Assessment and Connection Method of Fragmentary Urban Green Space Using Gravity Model

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Abstract. This research presents the connecting method for the ecological network among the selected areas through the evaluation of the connectivity of the classified urban green space in Seoul. The study was divided into two; 1st stage of the classification of the types of greens and 2nd stage of the evaluation of connectivity. In the stage of classification of the type of the greens, the research evaluated the diversity of the vegetation and the value of the possibility of inhabitation of wild birds and then, classified the greens into a core green, which is a patch, base green, and connecting or stepping stone-type green, which is a corridor, in aspect of the landscape ecology. In the evaluation of connectivity, the research also selected and classified the areas for ecological network and suggested the connecting method by conducting the evaluation based on a gravity model with indexes such as area index, conference index, and fractal index, in order to find the relationship between the greens.

Keywords: Core Green Area, Base Green Area, Linkage or Stepping Stone Green Area, Gravity Model, District Ecological Network, Basin Ecological Network.

1 Introduction

Recently, development flow has been changed from physical development alone to balanced development with environment and restoring equilibrium of ecosystem for new understanding of necessity of new development flow. Based on this new understanding, preservation area and development area are divided through site analysis and new land use plan has been established for the future development area(Ministry of construction & transportation . Korea institute of construction technology, 2002).

The large scale of development may scatter the green spaces. This can block the opportunity of access to green space and increase air pollution because of damaging ecosystem and dropping capability of purification followed by declining green space in urban area (Kim, 1998). In terms of urban ecological geography, there are many wild animals have been exterminated and reduced biological diversity due to scattering green space and decreasing green area(Scott et al., 1993). On this reason, necessity of urban green space connectivity has been increased and greenway, green axis, ecosystem network and other idea have been introduced (MacArthur and Wilson, 1967).

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The biggest possibility of threatening species diversity is frequently occurred isolation of green spaces. This phenomenon, natural habitat fragmentation and isolation, lead to reduce the number of individual. Moreover, this affects the minimizing quality and quantity of habitat spaces or destroys the habitat and isolation through interfering ecosystem (Wilcove et al., 1986; Laurance and Bierregaard, 1997). The purpose of this research proposes ecological network method in ecologically isolated mountainous urban green spaces. The valuation and pattern of horticultural diversity and value of habitat for wild birds are analysed and proposed using research of linking scattered each urban green area.

2 Research Contents and Procedure

This research is divided by 2 phases, green spaces type and rating connectivity, to build ecological network in existing urban area. In the 1stphase, rating items, ecology diversity and valuation of wild birds habitat, are established through theory study for evaluating possibility of life habitat. Evaluating connectivity is proceeded followed by establishing connectivity index, evaluating connectivity, and site selection and modelling in phase 2.

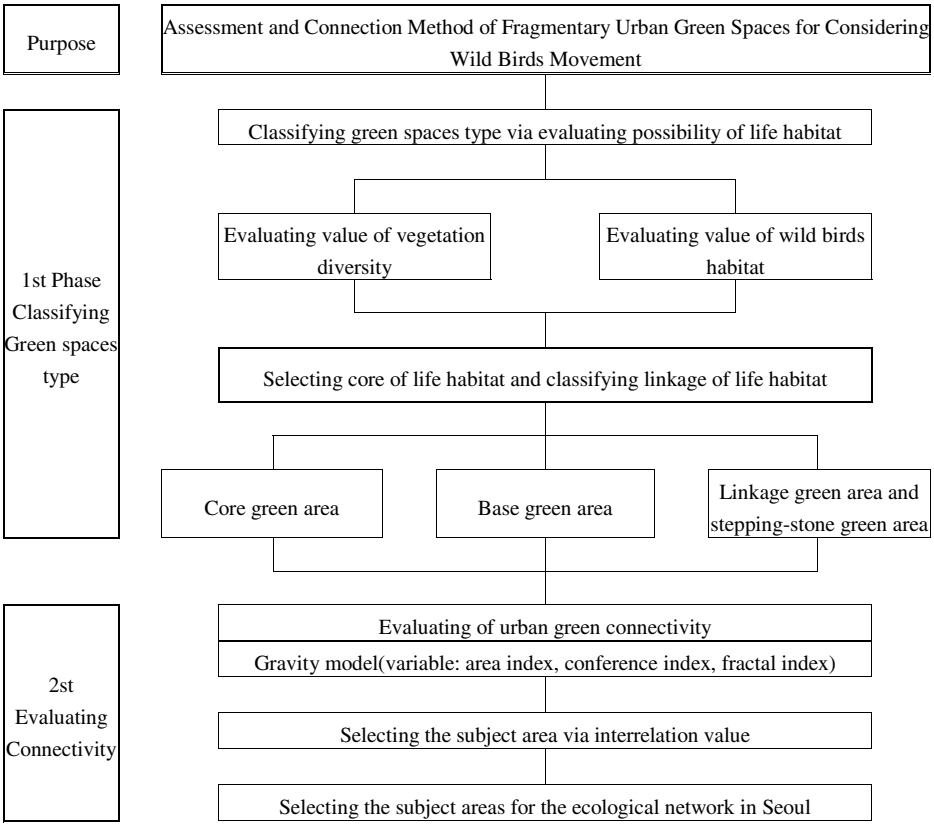

Fig. 1. Research Procedure Concept

In order to select the ecological network site, interrelation value between distance of patch, size, and fractal index are enumerated by matrix method to find out the relation between each patch. To select the site, location which has highest interrelation value between patch is selected and simple relation between core green area or base green area, linkage green area, and stepping-stone green area are excluded. Finally, patch interrelations are established; core green area or base green area~core green area or base green area, core green area or base green area~base green area or linkage green area and stepping-stone green area.

3 Material and Methods

3.1 Study Site

The concept of basin district can be assumed that it was formed early 10th century in Korea dynasty when the concept of Baekdudaegan was a scent of revolution. However, based on Sangyeongpyo which was systemized and for mountains the concept of basin district had been estimated constituted. In general, drainage basin goes around the Marukum like patch in the mountain area. And collected water at the basin is merged with other basin over and over again.

The research site is Seoul surrounded by Naesasan (linked with Bugaksan (Mt.)), Inwangsan (Mt.), Namsan (Mt.), Naksan (Mt.) very natural way like castle walls) and Oesasan (basin formed by Bukhansan (Mt.), Gwanaksan (Mt.), Yongmasan (Mt.), Deoyangsan (Mt.)). Therefore, basin district is established by Oesasan, surrounding outside of Seoul and City limit which is linked with Dobongsan (Mt.), Suraksan(Mt.), Buramsan(Mt.), Yongmasan (Mt.), Iljasan (Mt.), Daemosan (Mt.), Guryongsan (Mt.), Illeungsan (Mt.), Cheonggyesan(Mt.), Bongsan(Mt.), Marukum of Seo-o-reung urban natural park. As a matter of selecting inside of basin district, 5 basin district(boundary of Hangang (River), Jungnangcheon (Stream), Anyangcheon (Stream), Tancheon (Stream)) which are soundly maintain its function are selected by Sanjabunsuryeong in inside of Marukum. Among these selected basin district, ecological network site is established through green space type and connectivity in Gangbuk area.

3.2 Methodology

3.2.1 Study Area Survey and Data Analyses

To estimate fragmentized and patched vegetation diversity inside of urbanized area, it should be considered both current site condition and potential value at the same time (Kleyer, 1994). It is desired that area and current disturbance scale are estimated to maintain vegetation diversity in urban area for estimation of current condition and the age of a tree showing ecological succession stage, constituted multi-layered vegetation structure or not, and forest stabilization is estimated to analyse potential value estimation(Kim and Lee, 1977).

Based on all these results, stability, characteristics of nature, rareness, generation period are estimated. In the point of green vegetation diversity estimation, stability is estimated by minimum area which can keep stable condition without disturbance and

irruption from outside (Wilcove *et al.,* 1986). Ogle (1981) and Wittig *et al.*(1983) classified as 3 classes which are over 40ha, stable regardless of outside condition, under 10ha, unstable against the artificial damage and penetration, and in between. To estimate characteristics of nature which has been used to estimate indigene and introduced species ratio, damaged degree of substratum followed by human intervention, it is classified as 3 classes followed Ogle (1981) and Tans' standard (1974) over 70% of natural forest (no change more than 50% in all layers), between 50~70% of natural forest(high ratio of damaging lower layer vegetation) and under 50% of natural forest(high ratio of damaging lower layer). Rareness is showing richness of habitat type and this is used for estimating ecological succession stage and changed degree of vegetation (Woodland *et al.,* 1995).

It is classified as 3 classes; later, primary or middle period of succession, and artificial forest including natural forest. Generation period estimates forest stability following its growth (Witting & Schreiber, 1983). Less than 10 years forest or ecosystem are fairly stabilized because it is generated stage. Therefore it is classified as 3 classes that over 20 years trees are standardized for estimation in terms of preservation and development(Korea Land Corporation, 2001), under 10 year forest or ecosystem and others.

Table 1. Criteria for evaluating the diversity of vegetation in the urban green area

Degree of category	Evaluation criteria
Stability	▪High: 40 ha>, Medium: 10~40 ha, Low: 10 ha<
Nature	▪High: more than 70% of natural forest, more than 50% of changeless forest in the whole tree layer structure, Medium: natural forest 50~70%, 50% of changeless forest in the whole tree layer structure or more than 70% of natural forest but where is damaged under tree layer structure, Low: less than 50% of natural forest and damage under tree layer structure.
Rareness	▪High: the late succession natural forest, Medium: the primary natural forest, the middle period of succession natural forest, Low: the artificial forest or natural forest which including artificial afforestation species
Generation period	▪High: more than 50years of climax forest, 20~50years of stably natural forest , Medium: 20~50years of Unstably artificial forest, 10~20years of young age class natural forest, Low: 3~10years of initial stage forest, less than 3years of bare land and grassland

In the result of research about wild birds which inhabit in urban green area, even there are some differences in quality of green spaces, there are very close relation with urban green area and diversity of wild birds (Linehan *et al.,* 1967). In addition to, diversity of green, tree layer structure, rear green space distance and other effects from outside are closely related with wild birds abundant chart (Shibuya et al., 1987; Hayama, 1994; Cho, 1993). Based on these items, stabilization, diversity, isolation and growth of forest are estimated.

Based on the number of community and age of tree, it is classified as 3 classes. The most suitable distance to keep maintaining wild birds population in green area which is separated from back green area is under 500m and the maximum distance is 1500m. Over 1500m, the research presents that it is impossible to move (Miller et al., 1998). In urbanized area, however, the possible distance of exchange for individual and gene is less than 200m and for extermination is 1000m based on including obstruction and intensive land use (Jedicke, 1994). It is classified as 3 grade because there are structures, road and other obstructions in urban green area. Habitat possibility to find out development degree of forest is classified as 3 levels which are considered with diameter at breast height (D.B.H) of upper tree layer and natural characteristics of dominant species (Park, 1994; Choi, 2004).

Bio-Tope map by Seoul metropolitan government has been used for fundamental data to estimate vegetation and diversity of wild bird habitat in urban green area. Stability is calculated from area per green area. The characteristics of nature is calculated from each type of vegetation area. Each category are classified as natural forest, artificial forest, and mixed forest. Rareness is calculated with total area of sere and growth period is calculated and applied using piece of wood from tree.

Each type of area is mapped by each vegetation type green boundary using AutoCAD MAP 6 and measured the area by Arc-View 3.3. To estimate isolation, the distance between green area is measured by Arc-View 3.3 to find out the shortest distance. The distance between green area is measured by the shortest distance between circumscribed circle. Because there are possible errors come from when we measure the distance between each center of circle. To measure diameter at breast height(D.B.H) which is needed to estimate the growth of forest, D.B.H of natural forest, artificial forest and mixed forest, Bio-tope research data in actual vegetation type in Seoul, is measured and analyzed using Microsoft office excel 2003.

3.2.2 Classification of Urban Green Types

The characteristics of nature, rareness, originating period/diversity, inhabitability and isolation are considered to estimate diversity, stabilize, habitat of wild birds and richness of species based on patch area. And types are classified as the core patch, base patch, and stepping stone patch.

Result of green type based on vegetation diversity, it is chosen that the core patch is over 40ha which have good characteristics of nature, rareness, originating period patch and good patch which is 10~40ha with good characteristics of nature, rareness, originating period. Point patch is considered and chosen that over 40ha patch which has high stabilize (low characteristics of nature, rareness, originating period), and 10~40ha which has mid stabilize, characteristics of nature, rareness and originating period. Stepping stone type of patch is chosen the area which has 10~40ha which has more or less stabilize, and low value of nature, rareness, and originating period or less than 10ha patch. The result of value of wild birds habitat diversity, the core patch which has over 100ha with good diversity, inhabitability, isolation and the area between 10~100ha with good diversity, inhabitability are chosen. The stepping stone patch which has mover 100ha with low diversity, inhabitability, isolation or the area between 10~100ha which has mid stabilize, diversity, inhabitability, and isolation are chosen. The stepping

stone type of patch has 10~100ha patch area which has more or less stabilize, low value of diversity, inhabitability, isolation or less than 10ha with low diversity, inhabitability, and isolation are chosen.

3.2.3 Estimating Connectivity

Connectivity estimation is calculated from each patch per basin district range and each relation was analyzed by gravity model applicated with patch index (estimation index value about the each patch by basin district range). In landscape ecology fields, gravity model similar with Newton's gravity formula has been used to estimate each patch relation (Forman and Godron, 1986; Sklar and Constanza, 1991).

$$F = G \frac{Pi \cdot Pj}{Dijb} \quad (1)$$

where:

- F is the magnitude of the gravitational force between the two point masses
- G is the gravitational constant
- Pi, Pj is the mass of two subject masses
- Dij is the distance between the two point masses

4 Study Result

4.1 Classification of Urban Patch Type by Inhabitability of Living Creatures

4.1.1 Current Ecological Condition of Patch

In the survey of actual vegetation type, natural forest is 0.2~98.1%, Gangbuk-70(Namsan (Mt.)), Gangbuk-81(Bukhansan (Mt.)). Artificial forest is 6.6~100%. More than 50% areas are artificial forest. However, it is very high ratio in narrow patch area. The size of dominant tree per actual vegetation type can be used to estimate inhabitability. Natural forest's diameter at breast height(D.B.H) is 6.0~36cm and artificial forest's D.B.H is 13.3~30cm. Narrow area's D.B.H is 15~20cm. Large area's D.B.H is over 20cm. The average D.B.H size in pitch in the north of Han River is over 20cm.

The area ratio per actual vegetation type is used to analyse succession stage. The artificial forest and *Pinus densiflora* are considered as early succession. *Quercus spp.* is considered as mid succession. *Carpinus laxiflora*, *Carpinus cordata* are considered as late succession. Decideous tree forest such as *Alnus japonica*, *Betula davurica Pall*. are correspond with later succession stage. Considering the area ratio per types, the area ratio dominated by artificial forest such as *Robinia pseudo-acacia*, *Fontanesia phyllyreoides*, appeared to early succession phase, are 1.92~100%. More than 50% of patch among 52, excluding 32 patches, have same result. The areas which is dominated by Pinus densiflora are 0.05~98%. The areas dominated by Quercus spp., appeared mid succession phase, are 0.85~65.33% with less than 50% excluding 4 patches. The areas dominated by Decideous tree forest, appeared late succession phase, are 0.12~12.84% with narrow area. While there are artificial forest such as *Robinia pseudo-acacia*,

Fontanesia phyllyreoides, *Pinus koraiensis* largely distributed in patch, north of Hangang (River), it is considered that *Quercus spp*. is early succession period because of small area. However, in some area, Deciduous tree forest such as *Carpinus laxiflora*, *Alnus japonica*, *Betula davurica Pall*. are appeared and this reason should be needed more study.

It is analyzed with extract sampling from trees by increment borer in Bukhansan(Mt.), Namsan (Mt.) and Choansan (Mt.). Excluding (22.5 year old) and *Quercus acutissima* (28.5 year old) which have less than 20cm of D.B.H in natural forest, *Pinus densiflora*, the age range of *Fraxinus rhynchophylla*, *Quercus mongolica* are 33.5~78.4 year old. Excluding *Pinus koraiensis (*23.5 year old) which has less than 20cm of D.B.H, in artificial forest, the age range of *Pinus rigida*, *Robinia pseudo-acacia* are 31.7~91 year old.

After all these vegetation status research in Gangbuk, large patch area, Bukhansan (Mt.)(Gangbuk-81), Namsan (Mt.)(Gangbuk-70), and Bongsan (Mt.)(Gangbuk-4) are located in outskirts of the city. However, Ansan (Mt.) (Gangbuk-18), Baegyeonsan (Mt.) (Gangbuk-22) are separated from rear green space and located inside of city. The small area such as Seongsan (Mt.) (Gangbuk-11), Wau neighbourhood park (Gangbuk-12), Nogosan (Mt.)(Gangbuk-13) are isolated in urbanized area.

Reviewing the result of actual vegetation status which affect to nature, there are more than 50% of artificial forest such as *Robinia pseudo-acacia* in the small patch area with bad nature. However, decideous tree forest such as *Quercus spp.* are in large patch area with good condition of nature. The layer structure and succession phase can effect to rareness. Excluding 3 patches, layer structures have simple structure with artificial and natural forest with less than 50%. In the succession phase, artificial forest such as *Robinia pseudo-acacia*, *Fontanesia phyllyreoides*, *Alnus hirsuta*, *Pinus rigida* are dominated. However, the most of *Quercus spp.* are less than 20% which shows early succession phase. Total trees' age, standards of estimating originating period, is more than 30 years excluding *Pinus densiflora* (22.5 year old) and *Quercus acutissima* (28.5 year old), less than 20cm D.B.H. Actual vegetation type, standard of estimating diversity to estimate the wild birds' inhabitability, are showing that 40 patches have more than 4 types. The north of Han River has small patch with bad nature. However, *Quercus spp.* are dominated in large area with good nature. All trees in natural and artificial forest have more or less 20cm of D.B.H. which is standard of estimating inhabitability.

4.1.2 Estimation and Classification of Patch Type

In the result of diversity of vegetation, patches, over 40ha, have stabilization in outer and inner of urban place even there is environmental change. Excluding some cases, most of patches which are less than 40ha are estimated as mid or less stabilization. The rareness showing disturbance degree followed by nature and succession phase got low value of nature and rareness. Because there are large introduced species dominated excluding Bukhansan (Mt.)(Gangbuk-81) and Namsan (Mt.)(Gangbuk-70). By the originating period estimated by age of dominant tree, trees between 20~50 years tree are dominated. However, patch which has mid value with artificial forest such as *Robinia pseudo-acacia*, *Pinus rigida* has The origination period estimated by age of

dominant tree is the largest group. Based on the above research result of estimation of vegetation diversity value, core patch 3, strategic patch 16 and stepping stone patch 63 are classified.

The result of value of wild birds' inhabitability, the area to maintain diversity of species is over 100ha of stabilized patches not relating with outer environmental change and disturbance. The most of patches between 10~100ha are unstable. The inhabitability analysis by diversity and D.B.H of dominant trees showing spontaneity of vegetation and differentiate degree of layer structure, shows that the introduced species are dominated largely excluding massive patches located in the city limit of north of Seoul and it is estimated with less value (less than 50%) excluding 3 patches.

The isolation showing the distance between surrounding patches exist within 200m from background patch which has large area with good nature to project patch blocked by road. Extinct patch by urbanization act has larger than extinct by road. However it is interpreted that area within 1000m will not effect on wild birds' moving route. After all these results, core patch 7, strategic patch 24, and stepping stone patch 51 are classified.

5 Conclusion

Seoul has conducted park patch expansion 5 year plan and planting ten million preserver trees for expansion of patch area. To improve the quality of urban eco-system, current Bio-tope research and evaluation of those patterns were conducted. To develop eco-friendly urban places, there are 3 things have to be done for building eco-network plan. Firstly, in-depth study about the patch distribution condition in urban area has to be preceded. Secondly, through the ecosystem, vegetation and wild animal, research, evaluation of life inhabitability and site selection has to be done. Thirdly, selecting target species in each patch, providing improvement patch structure and connection plan will be desirable.

The purpose of this study is that valuating the connection of mountain type of urban patch and proposing the connection techniques for building eco-network using with existing Bio-tope map and data. It is desirable that proposing the connection techniques through in-depth analysis in each site. Considering evaluation of vegetation diversity, the search would be reliable because this research was done with Bio-tope attribute data done by Seoul. However, the data for wild birds' inhabitability was used for former evaluation research based on vegetation data. It could be less accurate than using current data. In the next research after this, the study of vegetation diversity and wild birds' inhabitability to build the most accurate standard of patch in urban area have to be conducted.

From now, conducting eco-network research in existing urban area, it is considered that the research of site selecting standard for decision and evaluation has to be conducted. To propose connectivity techniques, research and analysing about the character of Bio-Tope, land use, actual vegetation type, and wild birds habitat character have to be done. Based on these research, deciding target species in the site and patch expansion plan should be proposed. Therefore, to propose connection techniques about proposed eco-network site in this research, the basic study about vegetation and wild animal in entire site has to be conducted.

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