S-1

Restoration planning of the Seoul Metropolitan area, Korea toward eco-city

Lee, Chang Seok

Faculty of Environment and Life Sciences, Seoul Women's University, Seoul
139-774, Korea

ABSTRACT

In order to prepare a basis for ecological restoration of the Seoul Metropolitan area, ecological diagnoses on soil physico-chemical properties and vegetation structure were carried out. Land use patterns, actual vegetation, and biotope patterns were also investigated based on aerial photograph interpretation and field checks. I formulated landscape elements overlaying those data and evaluated the ecological value of each element.

Soil pollution was evaluated by analyzing soil samples collected in each grid on the mesh map, divided by 2km x 2km intervals. Soil samples were collected in forests or grasslands escaped from direct human interference. Soil pollution evaluated from pH, and SO_4, Ca, Mg, and Al contents of soil was more severe in the urban outskirts than in the urban center. Those soil environmental factors showed significant correlation with each other. Vegetation in the urban area was different in species composition from that in suburban areas and showed lower diversity compared with that in the suburban areas. Successional process investigated by population structure of major species also showed a difference. That is, successional trend was normal in suburban areas, but that in urban areas showed a retrogressive pattern. The landscape ecological map of Seoul indicates that the urban center lacks vegetation and greenery space is restricted in urban outskirts. Such an uneven distribution of vegetation has caused a specific urban climate and thereby contributed to aggravation of air and soil pollution, furthermore causing vegetation decline. From this result, it was estimated that such uneven distribution of vegetation functioned as a trigger factor to deteriorate the urban environment. I suggested, therefore, a restoration plan based on landscape ecological principles, which emphasizes connectivity and even distribution of green areas throughout the whole area of the Seoul to solve this complex environmental problem. In this restoration plan, first of all, I decided the priority order for connection of the fragmented greenery spaces based on the distances from the core reserves comprised of green belt and rivers, which play roles as habitats of wildlife as well as for improvement of urban environment. Next, I prepared methods to restore each landscape element included in the paths of green network to be constructed in the future on the bases of such preferential order. Rivers and roads, which hold good connectivity, were chosen as elements to play important roles in constructing green network by linking the fragmented greenery spaces.

INTRODUCTION

Urbanization is a big problem not only in developed countries but also in developing countries. For a long history, we have recognized the natural environment as a resource to be exploited. However, our attitude toward nature has begun to shift profoundly as the negative effects of our industrialized economy have become clearer and more catastrophic. In an urban environment, greenery space within a city is indispensable for the well being of citizens, considering its diverse ecological functions, such as filtering pollution, conserving biodiversity, controlling climate, and so on (Gilbert 1991, Grey and Deneke 1986, Miller 1997).

The space that the natural environment occupies is getting reduced with the progress of urbanization in the urban area. Meanwhile the artificial environment is extended more and more, thereby worsening environmental stress due to the unbalance between both environments. As a consequence, the ecological functions of nature, which are responsible for buffering those environmental stresses gradually shrink (Taoda 1979, Freedman 1986, Smith 1990, Miller 1997).

The ecosystem maintains balance through homeostatic mechanisms, but environmental pollution due to rapid population growth and industrialization prevent it from sustaining its normal structure and function (Innes and Oleksyn 2000). In Korea, vegetation has begun to show decline symptoms in the vicinity of the industrial complexes and big cities (NIER 1981, Lee 1992) and loss of basic cations, such as Ca^{2+} and Mg^{2+} as essential elements, and an increase of toxic Al^{3+} in soil due to acidification have made the ecosystems degraded even more (Kim 1991, Lee 1992, Kim 1994, Rhyu 1994, Rhyu and Kim 1994). Restoration of degraded ecosystems is, therefore, urgently required to prevent the spread of such additive pollution damage (Gunn 1995).

In urban areas, human influences are everywhere, and some ecosystem types are virtually gone. Therefore, no big restoration project is adequate in a big city without a major restoration component. But the vast majority of restoration projects are tiny because most people recognize that restoration in the level of landscape requires much cost (Noss 1991). But landscape restoration need not be prohibitively expensive. Landscape-scale restoration can rely largely on the natural recovery processes of ecosystems, aided by human labor. Restoration ecology must be expanded from the local and community levels to the regional landscape level to achieve human re-harmonization with nature in urban areas. Recognizing spatial contexts is a key to carrying out landscape-scale restoration projects. In the projects, obtaining a regional land database is preferentially required (Noss 1991). A map with information on land in the region of interest is a good place to start. Such a map portrays the skeleton to which we add flesh.

This study has two goals. The first is to get information on the ecological degradation in terms of soil properties, vegetation structure and land use in the Seoul Metropolitan area. The second is to suggest a restoration plan at the landscape level by synthesizing those results.

STUDY AREA

Seoul, the capital city of Korea is located in the central Korean Peninsula and covers 605.4km^2 of land (long. 126°46′15″- 127°11′15″E, lat. 37°25′50″- 37° 41′45″N). The altitude of the study area ranges from 20m to 799.5m above the sea level (Fig. 1). Parent rock of the mountainous areas around Seoul mostly consists of granite and gneiss, and that in the flat land of the riverside is of alluvium (Fig. 2). The soil of these areas is composed of Suam, Osan, Asan, and Anryong series developed on bedrocks of gneiss and granite (Seoul City 1997). The climate of Seoul is best described as a continental climate with warm and moist summer and cold and dry winter. The mean annual temperature and precipitation for the most recent 30 years were 11.5 C° and 130.7 cm, respectively (Korea Meteorological Administration, 2002).

The mountainous vegetation of Seoul consists of four major plant communities in an elevation gradient: *Pinus densiflora* community in mountain peaks; *Quercus mongolica* community in upper slopes; *Carpinus laxiflora* community in lower slopes; *Zelkova serrata* community in mountain valleys (Lee 1997b). On the other hand, alder (*Alnus japonica*) stands remain in plains and valleys of lowlands, which have escaped urbanization (Seoul city, 1997, 1998).

Much of the natural landscape in the Seoul metropolitan area has disappeared by extensive deforestation for fuel, building materials, and other activities during the 20th Century (Yim 1989). The human population of Seoul has increased from 2.4 million in 1960 to 11 million in 1998. During this period, the percentage of green space has decreased from 70% in 1960 to 24% in 1998 to accommodate housings for such population (Yim 1989, Kim and Choe, 1997, Seoul City 1998). Seoul City has designated most of the forested mountains in its suburb areas as "greenbelt zones" as an attempt to prevent further loss of green space. Under the current City's ordinance of "Green Belt," no commercial, industrial, or urban development is permitted (Kim and Choe 1997).

METHODS

Monochrome aerial photographs (1:5,000 scales), taken in winter of 1996, were used to identify vegetation types and landscape boundaries. Identified vegetation types and landscape elements were confirmed by field checks. All of the landscape elements in the urbanized areas were confirmed by visiting all the blocks divided by roads with widths of more than 8m. The identified landscape attributes were overlapped on the topographical maps at 1:1,000 scale. Patches smaller than 1mm on the map were excluded from this study due to uncertainty of their sizes and shapes (Nakagoshi *et al.*, 1992). Mapping was carried out by using ArcView GIS (Geographic Information System). Landscape ecological analyses on the map were determined with ArcView GIS software (ESRI, 1996).

Soil samples were collected from 320 grids divided by 2km × 2km throughout the whole area of Seoul. Soil pH was measured with a bench top probe after mixing the soil with distilled water (1:5 ratio, w/v) and filtering the extract (Whatman No. 44 paper). Ca^{2+} and Mg^{2+} contents were measured from the extract by 1N ammonium acetate solution of pH 4.0 by inductively coupled plasma atomic emission spectrometry (ICP), and the extract for Al^{3+} analysis was prepared by using 1N ammonium acetate solution of pH 7.0. SO_4 content was measured by spectrophotometer (Allen et al. 1986).

Cover and abundance data of major tree species in each community were transformed from the ordinal scale of Braun-Blanquet (1964), and subjected to Detrended Correspondence Analysis (DCA; Hill 1979). The difference of plant species diversity between urban and suburban areas was compared by species order-dominance curve. Dynamics of landscape pattern was extrapolated from the changes in species compositions from relatively young to mature forests as reflected by frequency distributions of tree diameters (at breast height for mature trees and at stem base for saplings and seedlings).

RESULTS

Landscape structure

In a landscape ecological map of Seoul, vegetation composed of secondary forest, plantation, and agricultural fields was restricted in the urban outskirts; consequently, the urban center has little vegetation (Fig. 3). Moreover, vegetation in the urban center was low in ecological quality as most was usually fragmented into small patches and, in addition, had been introduced for landscape architecture without ecological consideration. Table 1 summarizes a configuration of landscape element types identified from the map. The area was larger in the order of urbanized area, secondary forest, plantation, agricultural fields, and so on.

Spatial differences of soil properties

Soil pH tended to lower in the urban outskirts than in the urban center (Fig. 4). Ca^{2+} and Mg^{2+} contents of soil showed similar trends to pH, but sulfate

Changes of vegetation structure

With respect to the results of DCA ordination on the Mongolian oak (*Quercus mongolica*) stands, which distribute widely as the representative vegetation of the late successional stage in Korea, stands in the urban area showed different species composition from those in the suburban area (Fig. 5). Stands in the urban area were also different in species diversity. That is, the urban stands were lower in species richness and the species order-dominance curve was steeper compared with suburban ones (Fig. 6).

As a result of size class distribution of major trees composing Mongolian oak stands, the suburban stands possessed individuals of Mongolian oak as young plants on the forest floor, while urban ones did *Sorbus alnifolia* instead of them (Fig. 7). From those results, continuous maintenance of the former stands and succession of the latter ones by *Sorbus alnifolia* were expected.

Discussion

The effects of vegetation lack in the urban center on climate

The climate of a given location may be described from three aspects: macroclimate, mesoclimate, and microclimate (Hiesler and Herrington 1976). Cities do not exert an influence on the macroclimate as it is the general climate for a given region covering hundreds of square kilometers. Mesoclimate describes variations from the macroclimates due to effects caused by topographic features, water bodies, and other influences. Vegetation reduces air temperature in the urban area and, thereby, can influence the urban mesoclimate (Parker 1989, Souch and Souch 1993).

Cities are often referred to as urban heat islands, with the urban center having the highest temperatures. This is primarily due to the low amount of vegetation in an urban center compared to that in the suburbs and beyond (Figs. 3 and 8 as an attempt to prevent further loss of green space). Cities also use large amounts of energy and emit this energy as waste heat, further warming urban heat islands.

Buildings, asphalt, and concrete absorb solar radiation and emit long-wave radiation that heats the atmosphere (Akbari et al. 1990). Moreover, those artificial structures hold heat for extended periods. The heat occurring from buildings, asphalt, and concrete heated by solar radiation moves from those structures to the cool air as the air temperature decreases after sunset and, thereby, forms atmospheric temperature inversion (warm air over cold air) (Chiras 2001, Seoul City 2000).

On the other hand, trees and other vegetation use large amounts of solar energy, evaporating water to cool leaf surfaces. This function can also contribute to reduce the air temperature in the urban area. Trees and other vegetation can also contribute to temperature reduction by reducing urban energy consumption in the following two ways; by intercepting and using solar energy, and by reducing building energy demand through shading and reducing wind speed. Such vegetation functions cause a greater temperature difference between the urban area and suburbs or beyond (Akbari et al. 1992). Indeed, Seoul shows a remarkable heat island effect (Seoul City 2000).

The effects of the urban mesoclimate on soil physico-chemical properties

Air temperature inversions trap polluted urban air masses over cities for extended periods. Moreover, the micro-current of air caused by temperature differences between urban areas and suburbs and beyond can transport light gaseous air pollutants from the urban center to the urban outskirts (Miller 1997).

The differences of soil properties depended on the site in Seoul could be explained in relation to such transport of pollutants by micro-currents of air (Fig. 4). Soil acidification was more severe, and sulfate (SO_4) content was higher in the urban outskirts compared with the urban center (Fig. 4). Soil acidification in those sites was due to deposition of acid precipitates, such as SO_x and NO_x (Rhyu and Kim 1994). Gaseous SO_x and NO_x are transformed to sulfuric acid (H_2SO_4) and nitric acid (HNO_3) in response to water in the air and soil and, thereby, become the causal factors of soil acidification.

The acidified soil of the urban periphery contains a lower concentration of the essential cations, such as Ca^{2+} and Mg^{2+} than in the urban center because they were leached through cation exchange mechanisms (Ulrich 1980). But higher contents of Ca^{2+} and Mg^{2+} in the urban center are also related to heavy particles occurring from building materials, or from calcium chloride ($CaCl_2$) used for snow smelting. Furthermore, the acidified soil releases toxic ion, Al^{3+}, which inhibits cell division and consequently induces retardation in plant growth. Such serial change of soil chemical properties known for causal factors of forest decline was found in the results of this study (Ulrich 1980).

The effects of urban mesoclimate on vegetation structure

The Mongolian oak forest located in urban areas showed different species composition, lower diversity, and retrogressive successional trends compared to those in suburbs and beyond (Figs. 5, 6 and 7). Such serial changes in vegetation are initiated by the development of thin crowns due to the decline of the vigor of dominant Mongolian oak, which composes the overstory canopy exposed to severe air pollution (Kim 1994). The thin crowns of the canopy trees cause a thick growth of sub-trees, such as *Sorbus. Alnifolia,* with an increased supply of light and precipitation, thereby leading to a change of vegetation structure and successional trends (Smith 1974, McClenahan 1978, Scale 1980, Lee et al. 1998, 2000). Such change of vegetation structure again induces another alteration. Such alterations appear in decrease of light intensity and decline in species richness due to that (Fig. 7).

Retrogressive succession appears usually under excessive disturbance and a possible phenomenon in intensively or frequently disturbed sites (Runkle 1985). Although such situations have been frequently observed around the industrial complexes exposed to severe air pollution (Kozlowski 1985, Shugart and McLaughlin 1985 Freedman 1986, Gunn 1995, Lee 1993), it is a very rare phenomenon in urban areas. Such a difference would be due to that the pollution damage in the industrial areas is usually intense and acute, whereas the pollution in the urban areas is mild and chronic (Freedman 1995). From this viewpoint, we might expect severe air pollution in Seoul. But several indices related to pollution refuse such deduction (Seoul city 1997, Ministry of Environment 2000). Therefore, such results could be explained due to synergistic effects of chronic air pollution and urban climate rather than from the aggravation of pollution (Olson and Sharpe 1985). That is, several factors, such as atmospheric temperature inversion, occurrence of micro-current of air due to local temperature difference, and soil acidification due to air pollutants transported by such micro-currents of air all exert influence on vegetation change.

Those changes recognized as "new type of forest decline" appear as a general phenomenon above the upper slopes on the mountainous ridge enclosing Seoul as a basin type city, in which Mongolian oak stands dominate (Seoul city 1997, 1998).

Strategy for ecological restoration

Ecological maps made by dividing each landscape element type show that most of vegetation are restricted in urban fringe, whereas artificial facilities occupy urban center and evenly distribute (Fig. 8). Such uneven distribution of vegetation can be regarded as an effective causal factor of various phenomena related to ecological degradation, which was mentioned above. In this respect, a restoration plan based on landscape ecological principle, that is to say, creating the even distribution of vegetation can provide a clue to solve the problem. As was shown in Fig. 8, we should introduce greenery space in the urban center occupied by artificial facilities to get the even distribution of vegetation. In order to practice such a restoration, first of all, we have to decide the direction of the green network and the restoration methods for each landscape element included on the network. To find out the direction of the green network, first, I postulated enlargements of greenery space with 100m to 400m widths at 100m intervals from forest vegetation and rivers that I regarded as existing base vegetation. Forest vegetation includes natural vegetation and artificial plantation, which is similar to natural vegetation as it is replaced by natural vegetation through succession (Fig. 7). Rivers show connectivity although the landscape element types had low ecological quality, therefore, I included them in base vegetation.

Enlargement by 100m breadth can contribute to ensure connectivity of many fragmented forest vegetations as were shown in the hypothetical green pathways 1 to 7. 200m enlargement improved greatly the connectivity between forest vegetation themselves (hypothetical green pathways 10 and 13) and forest and river (hypothetical green pathway 8, 9, 11, and 12; Fig. 9). 300m and 400m enlargements restored not only almost complete connectivity but also realized even distribution of greenery space (Fig. 9). Connecting the fragmented patches by those green pathways can make the urban landscape equipped with incomplete structure restore the ecological health in both terms of biological conservation as well as environmental problems. On the other hand, Seoul has many satellite cities in the surrounding areas. Urban sprawl of this type causes severe environmental problems as well as biological conservation problems. From this viewpoint, these interconnections of the fragmented patches in the urban outskirts could also contribute to solve the problems.

The above maps, in which natural vegetation was hypothetically extended, show the direction of green network that should be created in several parts. Up to now, Seoul City has carried out "an environmental policy" to increase the dimension of the green area and improve its quality through "a project for the creation of the urban environmental forest", "a 10 million tree planting campaign", "a campaign to create school forests", and so on. Most of these greening projects have not followed this ecological restoration strategy, at least until now. But in order to realize true ecological restoration to solve environmental problems and to achieve desirable biological conservation, such a systematic strategy is inevitably required.

Furthermore, a restoration plan of each landscape element included in hypothetically extended parts should be also prepared. Landscape elements, such as excessively managed plantation located in the urban center, agricultural fields, and urbanized areas appearing in the extended parts of each hypothetical map are objects for restoration. A restoration plan of each landscape element type can be practiced on the bases of information about the potential natural vegetation (See Table 3, Seoul city 1997, 1998).

Our restoration plans were focused on the riverside and footpath, which maintain good connectivity. When I sought to restore the footpath, I chose two methods, depending on width of the space (Fig. 10). When it is narrow, I tried to transplant street trees, which are planted on the roadside, to the center of the footpath. Furthermore, I planned to increase vegetation volume by introducing sub-trees, shrubs, and herbs on both sides. In the case of wide footpaths, I applied similar methods but increased the number of tall trees.

In order to restore the urban river with low ecological quality, I selected a stepwise restoration, in which the urban river will recover a feature of the natural river gradually over time, by imitating natural rivers (Fig. 11). I regarded natural rivers within the CCZ (civilian control zone), which have remained without any artificial disturbance for about 50 years since the Korean War, as our restoration model (Lee, C.S. unpublished data). In the initial stage, I plan to introduce plants on concrete block remained to ensure safety at flooding. To accomplish this restoration practice, I used soil ameliorators to improve the physicio-chemical properties of the planting bed.

S-2

댐 저수지에서의 어류서식환경 복원

김동섭
한국수자원공사 수자원연구소

우리나라의 대형댐은 다목적댐으로서 1965 년과 1973 년에 완공된 섬진강댐과 소양강댐을 시작으로 최근까지 13 개의 댐이 건설되었다. 이 외에도 용수전용댐과 농업용 댐을 포함하는 대댐(높이 15.0m 이상, 높이 10m~15m 로서 길이가 2,000m 이상과 저수용량이 300 만㎥이상)은 1999 년말 기준으로 1,214 개로 조사되었다(수자원공사, 2001). 대부분의 대형댐들은 농□생□공업용수를 위한 수자원확보, 홍수조절과 전력생산을 목적으로 건설되었다. 이러한 댐의 건설은 하천의 물 흐름을 차단함으로서 그곳에 서식하는 생물의 환경에 영향을 미치게 된다. 특히, 바다와 하천을 왕래하는 회유성 어종에게는 댐의 위치에 따라서는 서식처와 산란처가 소실되는 치명적인 영향을 줄 수도 있다. 또한 최근에 건설되는 댐들은 작은 강을 대상으로 하면서 하구로부터 가깝게 위치하게 되는 경향을 보이게 되었다. 댐이 하구로부터 가까워지면서 회유성 어류 등의 어족보호에 대한 관심이 사회적으로 문제가 대두되게 되었다. 우리나라에는 낙동강, 영산강, 금강 하구둑의 대형 하구언에 어도가 시설되어 있으며, 하천을 횡단하는 작은 보에 어도가 설치되어 있다. 대형 다목적댐의 어도는 국내에 설치된 곳이 전무하며, 최근에 양양 양수발전댐에 시설되는 어도가 유일한 실정이다. 외국의 경우 높이 20-30 m 이상의 대형댐에는 경제적인 부담과 어류소상에 대한 비효율이 우려되어 어도시설을 하지 않고 있는 실정이다(寺薗등, 1996).

하천을 차단하는 구조물에 의한 어류 서식□산란처에 대한 영향은 단순히 어도에 의해서만 해결할 수 있는 문제는 아니다. 하천에 서식하는 어류는 다양한 종이 분포하며, 또한 각 종마다 특정한 생리□생태적 특성을 갖는다. 그러므로 저수지 및 하천에서 어류를 보전하기 위해서는 어류의 분포 및 생활사와 하천이 갖는 고유의 특성을 고려한 다양한 대책이 필요할 것으로 사료된다.