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Degradation of Lowland Forest Landscape and Management Strategy to Improve Ecological Quality in Mt. Baekja and Its Surroundings

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ABSTRACT: The number of species and forest area has decreased as urbanization is progressed. The landscape degradation was examined by analyzing vegetation map, satellite image and characteristics of actual vegetation. The study was conducted in Mt. Baekja and its surroundings located on Gyeongsan city, south-eastern Korea. As the result of landscape analysis, agricultural field was a characteristic attribute of the study area. Lowlands of this study area were occupied by agricultural field and various plantations. For 15 years from 1987 to 2002, forest area decreased from 2,072.9 ha to 1,853.2 ha, and shape index and fractal dimension of vegetation patches increased from 1.32 to 1.65 and from 1.05 to 1.09, respectively. *Pinus densiflora* Siebold & Zucc. community showed the highest species diversity, whereas *Larix kaempferi* (Lamb.) Carriere community showed the lowest species abundance. As forest management implications, monitoring of endangered plant species (*Jeffersonia dubia* (Maxim.) Benth. & Hook.f. ex Baker & S.Moore), and restoration of lowland forest from plantation to natural forest were discussed. Further, establishment of greenways utilizing existing streams, roadside, and public facilities were recommended.

Key words: Enrichment planting, Gyeongsan, Landscape degradation, Lowland, Plantation, Rehabilitation

INTRODUCTION

The number of species and forest area has decreased as urbanization is progressed (Cho et al. 1998). Forests of large area have been disappeared or degraded, and landscapes everywhere are being simplified by excessive land use throughout the world (Dobson et al. 1997). Kinds and structure of forest vegetation in urban area are determined by artificial interference (Kamada et al. 1991).

In Korea, lowland of mountainous area has been usually utilized for the residential area and the place to get fuel, timber, non-timber products and so on. Pine (*Pinus densiflora* Siebold & Zucc.) forest and oak forest dominated by *Quercus acutissima* Carruth. near to the village usually reflect the effect of such interference (Lee and You 2001). During the period of Japanese occupation (1910~1945) and Korean War (1950~1953), extensive forests in Korea were severely degraded by over-cutting and fire, but since then reforestation by massive plantation became a national priority (Lamb and Gilmour 2003). The afforestation project was usually carried out by introducing the exotic species such as *Robinia pseudoacacia* L., *Pinus rigida* Mill., and *Larix kaempferi* (Lamb.) Carriere. Lower areas of mountains were occupied by many introduced species. Consequently, natural quality of lowland forest is relatively low. In such conditions, rapid economic growth led to another alteration of lowland from forest to agricultural land or urbanized area. The changes resulted in landscape fragmentation and thereby degraded landscape quality in nationwide.

For forest landscape around big cities, analyses on type, structure, and diversity of vegetation were carried out (Cho et al. 1998, Lee and Cho 1998, Cho et al. 1999, Cho et al. 2000, Cho and Cho 2002, Oh 2002), and studies focused on change of landscape structure were also executed (Oh 1997, Jung et al. 2002, Jung et al. 2003, Choi et al. 2005, Lee et al. 2006). But, landscape and vegetation around small cities didn't attract attention up to now.

Landscape ecological perspectives are emerging principles in the plan for environmental management. Resource managers need insightful guidance and new perspectives from emerging disciplines such as landscape ecology (Noss 1983, Sharitz et al. 1992, Swanson and Franklin 1992, Dale et al. 2000, Liu and Taylor 2002).

In our study, we focused on constructing regional environmental management plan based on ecological information, which can be fundamental for preventing landscape or ecosystem deterioration. In order to meet the goal, information on landscape and vegetation was collected. Further, management implications to improve the ecologi-

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cal quality of lowland forest were discussed.

Objectives of this study are as follows: 1) clarifying landscape structure and NDVI of each landscape element, 2) clarifying areal change of forest landscape for recent 15 years between 1987 and 2002, 3) analyzing species composition and diversity of major plant communities, and 4) preparing for a management plan based on ecological information obtained from the above mentioned studies.

STUDY AREA AND METHODS

Study Area

The study area is located on southern part of Gyeongsan city, which is adjacent to Daegu metropolitan area, southeastern Korea and functioning as satellite city of Daegu (Fig. 1). Geographical location is from 35° 45' 16" to 35° 49' 12" in latitude and from 128° 43' 17" to 128° 48' 27" in longitude. For 30 years (1971～2000), mean annual precipitation and temperature were 830 mm and 14.2° C, respectively (KMA 2006). Study area covers 3,319.8 ha, and is distributed from 70 m to 480 m above sea level in elevation. In recent years, dominant land use type of Gyeongsan city have changed from agricultural to urbanized landscapes, and forest area has decreased getting encroached by agricultural and built-in areas increased due to population growth of Gyeongsan city and Daegu metropolitan city (Jung et al. 2002).

METHODS

Landscape Analysis

We constructed a vegetation map including landscape use type. The map was based on physiognomic and land use maps, and verified through field check. Normalized Different Vegetation Index (NDVI) as measure of vegetation quality or thickness was calculated by analyzing Landsat TM satellite image taken in 5 April, 2002. NDVI of secondary forest, plantations, agricultural field, urbanized area, and aquatic area, which were obtained from vegetation map, was analyzed by image of 2002. In order to clarify the areal change of forest landscape for recent 15 years, forested land in 1987 were extracted from Landsat TM satellite image taken in 23 June 1987 using NDVI, and the area was compared with forest area, which obtained from vegetation map, in 2002.

Change of forest landscape between 1987 and 2002 was determined through quantitative analysis by Fragstats 3.3 (McCarigal and Marks 1995). Indices used were total area, shape index, fractal dimension and cohesion index. Range of shape index is above 1, and it is 1 when the patch is maximally simple (i.e., square or almost square) and increases without limit as patch shape becomes more irregular. Fractal dimension is between 1 and 2, and it approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. Cohesion index ranges from 0 to 100, and it approaches 0 as the proportion of the landscape comprised of the focal class decreases and becomes increasingly subdivided and less physically connected.

Satellite images were used after geographical and radiometric correction procedures by ERDAS Imagine 8.6 and its Modeler, and Arcview 3.3.

Vegetation Analysis

Vegetation survey was carried out during July to October 2002 by applying phytosociological procedure (Braun-Blanquet 1964). Vegetation data was collected in 68 plots chosen randomly. Plot size was varied from 10 m × 10 m to 20 m × 20 m considering vegetation characteristics. Ordinal cover was converted to the median value of percent cover range in each cover class. Importance value of each species was calculated by sum of relative frequency and relative coverage of each species (Curtis and McIntosh 1951). A matrix of importance values for all species in all plots were constructed, and fed to Detrended Correspondence Analysis (DCA) for ordination (Hill 1979).

As a measure of species diversity, a rank abundance curve was constructed for each vegetation type (Magurran 2004, Kent and Cocker 1992, Lee et al. 2002). All the plant species occurred in each plot were identified, following Lee (1985), Park (1995), and Korean Plant Names Index (2006).

RESULTS

Landscape Characteristics

10 vegetation types including *Quercus variabilis* Blume, *Q. mongolica* Fisch. ex Ledeb., *Q. aliena* Blume, *Q. acutissima*, *Pinus densiflora* stands, mixed forest, *R. pseudo-acacia*, *P. rigida*, *P. koraiensis* and *L. kaempferi* were identified (Fig. 1). Agricultural field was composed of paddy field, orchard, greenhouse and upper field (Fig. 1 and Table 1). Urbanized area was composed of built-in area, bare ground and grassland.

In the spatial distribution of landscape elements, agricultural field, urbanized area and aquatic area occupied the lowest area (Fig. 2). Among vegetation patches, *Q. mongolica* stand was distributed in the highest elevation and followed by *Q. aliena*, mixed forest, *Larix kaempferi*, *P. densiflora*, *P. koraiensis*, *Q. variabilis*, *P. rigida*, *R. pseudo-acacia* and *Q. acutissima* stands. *P. densiflora* stand was the most widely distributed landscape element and followed by *L. kaempferi* and *Q. variabilis* stands.

Natural forest element covers 1520.4 ha as 45.8% of total study

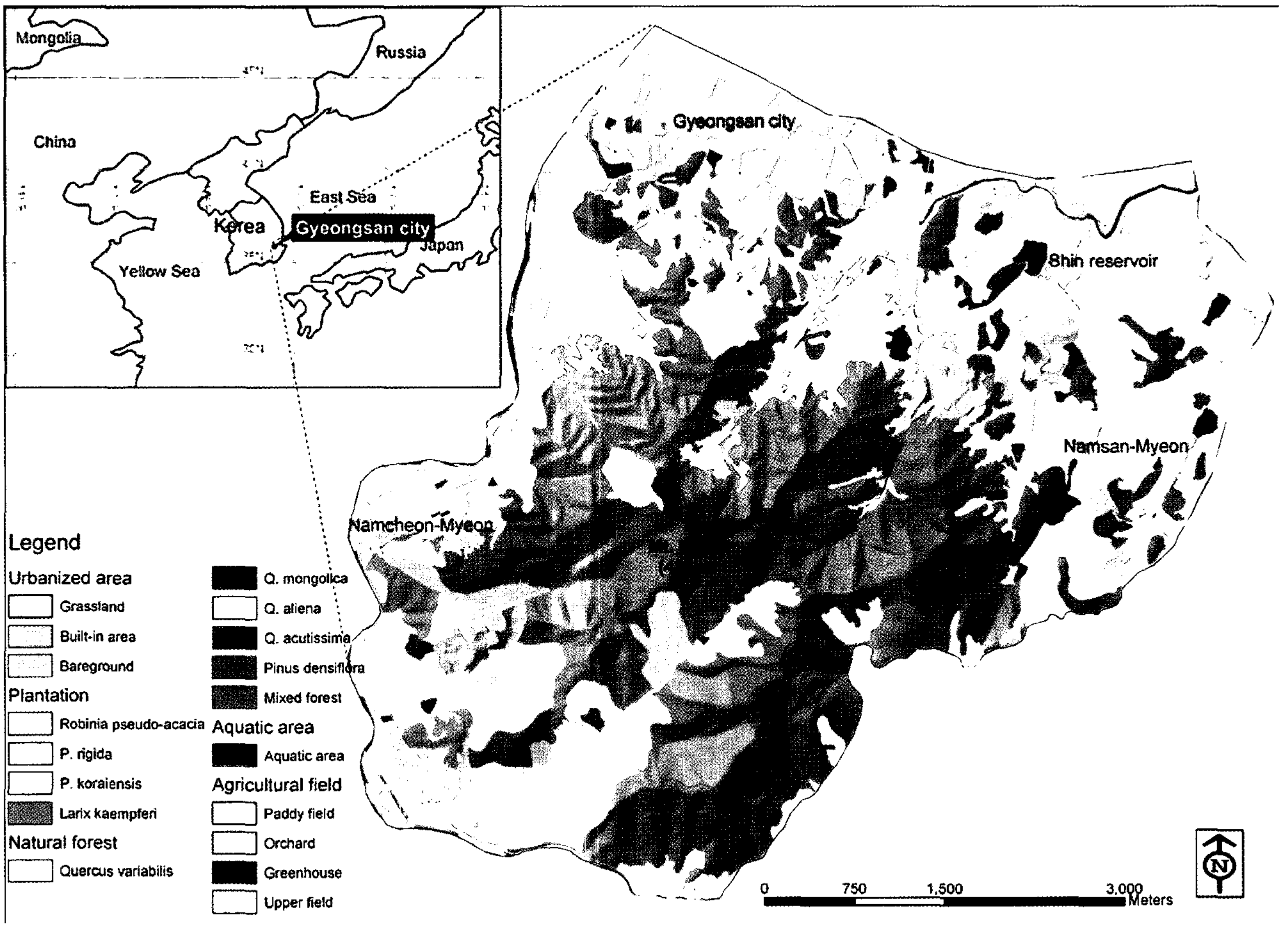

Fig. 1. A landscape ecological map showing the southern part of Gyeongsan city, Gyeongsangbuk-do, Korea.

area (3,319.8 ha) (Table 1). Agricultural field, urbanized area, plantation and aquatic area occupied 899.3 ha (27.1%), 561.7 ha (17.0%), 330.3 ha (10.0%) and 8.1 ha (0.2%), respectively. Among natural forest elements, mixed forest and *P. densiflora* stands occupied 18.2% (605.0 ha) and 18.1% (600.2ha), respectively. Among plantation, *L. kaempferi*, *P. rigida*, *R. pseudo-acacia* and *P. koraiensis* stands occupied 108.2 ha (3.3%), 96.3 ha (2.9%), 65.8 ha (2.0%) and 60.1 ha (1.8%), respectively.

The largest element of agricultural field was orchard, which occupies 557.9 ha (16.8%), and upper field and paddy field had similar area as they occupied 169.7 ha (5.1%) and 168.6 ha (5.1%), respectively. Greenhouse occupied 3.1 ha (0.1%). Among urbanized area, built-in area, bare ground, and grassland occupied 370.5 ha (11.2%), 139.4 ha (4.2), 51.8 ha (1.6%) of total area, respectively. Aquatic area occupied 8.1 ha (0.2%).

Total number of patches was 902, and the number was more in the order of urbanized area (422, 46.7%), agricultural field (311, 34.5 %),natural forest (100, 11.1%), plantation (41, 4.5%) and aquatic area (28, 3.1%) (Table 1). Built-in area had the highest number as 325 (36.0%) among landscape elements. Orchard (127, 14.1%) and upper field (117, 13.0%) were followed.

Change of Forest Landscape

NDVI was higher in the order of secondary forest (0.25), plantation (0.23), agricultural field (0.05), urbanized area (−0.02) and others (−0.06) (Fig. 3).

Area of forest was reduced about 10% for recent 15 years from 2072.9 ha (1987) to 1853.2 ha (2002) (Table 2). Shape index and fractal dimension increased from 1.32 and 1.05 to 1.65 and 1.09 during the same period, respectively. Connectedness of focal patches decreased from 99.3 to 97.0.

Species Composition and Diversity

The DCA ordination of the 68 plots based on matrix of importance values was conducted (Fig. 4). The eigen values of Axes 1 and 2 were 0.823 and 0.589, respectively. Stands were distributed in the order of *Q. variabilis*, *Q. aliena*, *L. kaempferi*, *P. densiflora*, *R. pseudo-acacia* and *Q. mongolica* on the Axis 1, and were in the order of *Q. acutissima*, *R. pseudo-acacia*, *Q. aliena*, *Q. variabilis*, *Q. mongolica* and *L. kaempferi* on the Axis 2. In the spatial arrangement of stands, *P. densiflora* community showed the widest distribution, whereas *Q. variabilis* plots showed the narrowest distribution (Fig. 4).

Species abundance based on species rank-abundance curves was higher in the order of *P. densiflora*, *R. pseudo-acacia*, *Q. aliena*, *Q. mongolica*, *Q. variabilis*, *Q. acutissima* and *L. kaempferi* (Fig. 5).

Table 1. Configuration of landscape structure derived from vegetation map of study area

Landscape element	Area (ha)	%	N/P	%
Natural forest				
Mixed forest	605.0	18.2	17	1.9
Pinus densiflora	600.2	18.1	35	3.9
Quercus variabilis	210.2	6.3	17	1.9
Q. acutissima	56.2	1.7	25	2.8
Q. mongolica	28.2	0.8	4	0.4
Q. aliena	20.7	0.6	2	0.2
Subtotal	1,520.4	45.8	100	11.1
Plantation				
Larix kaempferi	108.2	3.3	6	0.7
Pinus rigida	96.3	2.9	23	2.5
Robinia pseudo-acacia	65.8	2.0	7	0.8
P. koraiensis	60.1	1.8	5	0.6
Subtotal	330.3	10.0	41	4.5
Agricultural field				
Orchard	557.9	16.8	127	14.1
Upper field	169.7	5.1	117	13.0
Paddy field	168.6	5.1	59	6.5
Greenhouse	3.1	0.1	8	0.9
Subtotal	899.3	27.1	311	34.5
Urbanized area				
Built-in area	370.5	11.2	325	36.0
Bareground	139.4	4.2	66	7.3
Grassland	51.8	1.6	31	3.4
Subtotal	561.7	17.0	422	46.7
Aquatic area	8.1	0.2	28	3.1
Total	3,319.8	100.0	902	100.0

DISCUSSION

Land Use Change and Forest Landscape Degradation

Rapid and wide urbanization results in alteration of land use pattern and degradation of landscape quality. Those effects are sprawling out and can affect adjacent regions (Forman 1995). Landscape pattern of the study area are influenced by inner factors such as population growth, economical state, and regional history and development of Daegu metropolitan area that shows continuous population growth for half century (Korean Statistical Information System 2006). High occupancy of agricultural field (27.1%) would be attributed to land use characteristics of Gyeongsan city, which is a new city originated from a rural area. Wide agricultural fields

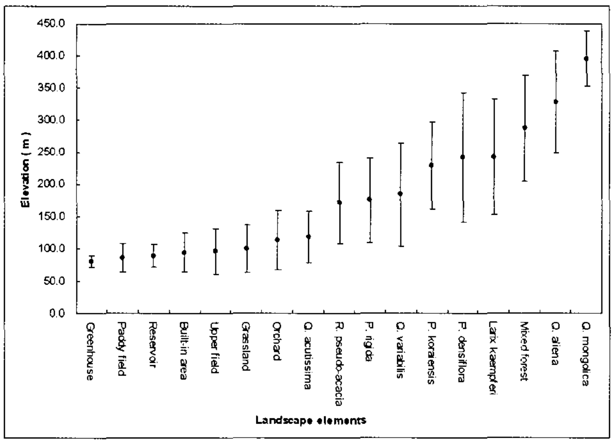

Fig. 2. Elevational distribution of landscape elements identified in study area. Error bars in each element indicate standard deviation.

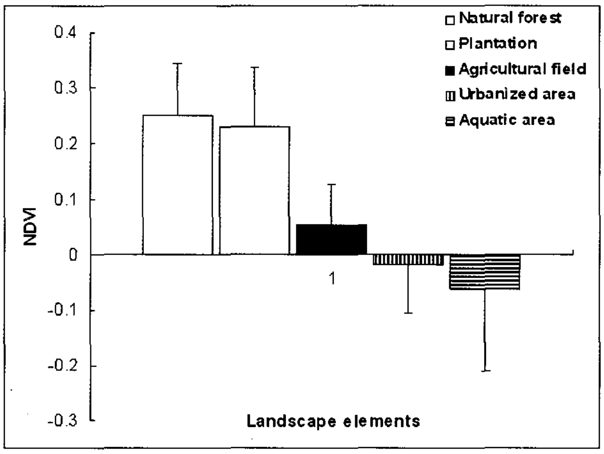

Fig. 3. A comparison of NDVI (5 April, 2002) among secondary forest, plantation, agricultural field, urbanized area, and aquatic area. Error bars indicate standard deviations.

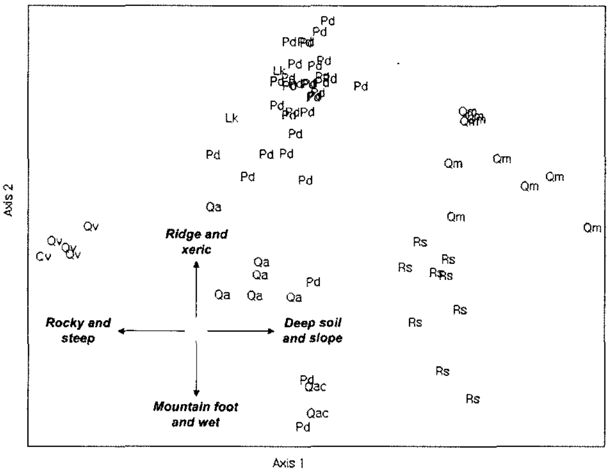

Fig. 4. DCA ordination of *P. densiflora* stand (Pd), *Q. mongolica* stand (Qm), *Q. aliena* stand (Qa), *Q. variabilis* stand (Qv), *Q. acutissima* stand (Qac), *R. pseudo-acacia* stand (Rs), and *L. kaempferi* stand (Lk) based on vegetation samples.

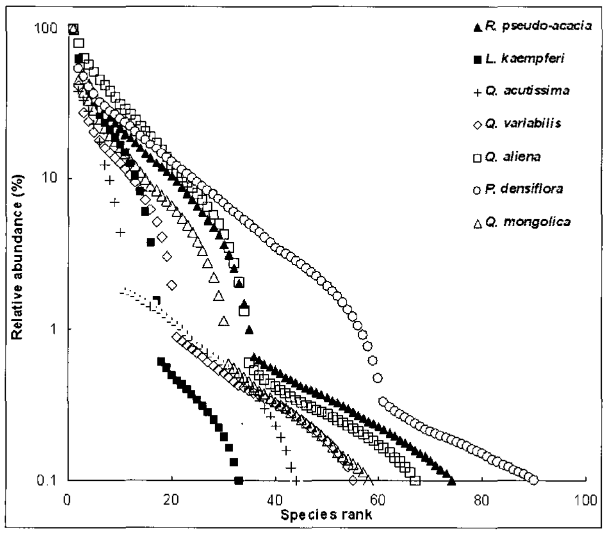

Fig. 5. Species rank-abundance curves of vegetation types. Importance values are derived from relative cover estimates from 68 quadrat samples of seven stands.

of the study area are usually used to support big population of Daegu metropolitan area, and consequently, depend on socio-economic condition of the area (Choi et al. 2005). Among agricultural elements, orchard is a distinctive element around big city (Table 1, Oh 1997, Jung et al. 2002). Lee et al. (2006) clarified that increase of agricultural elements such as orchard and greenhouse is corresponding to urbanization processes around Seoul metropolitan area.

Forest landscape was degraded for recent 15 years (Table 2). Urbanization and transformation of lowland forest from a natural or semi-natural habitat to agricultural field (Fig. 1 and 2) resulted in reduction of forest area. In addition, connectedness of forest landscape decreased, and complexity of forest patches increased (Table 2). Such results corresponded to the results of Jung et al. (2002) and Choi et al. (2005). Those results were usually induced to anthropogenic disturbance such as expansion of orchard, which has flexible boundary differently from paddy field and cropland, and indiscreet utilization of forest area in lowland (Hammett 1992, Forman 1995). Increased shape complexity made forest edges contact with heterogeneous elements such as agricultural fields and urbanized area.

Table 2. Comparison of forest landscape by quantitative analysis during 15 years from 1987 to 2002.

Year	Total Area (TA)	Shape Index (SI)	Fractal Dimension (FD)	Cohesion Index (CI)
1987	2,072.9	1.32	1.05	99.3
2002	1,853.2	1.65	1.09	97.0

Among processes driven by landscape degradation such as reduction of forest area and change of patch shape, the decline of population size of forest species, the alteration of species interactions (e.g. predation, pollination), and the disruptions of key ecological functions are major causes of forest biodiversity loss (Harison and Bruna 1999, Davies et al. 2001, Lindernmayer and Franklin 2002). Forest landscape in urban area is not only a habitat of diverse species in a viewpoint of biodiversity conservation (Hudson 1991, Saunders and Hobbs 1991, Spellerberg et al. 1991), but also a forest for environmental protection with buffering function against environmental stress occurring from urbanized area (Bradly 1995). Reduction of forest area and changes of patch shape appeared in this study can be examples of landscape degradation. Furthermore, such phenomena can influence on biodiversity conservation and environmental quality in urban area.

Vegetation Characteristics

On the horizontal and vertical Axes (Axes 1 and 2), plots were distributed depending on habitat conditions, from which species composition derived (Fig. 4).

Q. variabilis stands were usually established in steep and rocky site, and formed site specific species composition. Therefore, these stands revealed relatively lower variation in species composition compared with the other stands. On Axis 2, broad distribution of *P. densiflora* stands (Fig. 4) is due to that *P. densiflora* stands have habitats of two types: natural and artificial habitats (Lee and Hong 2001). The former type is rocky site with dry and infertile conditions. Physiological characteristics of *P. densiflora* tolerant to such conditions made *P. densiflora* to dominate this habitat type (Lee et al. 2004). The latter is lowland, which is exposed to frequent disturbance by human and *P. densiflora* favors the condition.

In *R. pseudoacacia*, *Q. aliena*, and *Q. mongolica* stands, *Jeffersonia dubia* (Maxim.) Benth. & Hook. f. ex Baker & S. Moore, an endangered plant species was found (Ministry of Environment 2005). For conserving of the endangered species, continuous monitoring is required. In particular, *J. dubia* population is usually established in *R. pseudo-acacia* stand, which is in degenerate phase. Therefore, monitoring of *J. dubia* population is required in relation to decay process of black locust.

As the results of analysis on species diversity by species rank-abundance curve and diversity index, special relationships were not found among vegetation types. High species abundance of *P. densiflora* and *R. pseudo-acacia* stands would be related to dynamics of species abundance along forest development (Odum 1969, Eom et al. 2004).

Lowland Forest as a Starting Point for Improving Ecological Quality and, Its Management Implications

Landscape deterioration such as loss of forest habitat and fragmentation has not occurred at random processes. Historically, suitable areas for human land use were plains and mountain foot. Moreover, available area was utilized more extensively as population and technology grow. Lowland forest, therefore, has become a target area for land use for urbanization and agricultural field. There are evidences that biodiversity was reduced on a landscape and regional scale in the area where clearing and fragmentation have removed much of natural vegetation (Matthiae and Stearns 1981, Bennett and Ford 1997, Bennett 1999).

Urbanization related intimately to human function has brought various alterations to our abiotic and biotic surroundings. Such environmental changes occurred surely in spatial scale beyond ecosystem level, and in this respect, resource managers and politicians should perceive the perspective of landscape scale. It may impossible to increase natural area in lowland, because local demands for land are high owing to economic growth and improvement of living standard. Therefore, we have to evaluate and optimize present ecological resources, which were shrunk and degraded, and it would be essential step to elevate ecological quality of region and nation wide.

In lowland, isolated forest patches by exploitation and fragmentation are usually positioned on piedmont gentle slope, and are mainly composed of *Q. acutissima,* and *P. densiflora* stands, which are cultural landscape elements as they typically compose village grove in Korea (Lee and You 2001). Natural forests were distributed relatively higher areas and upper slopes (Figures 1 and 2). Except for those vegetation types, forests of lower area were usually composed of many introduced plantations (Figures 1 and 2), and this trend is usually shown in most areas of Korea (Fig. 3, Cho et al. 1998, Lee and Cho 1998, Cho et al. 1999, Cho et al. 2000, Cho and Cho 2002, Oh 2002). Although those plantations achieved quantitative improvement such as NDVI (Fig. 3), qualitative advance such as species diversity (Fig. 5) is still required compared with natural forest.

Cho et al. (2006) emphasized importance of lowland forest for biodiversity conservation in Gwangneung National Arboretum. In Korea, unmanaged plantations are usually recovered passively to natural forest such as oak stands (Lee et al. 2004, Shin 2005). Improvement of vegetation naturalness and properties could be achieved through enrichment planting when it is planned cautiously.

Enrichment plantings can also be used in situations where exotic monoculture plantations have been established but the management goal was changed for timber production as well as conservation or just conservation (e.g. Ashton et al. 1997). After gaps are created by selective cutting, the canopy tree seedlings of the desirable species are planted, or seeds are directly sown there. On the other hand, sometimes seedlings or seeds are introduced under canopy. This approach allows some gradual harvesting of the introduced species for income (Lamb and Gilmour 2003). A study of Lee and Lee (2004) showed notable improvement of ecological attributes such as species composition and diversity by enrichment planting.

Improving connectedness of natural landscape fragmented is also required (Table 2). Although establishment of large natural habitats as corridor or stepping stones among fragmented forests would be questionable in the present conditions, but existing streams, roadside, and public facilities can be utilized as ecological greenways instead of them (Fabos 1985, Lee 2003).

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