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Distribution Patterns and Characteristics of Plant Species by Human Impact in Urban Areas[1a]

- Case Study of Cheon-ju -

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인간의 영향에 따른 도시지역 식물종의 분포 패턴 및 특성[1a]

최일기[2*] · 이은희[3]

요 약

본 연구의 목적은 인간의 간섭 및 영향에 따른 도시지역에서의 식물종의 분포패턴 및 특성을 분석하는데 있다. 전주시에서 자생적으로 이입된 모든 유관속 식물종에 대한 포괄적 자료습득을 위하여 각 1헥타 크기의 106개 표본조사구가 분석되었다. 이러한 표본조사구는 전주시의 전형적인 토지이용유형을 대표하고 도심지역으로부터 다양한 이격거리를 갖도록 선정되었다. 종풍부성, 생활형의 패턴 그리고 외래종의 비율이 표본조사구의 헤메로비 정도와의 관계에 대해서 분석되었다. 식물종의 수는 적당히 영향을 받는 부지에서 가장 높게 나타남을 알 수 있었다. 이는 적당한 교란은 종풍부성 증가를 유도한다는 중간 교란 가설에 상응하는 결과이다. 인간의 영향을 가장 많이 받는 부지의 식물상은 일년생 식물과 외래종의 비율이 가장 높은 특징을 보였다. 그리고 일부 식물종들은 토지이용유형과 도시구역에 상응하는 유사한 분포를 갖는 세가지 그룹인 도시지역 기피종(땅비싸리, 졸참나무, 개옻나무 등), 도시지역 및 외곽지역에 널리 분포하는 종(닭의장풀, 개망초, 박주가리 등)과 도시지역 선호종(애기땅빈대, 개쑥갓, 서양민들레 등)으로 구분되었다.

주요어 : 토지이용유형, 종 풍부성, 일년생 식물종, 외래식물종

ABSTRACT

The purpose of this study is to analyze the distribution patterns and characteristics of plant species by human impact in urban areas. In order to achieve a comprehensive data acquisition of all autogenously introduced vascular plant species occurring in the city of Cheon-ju, this study made an analysis of 106 sample plots, each with a size of one hectare, These sample plots were selected to represent the typical land-use patterns within the city of Cheon-ju and to cover the various distances from the city center. Species richness, patterns of life forms, and the percentage of non-native species were analyzed in relation to the degree of hemeroby of the sample plots. It was found that the species number appeared the largest in sites that were moderately influenced. This result corresponds to the intermediate disturbance hypothesis that moderate disturbance leads to an increase in species richness. The flora of sites which were subject to the highest level of human impact, was characterized by a high proportion of annual species and non-native species. In addition, some species were

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divided into three groups with similar distribution corresponding to land-use type and urban zone: urbanophobic (e.g. *Indigofera kirilowii, Prunus sargentii, Rhus trichocarpa*), urbanoneutral (e.g. *Commelina communis, Erigeron annuus, Metaplexis japonica*) and urbanophilus (e.g. *Euphorbia supina, Senecio vulgaris, Taraxacum officinale*).

KEYWORD : LAND-USE TYPE, SPECIES RICHNESS, ANNUAL SPECIES, NON-NATIVE SPECIES

INTRODUCTION

Continuous land use and urbanization directly and indirectly influence environmental conditions, which play a major role in the landscape dynamics and changes. In Europe, flora and vegetation in urban-industrial areas were intensively investigated with regard to their ecological characteristics and habitats during many decades(e.g. Kunick, 1974; Sukopp, 1983; Sukopp, 1990; Sukopp and Wittig, 1993; Schulte *et al.*, 1993; Zerbe and Sukopp, 1996; Zerbe *et al.*, 2002).

Europe has a long tradition of assessing the naturalness of landscape and vegetation. According to the state of nature to which the man-induced changed state is related, two main approaches can be distinguished by their temporal perspectives: historical and status quo-oriented concepts(Kowarik, 1988; 1999). In the first, vegetation or habitats are related to pristine nature, i.e. that which has not been affected by human effect. For example, the degree of naturalness of a site is how similar it is to its original state without the influence of man. In contrast, status quo-oriented concepts, such as the hemeroby approach, assess the naturalness of a site without reference to former conditions. In this case the highest level of naturalness is when the system has not been affected by man and is self-regulated. The hemeroby concept was introduced by Jalas(1955) and further developed by Sukopp(1969) and Kowarik(1988). Kowarik(1990) defines hemeroby as "the sum of the effects of past and present human activities on the current site conditions or vegetation, which prevent the development to a final stage". This concept also integrates the site conditions that were irreversibly changed by human activities. Thus, the hemeroby approach allows us to assess human impact and the natural development, respectively, even of strongly changed urban-industrial sites(Kim, 2001).

Cities not only in Korea but all over the world, are gaining increasing importance as living spaces for humans. At present, approximately 78% of the Korean population are concentrated on 9% of the total land surface of Korea. About 25 million people(58.3% of the total population) live in big cities such as Seoul, Pusan, and Inchon(Ministry of Environment Korea, 1996). Urban ecology and nature conservation in urban-industrial areas has been recognized as a major task by the Korean administrations(Park, 1997; Seoul City, 2000; Kwon and Kim, 2001).

The present study focuses on the city of Cheon-ju in southwest Korea, considered representative for many continuously growing cities in Korea. This study aims to qualitatively and quantitatively assess human impact on the flora and sites in Korean urban area. First, which and how can influence anthropogenic impact on current flora? Thus, species richness, spectra of life forms, and the performance of non-native species are analysed in relation to the degree of hemeroby of the sites. Additionally, distribution of plant species was investigated with regard to land-use types and to the definite urban zone. This study is considered a contribution to the significant information for maintaining of biodiversity and nature conservation in Korean urban-industrial areas.

MATERIALS AND METHODS

The habitats in the city are differentiated according to land-use, which is decisive site factor in settlement areas(e.g. Schulte *et al.*, 1993). In order to achieve a comprehensive survey of all plant species occurring in the city of Cheon-ju, 106 sample plots, each with a size of 1 ha, were investigated(Figure 1). These sample plots met the following requirements: 1) they cover the whole distance from the city centre to the outskirts as a prerequisite for the subsequent analyse of floristic

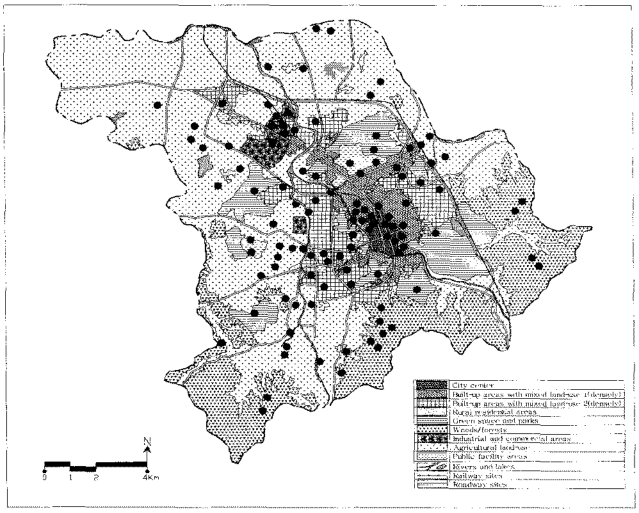

Figure 1. Location of the 106 sample plots and land-use in the city of Cheon-ju

gradients: and 2) they represent the typical land-use types within the city of Cheon-ju. The existing land-use types were classified into 31 categories according to the recommendations of Schulte *et al.*(1993) for European settlements and Seoul City(2000) for Korean settlements. This classification was based on aerial photographs, city maps, and field checks.

In order to analyse the varying human impact on the sample plots, which were differentiated according to the following disturbance factors(Table 1): (i) mechanical disturbances of the soils(impermeable paving ratio, built level); (ii) mechanical disturbances of the vegetation (percentage of planting of ornamental and useful plants, frequency of weeding or mowing); and (iii) chemical disturbance(frequency in use of fertilizers or pesticides).

The impact of each of the above mentioned disturbance factors was estimated and aggregated. The sample plots were then classified according to the five degrees of the hemeroby scale, ranging from oligohemerobic(H 1) to polyhemerobic(H 5)(Table 2). The sample plots with a similar degree of human impact were grouped according to their hemeroby value. Oligohemerobic(H 1) are very weakly influenced, like natural forests, mesohemerobic(H 2) weakly influenced, β-euhemerobic(H 3) moderately influenced, α-euhemerobic(H 4) strongly influenced and polyhemerobic(H 5) very strongly influenced sites, like city center.

The total number of species and the occurrence of life forms and non-native species were analysed with respect

Table 1. Matrix for the assessment of human impact on the sample plots

Disturbance factors		Class	Assessment	Rating
Mechanical disturbances of the soils	impermeable paving ratio (%)	0-20	very low	1
		20-40	low	2
		40-60	medium	3
		60-80	high	4
		> 80	very high	5
	Built level (number of stories)	0-2	very low	1
		3-4	low	2
		5-7	medium	3
		8-10	high	4
		> 11	very high	5
Mechanical disturbances of the vegetation	Percentage of planting of ornamental and useful plants	0-20	very low	1
		20-40	low	2
		40-60	medium	3
		60-80	high	4
		> 80	very high	5
	Frequency of weeding or mowing (per one year)	none or one time	low	1
		two times	medium	3
		over three times	high	5
Chemical disturbance	Frequency in use of fertilizers or pesticides (per one year)	none or one time	low	1
		two times	medium	3
		over three times	high	5

Table 2. Classifying according to the five degrees of hemeroby scale, ranging from oligohemerobic (H 1) to polyhemerobic(H 5)

Hemeroby degree	Designation	Total points
oligohemerobic(H 1)	very weakly affected	< 5
mesohemerobic(H 2)	weakly affected	6-10
α-euhemerobic(H 3)	moderately affected	11-15
β-euhemerobic(H 4)	strongly affected	16-20
polyhemerobic(H 5)	very strongly affected	> 21

to the sample groups with a different degree of hemeroby. The nomenclature of the plant species follows Lee(1993) and Park(1995). Informations on the origin of non-native species in Korea were taken from Lee(1993) and Park (1995). Life forms were distinguished on the basis of the system from Raunkiaer(1934) and the survey from Kim(2001) for species occurring in Korean rural areas.

On the basis of the cluster analysis of the inventory of species of the sample plots and with regard to their spatial location and to the dominant land-use the urban area of Cheon-ju was divided into three different zones: zone densely covered with buildings(Zone 1), loosely built-up zone(Zone 2), woods/forests zone(Zone 3).

RESULTS

1. Differentiation and quantification of the sample plots on a hemeroby scale

The distribution of the sample plots according to the five degrees of hemeroby is shown in Figure 2. Of the 106 sample plots, 42(ca. 40 %) were strongly influenced(H 4) and 12(11.3 %) very strongly influenced(H 5). The moderate disturbance sites(H 3 and H 2) were represent with 25(23.6%) and 20(18.9%) sample plots. Only 7(6.6%) sample plots were very weakly influenced(H 1). Thus, the majority of the sample plots in the city of Cheon-ju were subject to strong or very strong human impact.

2. Relationship between hemeroby and species richness

A total of 525 spontaneously occurring plant species were recorded in the 106 sample plots. The effect of increasing disturbance on species richness is shown in Figure 3, where the number of species that occurred in the sample plots with the same degree of hemeroby is displayed. Highest numbers of species occurred in the weakly(H 2 with 359 species) and moderately influenced (H 3 with 296 species) sample plots. However, only 129 and 154 species were recorded in the very strongly(H 5) and very weakly influenced(H 1) sample plots.

3. Relationship between hemeroby and the occurrence of different life forms

Figure 4 shows the percentage of life forms occurring

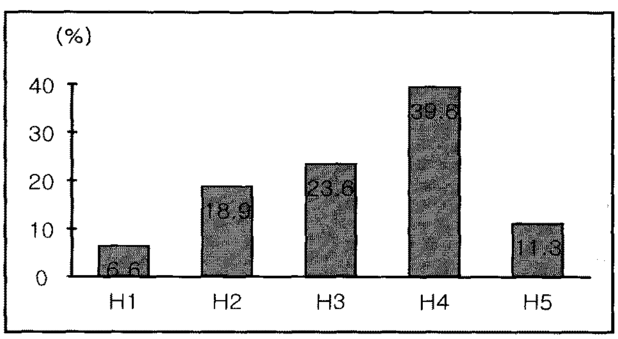

Figure 2. Percentage of the sample plots(n=106) on the hemeroby scale from H 1 to H5(H1: oligo-, H2: meso-, H3: β-eu-, H4: α-eu-, H5: polyhemerobic)

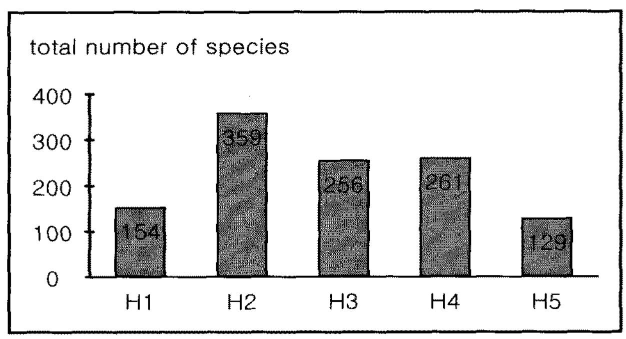

Figure 3. Total number of species occurring in the sample plots with different hemeroby degree(H1: oligo-, H2: meso-, H3: β-eu-, H4: α-eu-, H5: polyhemerobic)

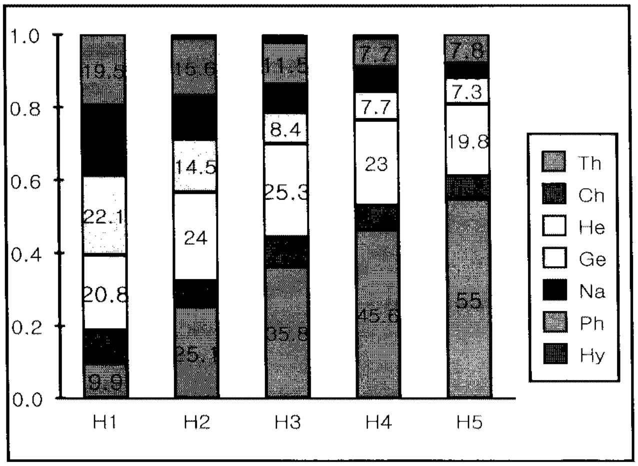

Figure 4. Percentage of life forms occurring in the sample plots with different hemeroby degree (H1: oligo-, H2: meso-, H3: β-eu-, H4: α-eu-, H5: polyhemerobic; Th: Therophytes, Ch: Chamaephytes, He: Hemikryptophytes, Ge: Geophytes, Na: Nanophanerophytes, Ph: Phanerophytes, Hy: Hydrophytes)

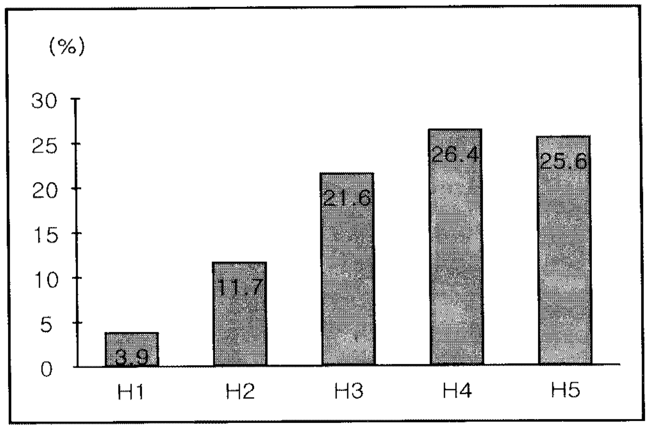

Figure 5. Mean percentage of non-native species occurring in the sample plots with different hemeroby degree(H1: oligo-, H2: meso-, H3: β-eu-, H4: α-eu-, H5: polyhemerobic)

in the sample plots with different hemeroby degree. The occurrence of annual species(therophytes) is correlated positively with the increasing anthropogenic impact. In very weakly influenced sample plots(H 1) only 9.9% of the species were therophytes. However, the percentage increased gradually to 55% in very strongly influenced sample plots(H 5). In contrast to therophytes the occurrence of phanerophytes, nanophanerophytes, and geophytes is correlated negatively with increasing anthropogenic impact. The percentage of phanerophytes, nanophanerophytes, and geophytes decreased from about 20% and 22% in very weakly influenced sample plots(H 1) to 7.8 %, 3.9% and 7.3% in very strongly influenced sample plots(H 5)(Figure 5).

4. Relationship between hemeroby and the occurrence of non-native species

Figure 5 shows mean percentage of non-native species occurring in the sample plots with different hemeroby degree. The occurrence of non-native is correlated positively with the increasing effect of man. In very weakly influenced sample plots(H 1) only 3.9 % were non-native species. However, the percentage increased to 26.4 % and 25.6 % in strongly influenced(H 4) and very strongly influenced(H 5) sample plots.

5. Distribution of species corresponding to land-use types and urban zone

In order to clear demonstrate the distribution types of species in the city of Cheon-ju, some species with similar distribution were selected on the basis their frequency (frequency>III) in the different urban zone(Table 3). These species were divided into three groups with similar distribution corresponding to land-use type and urban zone.

A lot of species of wooden plants or forest plants belonged to first group which occur with a high frequency in the outskirts of the city, especially in woods and forests(e.g *Agrimonia pilosa, Artemisia keiskeana, Cocculus trilobus, Indigofera kirilowii, Lespedeza maximowiczii, Prunus sargentii, Pteridium aquilinum v. latiusculum, Quercus acutissima, Quercus serrata, Rhododendron mucronulatum, Rhus trichocarpa, Rosa multiflora, Smilax china, Stephanandra incisa, Styrax japonica and Zanthoxylum schinifolium*)(Figure 6). 16 species belonged to second group as the most frequent species in the city of Cheon-ju(e.g. *Acalypha australis, Achyranthes bidentata v. tomentosa, Artemisia princeps v.*

Table 3. Table of overview of three groups with distribution of species corresponding to land-use types and urban zone(Zone 1: zone densely covered with buildings, Zone 2: loosely built-up zone, Zone 3: woods/forests zone; G1: very densely built development, G2: densely built development, G3: loosely built development with green space, G4: loosely build-up area with big ruderal area, G5: agricultural land-use, G6: parks, G7: woods/forests)

	Zone 1			Zone 2		Zone 3	
	G1	G2	G3	G4	G5	G6	G7
Number of sample plots	16	16	19	21	13	6	15
First group of species							
Agrimonia pilosa	.	.	I	.	.	V	III
Alnus hirsuta	.	.	.	I	.	III	III
Ampelopsis heterophylla	.	I	.	.	.	.	III
Artemisia keiskeana	.	.	.	.	.	V	III
Arundinella hirta	.	.	.	I	.	V	I
Athyrium brevifrons	I	.	.	I	.	IV	I
Athyrium pycnosorum	.	.	.	.	.	V	II
Carex humilis	.	.	.	.	.	.	IV
Carex siderosticta	.	.	.	.	.	II	III
Castanea crenata	.	.	I	.	.	.	III
Cocculus trilobus	.	I	I	I	.	V	IV
Corylus sieboldiana	.	.	.	.	.	II	III
Eupatorium chinense v. simplicifolium	.	.	.	.	.	IV	III
Eupatorium lindleyanum	.	.	.	.	.	III	II
Gymnocarpium dryopteris	.	.	.	.	.	IV	II
Indigofera kirilowii	.	.	.	I	.	V	V
Juniperus rigida	.	.	.	.	.	I	III
Lespedeza cyrtobotrya	.	.	.	I	.	I	III
Lespedeza maximowiczii	.	.	.	.	.	V	IV
Ligustrum obtusifolium	.	.	I	.	.	II	III
Lindera glauca	.	.	.	.	.	.	III
Lindera obtusiloba	.	.	.	.	.	I	IV
Lindernia micrantha	.	.	.	.	IV	.	.
Liriope spicata	.	.	I	I	.	V	II
Ludwigia prostrata	.	.	.	I	V	.	.
Prunus sargentii	.	.	.	.	.	V	IV
Pteridium aquilinum v. latiusculum	I	.	I	I	.	V	IV
Quercus acutissima	.	.	I	.	.	III	III
Quercus aliena v. pellucida	.	.	.	.	.	III	.
Quercus serrata	.	.	I	.	.	IV	IV
Quercus x urticaefolia	.	.	.	.	.	III	I
Rhododendron mucronulatum	.	.	.	.	.	IV	IV
Rhus chinensis	.	I	.	.	.	V	II
Rhus trichocarpa	.	.	.	.	.	IV	IV
Rosa multiflora	.	I	I	I	.	V	IV
Rubus corchorifolius	.	.	.	.	.	.	III
Smilax china	I	.	I	I	.	V	V
Smilax nipponica	.	.	.	.	.	.	III
Sorbus alnifolia	.	.	.	.	.	III	I
Spirodela polyrhiza	.	.	.	I	III	.	.
Stephanandra incisa	.	.	.	I	.	IV	III
Styrax japonica	.	.	.	.	.	V	III
Viburnum wrightii	.	.	.	.	.	III	II
Youngia denticulata	.	.	.	.	.	III	I
Zanthoxylum schinifolium	.	.	.	I	.	V	V
Second group of species							
Acalypha australis	V	V	V	IV	V	III	.
Achyranthes bidentata v. tomentosa	III	V	V	V	III	V	I
Artemisia princeps v. orientalis	V	V	V	V	IV	V	.
Commelina communis	IV	V	V	V	III	V	IV
Cyperus iria	V	V	III	III	V	IV	.
Eleusine indica	IV	V	III	III	V	III	.
Erigeron annuus	V	IV	V	V	IV	V	I
Erigeron canadensis	IV	V	V	V	V	IV	I
Lactuca indica v. laciniata	IV	V	V	V	III	IV	II
Metaplexis japonica	IV	V	IV	V	IV	V	I
Oxalis corniculata	V	V	V	III	II	V	.
Persicaria vulgaris	IV	IV	V	IV	IV	IV	.
Plantago asiatica	III	IV	V	III	II	V	.
Portulaca oleracea	V	V	V	IV	V	IV	.
Setaria viridis	V	V	V	V	III	III	I
Stellaria aquatica	IV	IV	V	IV	II	V	.
Third group of species							
Agropyron tsukushiense v. transiens	I	II	III	I	.	.	.
Amaranthus lividus	III	IV	III	I	II	.	.
Calystegia hederacea	III	II	V	II	I	.	.
Digitaria violascens	IV	IV	IV	II	II	I	.
Euphorbia supina	V	V	IV	II	.	I	.
Oxalis corniculata f. rubrifolia	V	IV	IV	I	.	.	.
Poa annua	V	V	V	I	II	I	.
Poa pratensis	II	II	III	.	.	.	.
Polygonum aviculare	II	V	IV	II	II	.	.
Rorippa indica	IV	V	IV	I	II	.	.
Sagina japonica	IV	I	II	.	.	.	.
Senecio vulgaris	III	II	III	I	I	.	.
Solanum nigrum	III	V	III	I	I	.	.
Taraxacum officinale	V	V	V	II	I	.	.

* I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%

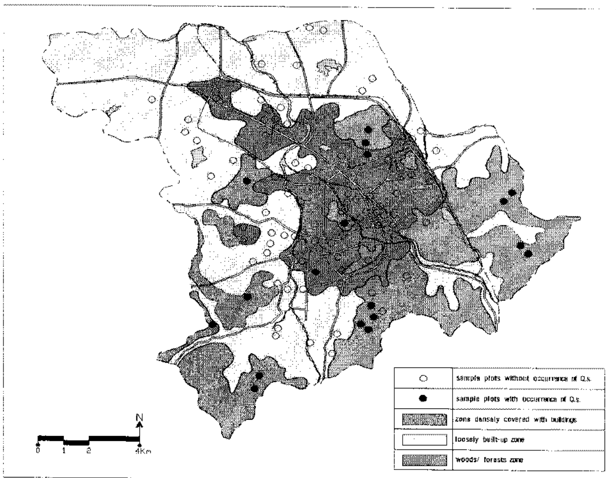

Figure 6. An example for urbanophobic distribution: *Quercus serrata* in Cheon-ju

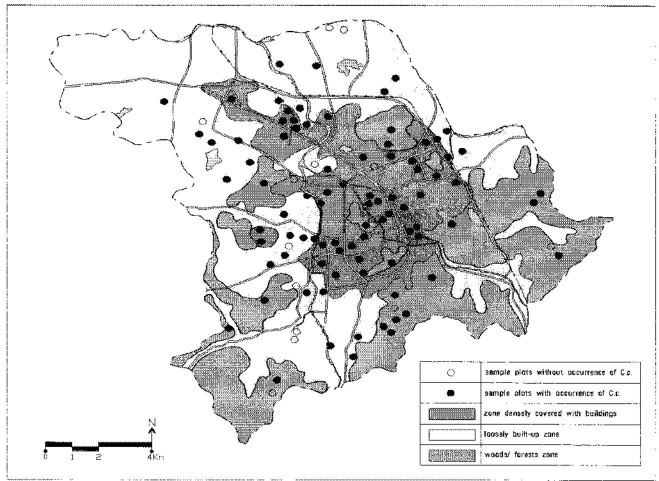

Figure 7. An example for urbanoneutral distribution: *Commelina communis* in Cheon-ju

orientalis, Commelina communis, Cyperus iria, Eleusine indica, Erigeron annuus, Erigeron canadensis, Lactuca indica v. laciniata, Metaplexis japonica, Oxalis corniculata, Persicaria vulgaris, Plantago asiatica, Portulaca oleracea, Setaria viridis and Stellaria aquatica)(Figure 7). Third group ofspecies which show a clear distribution in the built-up urban zone and occur with decreasing frequency in the non-urbanized area(e.g. *Agropyron tsukushiense v. transiens, Amaranthus lividus, Calystegia hederacea, Digitaria violascens, Euphorbia supina, Oxalis corniculata f. rubrifolia, Poa annua, Poa pratensis, Polygonum aviculare, Rorippa indica, Sagina japonica, Senecio vulgaris, Solanum nigrum and Taraxacum officinale*)(Figure 8).

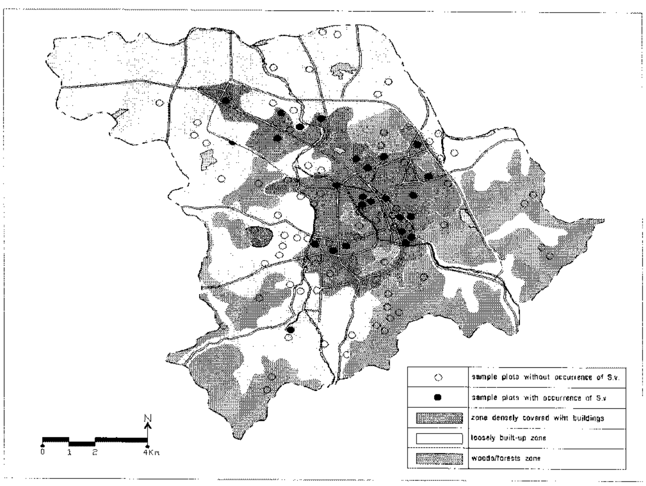

Figure 8. An example for urbanophilus distribution: *Senecio vulgaris* in Cheon-ju

DISCUSSION

The hemeroby concept was introduced by Jalas(1955) and further developed by Sukopp(1972), Blume & Sukopp (1976) and Kowarik(1988). The European concept of hemeroby as a measure of human impact integrates the spectrum of anthropogenic disturbances that influence a distinct ecosystem type. The study revealed that anthropogenic disturbance of natural sites has a considerable effect on species richness, life form patterns, and the occurrence of non-native plant species. According to the intermediate disturbance hypothesis, formulated by Connell(1978) and Grime(1979), moderate disturbance leads to an increase in species richness compared to sites that are very weakly or very highly disturbed. The highest number of species was found in the weakly(H 2) and moderately influenced (H 3) sites. Thus, both high or low levels of anthropogenic disturbance have a negative effect on species richness (Figure 3). This accords with the investigations on the flora of Berlin(Kunick, 1974; Kowarik, 1988; 1990; Schmitz, 2000).

The results on the occurrence of therophytes in sample plots with varying degree of anthropogenic disturbance are similar to those obtained for the urban flora of Berlin (Kowarik, 1988; Schmitz, 2000) and Vienna (Jackowiak, 1988), which show a positive correlation between the degree of hemeroby and percentage of therophytes. For the assessment of the intensity of human impact on sites and vegetation, Sukopp(1969) and Blume & Sukopp(1976) have suggested the quantification of both the percentage of the therophytes(annuals) and the non- native species. Whereas they considered the therophytes more an indicator for short-termed disturbances, the non-native species are more indicators for long-termed human impact. In Berlin for example, highest percentages of therophytes as well as non-native species were recorded within those vegetation types, where the intensity of human impact was assessed as being very high(Kunick, 1974; Kowarik, 1988). In general, the percentage of non- native species increased with increase in anthropogenic effects at a site. There is a close correlation between the percentage of non-native species and the intensity of human impact on sites and vegetation. Heavily disturbed sites show higher percentages of non-native species compared with less disturbed sites(Figure 5).

The consideration about the groups of plant species with similar distribution in urban area shows the dependence on species occurring in definite urban zone and land-use type. Taking into consideration the behaviour of species in the conditions of urbanization that appear in the form of the present local range, it has been proposed to divide by Wittig *et al.*(1985) urban flora into three groups of species: urbanophobic, urbanoneutral and urbanophilus. The three groups of species which were selected in this study correspond to the groups of urban flora by Wittig *et al.*(1985).

The knowledge for the connections between human impact and their effect on flora and vegetation are significant information for ecological landscape planning and useful nature conservation in urban-industrial areas. A major task for the future will be the developments of comprehensive data on flora, vegetation and habitats found in Korean in urban-industrial areas as an aid to ecological decision making and to nature conservation especially in urban-industrial areas.

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