflora* Sielbold & Zucc (422.6 ha) and *Caprinus laxiflora* (Sielbold & Zucc) Blume var. *laxiflora* (31.2 ha), were the most common secondary forest types. *Q. serrata*, with scattered *C. laxiflora*, occurred in the upper slope of Sori Peak and the lower slope of Jookyup Mountain. *P. densiflora* (422.6 ha) prevailed on the upper slope of Jookyup Mountain and in the southern end of the GNAD lowlands near Janghyun Village. *Q. variabilis* Blume appeared in western and southern slopes of Sori Peak. *Q. mongolica* appeared on the ridge in a belt form. And *Zelkova serrata* (Thunb.) Makino, *Cornus controversa* Hemsl. ex Prain, *Acer picum* subsp. *mono* (Maxim.) Ohasi, and *Hovenia dulcis* Thunb. ex Murray occurred in valley of the western slope of Jookyup Mountain.

The riparian zone covered 125.0 ha in 83 patches. Urban and agricultural lands (39.1 ha) and plantations (31.6 ha) dominated the riparian zones (Figure 1A and Table 1). *P. koraiensis* Siebold & Zucc (459.0 ha), along with *P. rigida* and *Larix kaempferi* (Lamb.) Carriere, was the most common type of plantation in the lower elevation. Urban (59.1 ha in 12 patches) and agricultural lands (21.4 ha in 3 patches) were concentrated near Bongsunsa Village, Jikdong Village, and GNA headquarters and the visitor center. Occurrence of a rare riparian forest, dominated by *Q. aliena*, was notable in center of GNA (near Gwangneung Mausoleum) (Fig. 2).

As a result of landscape analyses, natural forest patches (1.84) revealed significantly more complex shapes than plantation patches (1.59). Higher edge density in natural patches was also significant (Table 2).

Table 1. Composition of landscape elements in the vegetation maps of upland and riparian zones in GNAD.

	Upland				Riparian			
Landscape and vegetation type	area (ha)	%	No. of patches	%	Area (ha)	%	no. of Patches	%
Secondary forest								
Quercus serrata	583.5	24.3	19	2.5	2.4	1.9	4	4.8
Pinus densiflora	422.6	17.6	28	3.6	0.7	0.6	2	2.4
Carpinus laxiflora	31.2	1.3	22	2.9	-	-	-	-
Q. aliena	8.1	0.3	5	0.6	4.6	3.7	6	7.2
Q. mongolica	5.5	0.2	4	0.5	-	-	-	-
Mixed	119.1	5.0	9	1.2	3	2.4	5	6.0
Others	55.8	2.3	39	5.1				
Subtotal	**1,225.8**	**51.0**	**126**	**16.3**	**10.7**	**8.6**	**18**	**21.7**
Plantation								
P. koraiensis	459.0	19.1	197	25.6	12.5	10.0	12	14.5
Larix kaempferi	149.8	6.2	106	13.7	1.4	1.1	3	3.6
P. rigida	171.2	7.1	83	10.8	2.5	2.0	3	3.6
Abies holophylla	48.5	2.0	50	6.5	9	7.2	8	9.6
Q. acutissima	38.3	1.6	18	2.3	1.1	0.9	1	1.2
Others	217.8	9.1	168	21.8	13	10.4	11	13.2
Subtotal	**1,084.6**	**45.2**	**622**	**80.7**	**39.5**	**31.6**	**38**	**45.8**
Urban and agricultural area								
Urban	59.1	2.5	12	1.6	40.1	32.1	13	15.8
Agriculture	21.4	0.9	3	0.4	8.8	7.0	3	3.6
Subtotal	**80.6**	**3.4**	**15**	**1.9**	**48.9**	**39.1**	**16**	**19.3**
Other landscape								
Grassland	8.3	0.3	2	0.3	2.5	2.0	2	2.4
Bareground	2.2	0.1	6	0.8	-	-	-	-
Shrub land	-	-	-	-	0.6	0.5	1	1.2
Watercourse	-	-	-	-	22.8	18.2	8	9.6
Subtotal	**10.5**	**0.4**	**8**	**1.0**	**25.9**	**20.7**	**11**	**13.3**
Total	2,401.5	100.0	771	100.0	125.0	100.0	83	100.0

Table 2. Comparison of means (mean ± SE) of landscape indices for forest types in GNAD.

Forest type	* Shape index	** Edge density (m/ha)
Natural	1.84 ± 0.08	15.8 ± 7.3
Plantation	1.59 ± 0.02	4.9 ± 1.9

*Significance at $p<0.05$
**Significance at $p<0.001$

Stand Sequence and Dynamics

On Axis I of the upland vegetation DCA, the *P. densiflora* forest is the farthest left, moving to the right with *Q. mongolica*, *C. laxiflora*, *Q. variabilis*, *Q. serrata*, *Q. aliena*, *Fraxinus rhynchophylla* Hance, *A. picum*, *C. controversa*, *H. dulcis*, and *Z. serrata* forests (Fig. 3). In the riparian vegetation ordination, the stands were placed in the order of *Populus tomentiglandulosa* T. B. Lee and *Juglans mandshurica* Maxim. var. *mandshurica* for. *mandshurica*, *Q. aliena*, *Abies holophylla* Maxim, *P. koraiensis* and *Q. acutissima* Carruth, *Q. serrata*, *P. densiflora*, *L. kaempferi*, *P. rigida*, and *P. banksiana* Lamb from the left to the right on Axis I (Fig. 4). Figure 5 is a combined DCA of the upland and the riparian forests. This ordination revealed more diverse species composition in the riparian forests, suggested by a wider spread of the forests on Axes I and II than the upland.

The understory layer of the *Q. mongolica* forest was dominated by *C. laxiflora* and *C. controversa*. No seedlings or saplings of *Q. mongolica* (stem diameter < 10 cm) were found in this type. The *P. rigida* forest rarely had seedlings or saplings. In the *Q. aliena* stand, *Q. aliena* constituted approximately 20.0% of the woody stems with diameters less than 10 cm. In addition, more than 24.0% of the young woody stems were *Q. serrata* in the *Q. serrata* forest (Fig. 6).

Species Diversity

Mean species diversity (*H'*) and richness was significantly higher in the riparian vegetation (3.38 and 41) than in the upland (1.56 and 24) ($p<0.0001$). The *Q. aliena* stand showed the highest species diversity in both upland and riparian forests, but diversity was not significant in the upland (Fig. 7). Species richness of *A. picum* (upland) and *Q. aliena* (riparian) were significantly higher (Fig. 8).

In upland forest types that had less than three quadrats, species diversity was higher in the order of *F. rhychophylla* (2.23), *H. dulcis* (1.98), *Z. serrata* (1.65), and *C. controversa* (1.5); and species richness was higher in the order of *F. rhychophylla* (50), *Z. serrata* (38), *C. controversa* (36), and *H. dulcis* (34). In riparian forest types that had less than three quadrats, species diversity was higher in the order of mixed forest (3.42), *J. manshurica* (3.4), *Q. acutissima* (3.19), *P. densiflora* (2.95), *P. tomentiglandulosa* (2.55), and *L. kaempferi* (0.34); and species richness was higher in the order of mixed forest (42), *J. manshurica* (38), *Q. acutissima* (28), *P. densiflora* (4), *L. kaempferi* (18), and *P. tomentiglandulosa* (15).

Alien species composed 0 to 10.5% of the total number of species of each community established in the riparian zone (Table 3). No alien species were found in the upland forests.

The sum and average of beta diversity were 15.11 and 0.52, respectively, and revealed high variation that ranged from 0.26 to 0.98 (Fig. 9). The species turnover rate decreased along the transect. The average number of species in a single plot was 33. Species richness decreased, as reflected by beta diversity.

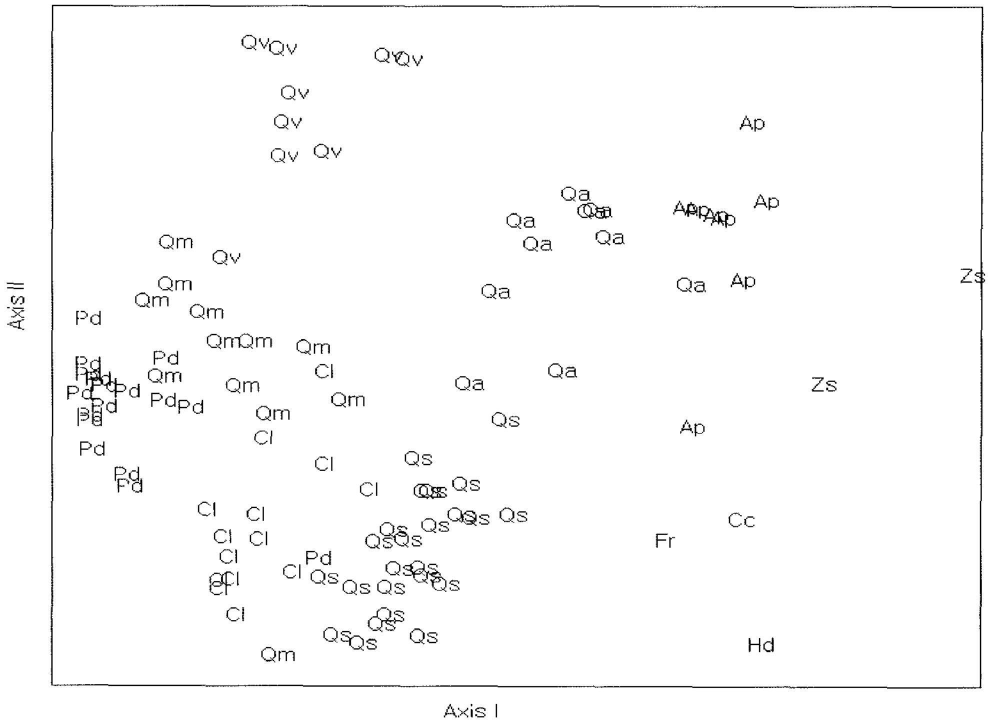

Figure 3. Ordination of study plots from upland in GNAD. The eigen values of Axes I and II were 0.237 and 0.080, respectively. The plots of *Q. serrata*, *Q. aliena*, *Q. mongolica*, *P. densiflora*, *H. dulcis*, *F. rhynchophylla*, *C. laxiflora*, *Q. variabilis*, *A. picum*, *Z. serrata* and *C. controversa* are signified with the letters Qs, Qa, Qm, Pd, Hd, Fr, Cl, Qv, Ap, Zs and Cc.

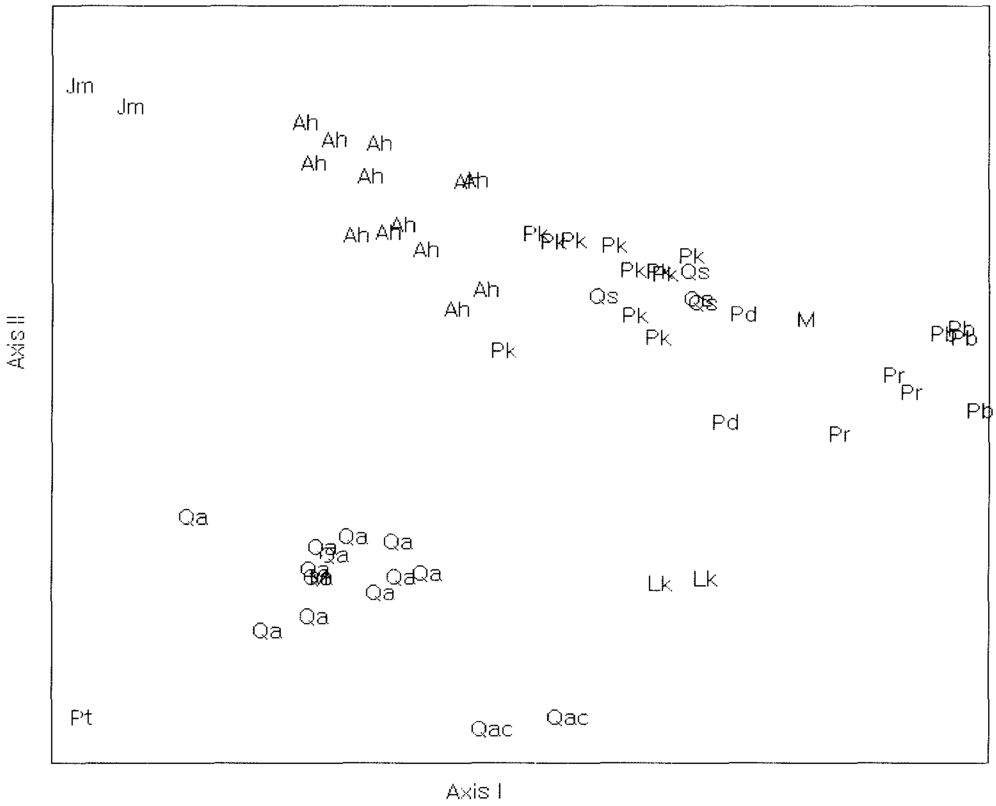

Figure 4. Ordination of study plots from bottomland in GNAD. The eigen values of Axes I and II were 0.428 and 0.126, respectively. The plots of *Q. aliena*, *Q. serrata*, *P. densiflora*, *Mixed forest*, *A. holophylla*, *P. koraiensis*, *P. banksiana*, *P. rigida*, *L. kaempferi*, *J. mandshurica*, *Q. acutissima* and *P. tomentiglanduloda* are signified with the letters Qa, Qs, Pd, M, Ah, Pk, Pb, Pr, Lk, Jm, Qac and Pt.

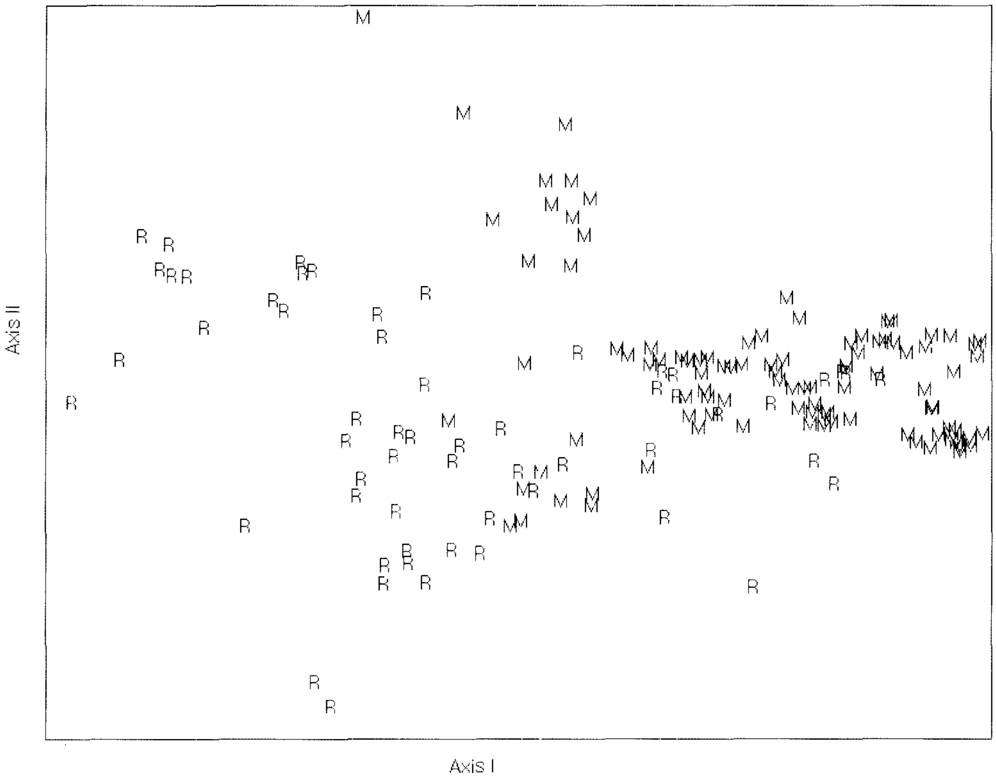

Figure 5. Ordination of stands established in two zones of riparian (R) and mountainous (M) in GNAD. The eigen values of Axes I and II were 0.767 and 0.587, respectively.

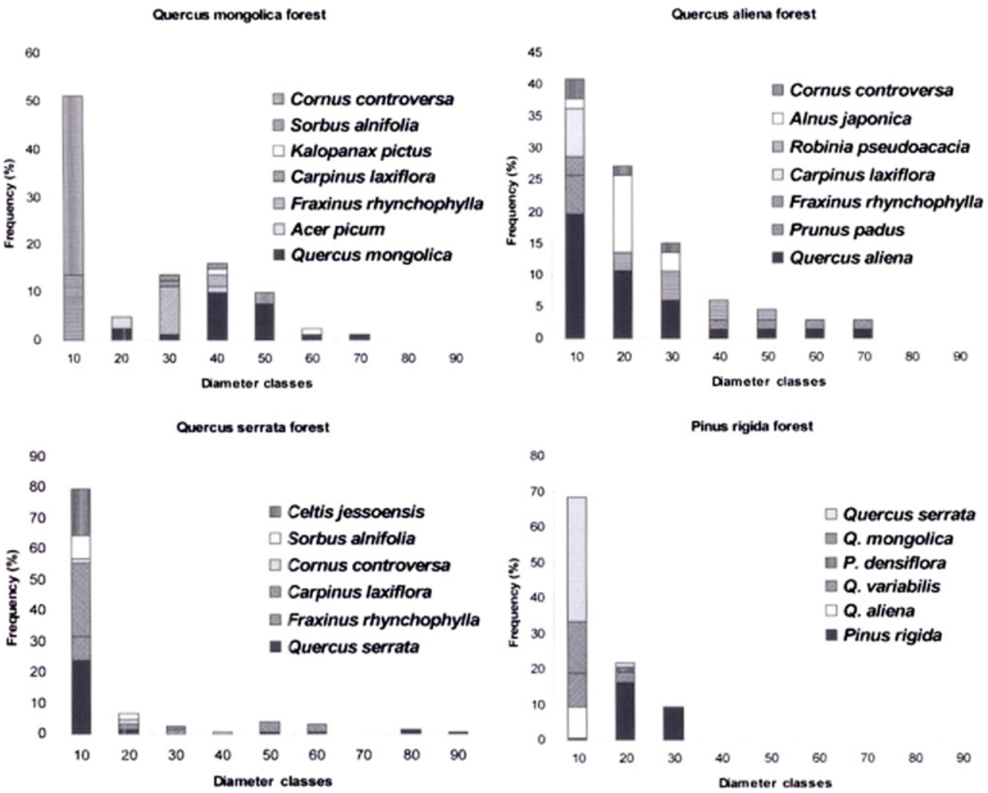

Figure 6. Diameter class distribution diagrams of major oak forests (*Q. mongolica*, *Q. aliena*, and *Q. serrata*) and pitch pine *Pinus rigida* forest in GNAD.

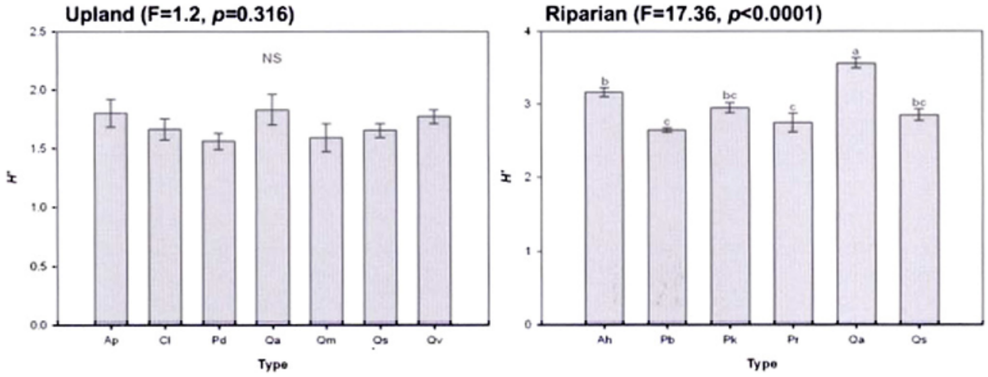

Figure 7. Species diversity (*H'*) of upland and riparian forests. Mean species diversity and standard error bars shown separately for forest types. Bars having different letters were statistically different ($p<0.05$). NS indicates no statistically significant difference ($p>0.05$).

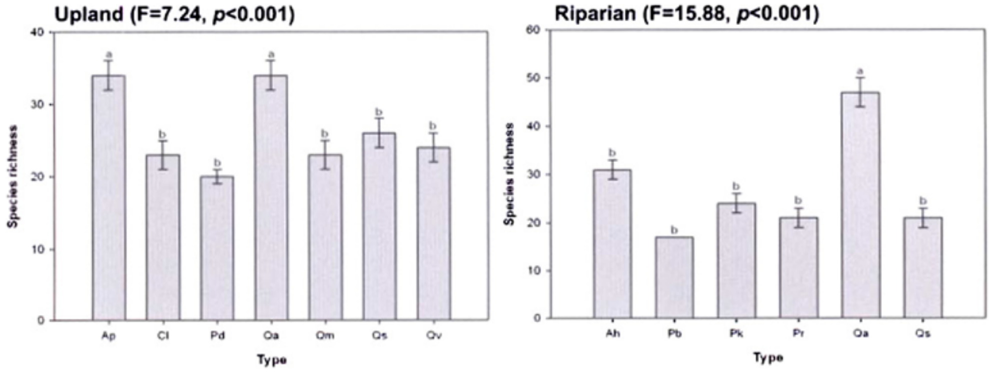

Figure 8. Species richness of upland and riparian forests. Mean richness and standard error bars shown separately for forest types. Bars having different letters were statistically different ($p<0.05$). NS indicates no statistically significant difference ($p>0.05$).

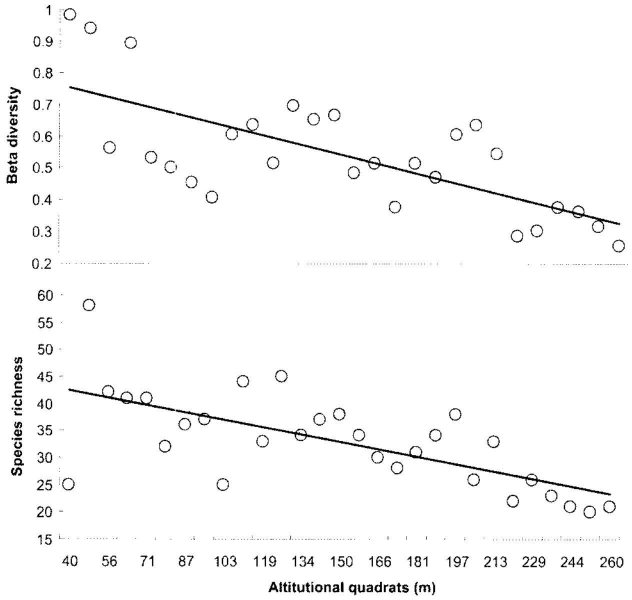

Figure 9. Changes of beta diversity and species richness indices for adjacent quadrats along an altitudinal gradient in the lowland of GNAD.

DISCUSSION

Vegetation Sequences and Dynamics

The forest stand sequence in the upland ordination (Fig. 3) appeared to follow a topographic elevation with moisture gradient. The isolated stands in the lower part, along Axis II in Fig. 5, were "cove forests" of *C. laxiflora*, *C. controversa*, and *H. dulcis* on a rocky substrate. *P. densiflora* and *Q. mongolica* stands occurred on mountain ridges or upper slopes, in contrast to *H. dulcis* and *Z. serrata*. Because the *Q. mongolica* stand lacked its own seedlings, Kim (1977) and Kang and Oh (1982) expect it to be replaced by other canopy tree species, such as *C. laxifolia*.

Like the upland, the stand sequence in the riparian vegetation ordination (Fig. 4) followed a moisture gradient. *P. banksiana*, *P. rigida*, and *P. densiflora* stands occurred in the xeric sites, and the opposite was true for *P. tomentiglanulosa* and *J. mandshurica* forests. The wider dispersion of riparian forest stands (along the Axis 1 in Fig. 5) suggests a diverse species composition in the environmentally heterogeneous ecotone (Pickett and Cadenasso, 1995; Smith and Smith, 2002). Such ecotonal stands contain species common to both communities and overlap, thereby showing high species richness (the edge effect) (Farina, 2006) (Figs. 7, 8, and 9).

Conservation of Riparian Forests

Properly functioning riparian wetlands provide invaluable ecosystem services (e.g., flood prevention, pollution remediation, improved water quality, and groundwater recharge) to humans (Pett and Calow, 1996; Schmidt, 1987). A majority of riparian lands, however, were converted to rice paddies or subjected to commercial, industrial, and residential development, and thus riparian wetlands with high biological diversity are now extremely rare in Korea (Lee et al., 2004a). Occurrence of *Q. serrata* and *Q. aliena* forests in the riparian zone of GNAD is notable for this reason (Cho et al., 1999; Lee et al., 2001a; 2001b). Particularly, the significantly higher species diversity and richness of natural riparian elements and turnover rate are an undisputable justification for conserving the riparian and lowland vegetation in GNAD (Figs. 7, 8, and 9).

Both beta diversity and species richness (Fig. 9) decreased along the belt transect. Our results revealed higher beta diversity than an earlier study (You et al., 1995) obtained from an upper slope in the same area. This higher heterogeneity is due to riparian characteristics that result from the ecological integrity of GNAD, such as flooding and various micro habitats, conservation of riparian vegetation and mature forest. Therefore, the lowland, including riparian zone, of GNAD should be conserved and managed ecologically.

Both *Q. aliena* and *Q. serrata* stands will likely sustain via substantial recruitment of their seedlings and saplings (Fig. 6).The introduction of alien species, however, may threaten sustainability of the native vegetation in the riparian zones. Various alien species (e.g., *Robinia pseudoacacia* L., *Magnolia obovata* Thunb., and *Pterocarya stenoptera* DC.) were introduced intentionally in all riparian stands, except the *Q. aliena*. Crawly (1997) noted that intentionally introduced species may cause more serious problems than those that

Table 3. Percentages of native species and exotic species classified by vegetation type established in bottomland of GNAD.

Vegetation type	No. of native species	%	No. of exotic species	%	total	%
Pinus rigida	34	89.5	4	10.5	38	100.0
Larix kaempferi	28	93.3	2	6.7	30	100.0
P. banksiana	29	93.5	2	6.5	31	100.0
Populus tomentiglandulosa	17	94.4	1	5.6	18	100.0
P. densiflora	27	96.4	1	3.6	28	100.0
Quercus aliena	146	98.0	3	2.0	149	100.0
P. koraiensis	98	98.0	2	2.0	100	100.0
Q. acutissima	54	98.2	1	1.8	55	100.0
Juglans mandshurica	65	98.5	1	1.5	66	100.0
Abies holophylla	145	98.6	2	1.4	147	100.0
Q. serrata	43	100.0	0	0.0	43	100.0

are accidentally introduced. Moreover, extensive brush removal, usually for landscaping purposes, may create vacant niches for invasive alien species (Mack et al., 2000, Lee and Lee, 2006). Additionally, potential disturbances from automobile emissions and foot traffic from adjacent roads and other urban installments may exacerbate the damage to vegetation and aid the invasion of alien species. Establishment of multi-layer vegetation would be necessary to prevent such invasions, particularly along the forest edges and roadsides (Lee and Lee, 2004).

Management Implications for Ecological Connectivity and Restoration

Sustainable forest management is a challenge for both researchers and practitioners that must be underpinned by good science and operate using sound scientific principles (Murphy and Noon 1992). The first task would be to connect the fragmented patches of natural forests (Andren, 1994; Norden and Appelqvist, 2001; Cooper and Walters, 2002; Fahrig, 2002). Spatial connection and interaction among aquatic, riparian, and upland ecosystems is essential to reduce the detrimental effects of fragmentation (Harison and Bruna, 1999; Davies et al., 2001; Lindemayer and Franklin, 2002). The well-preserved mature forests of GNAD (Table 1 and Figs. 1 and 2) could set the stage for this task (Peterken, 1996) if these forests are protected from development for human interests.

A higher shape index and edge density in the natural forests would be a theoretical and practical foundation for restoration. Landscape shaping by human activities brought rectangularity and rectilinearity, producing regular shapes with straight borders (Krummel et al., 1987; Forman 1995). Shape complexity would be a good parameter for human land-use intensity.

Recruitment and establishment of native species were found in numerous plantations (Fig. 6). Succession from these plantations to natural forests is likely in the foreseeable future. Should this happen, these plantations could connect fragmented patches of natural forests.

Connected patches can also be expanded with active restoration, particularly on the forest edges (SER, 2002). Moreover, the nearly pristine forests of GNAD with landscape elements that range from riparian, as the ecotone contributing to system integrity and a high rate of primary and secondary production (Farina 2006), to upland vegetation and a high degree of biological integrity may well serve as a national model for forest restoration (Karr, 1991).

In Asia, where people depend on rice as a food source, most riparian zones were transformed to rice fields; more recently, many rice fields were transformed to urban areas. In such continuing transformation processes, riverside communities have degenerated greatly or been destroyed by tree cutting, the introduction of exotic species, the diversion and channeling of water for agriculture, and the use of river beds and shores for cultivation or roads. Therefore, riparian landscapes including a river ecosystem and its surrounding environment hardly maintain original features. Riparian landscapes are usually managed in terms of use and disaster protection. The importance of a natural environment is being reevaluated today.

The ecological information we obtained about these riparian and upland forests will be available for ecological restoration and management of lowland ecosystems, which have disappeared in most of Korea. One of the most important aspects of ecological restoration is the identification of a reference ecosystem that serves as a guide to plan restoration projects and control to evaluate its success (SER 2002, Harris and Diggelen 2006). The ecological quality of GNAD is integrated, and thus, could be well adapted as a reference ecosystem for ecological restoration in South Korea.

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