Time Series Analysis of Building Greenery Systems for Landscape Simulation

G. Y. Ahn[1,*]

[1] Nature Research Institute, Seoul Woman's University, Seoul, 139-774, Korea

ABSTRACT

Recently, greenery system is frequently applied on buildings and artificial grounds to improve urban ecological functionality. Green roofs can reduce surface water runoff, provide a habitat for wildlife moderate the urban heat island effect, improve building insulation and energy efficiency, improve the air quality, create aesthetic and amenity value, and preserve the roof's waterproofing. Specifically, architectural greenery is also known as an architectural language that can meet the sustainable design concept of architects. Therefore, this study is expected to establish the contemporary architecture as building, landscape architecture and the greenery technology. And this result will be used as a basic study to promote developing the advanced system based on the concept of consilience.

The type of green roof system is generally divided into light-weight green roof and heavy-weight green roof and medium weight depending on building structure and permissible load of building in Korea. It is very important decision of green roof type for each building characteristics and properly management of green roof after construction. This study was conducted investigation of Index of Greeness and examining the time series for the final aim, landscape architecture conjunction simulation with building. It was carried out on five existing rooftop site from March in 2012 to October in 2013. Using CANON 450D with 18 ~ 55mm and Auto CAD ver.2010 program, landscape time series analysis of green roof were carried out. In this study, green roof planting type was divided into herbaceous plants group, shrub with herbaceous group and shrub and tree with herbaceous group. There was difference depending on management intensity in each type. Herbaceous plants group, is applicated generally low live-load building, had changes depending on irrigation management. Shrub with herbaceous plant group and arbor with herbaceous plants group, had differences by extensive or intensive management. Index of Greeness of two groups was recorded higher in intensive management than in extensive management, especially in summer and fall season.

KEYWORDS

Green roof, Landscape architecture simulation, Index of Greeness, Time series analysis

INTRODUCTION

Recently, green roof has emerged as a solution to realistically address the ecological and environment problems produced by urbanization. Green roof not only provides the basic functions of a green area including CO_2 absorption, air filtration, and dust absorption, but it also improves the comfort level and aesthetics of the cityscape by

* Corresponding author email: gyahn@swu.ac.kr

mitigating the urban heat island phenomenon. This facilitates rainwater harvesting and rooftop runoff control, and creates a nature-immersive green landscape. Among the myriad of effects described above, the most economical and practical ones relate to an increase in property value due to aesthetic improvement, reduced building heating and cooling costs, and increased building durability and endurance (Carter et al., 2008). In fact, a 30% rooftop cooling effect due to the evapotranspiration effect of rooftop greenery has been reported (Takakura et al., 2000). Such a cooling effect is expected to contribute significantly towards improving the harsh 'heat island' climate created by the city (Bianchini et al., 2012; Clark et al., 2010). Such benefits of green roof are already well known as an effect that is acquired from the active photosynthesis of healthy rooftop plants. In short, healthy growth and development of rooftop plants is directly related to the aforementioned economic effects of the building. Consequently, appropriate maintenance and management practices should be tailored to cater for the different green roof types.

It is expected that green roof area will continue to expand in the future. As a response to the anticipated age of climate change, green roof will not only help to increase green space in urban areas, but it will also be considered as a vital structural element in architecture. To this end, an organic communication link between architecture, landscaping, and horticulture must be established. The present study investigated the changes in the index of Greenness of green roof over time due to year-round management. By exploring an appropriate management plan of the vital architectural component, we sought to provide the green roof management plan as basic data for future building life cycle planning

RESEARCH METHODS

The present study investigated the green roof, one of the vital architectural components, by measuring the index of Greenness by green roof type. Through the above method, we sought to provide basic data for an architectural maintenance and management plan, and life-cycle simulation. Ultimately, we aim to develop a plan to maximize the economic effect of green roof and establish a management system among architecture, landscape, and horticulture. First, we examined the maintenance and management practices of existing green roofs in detail to identify the different management types of this system. To investigate this, we conducted a field survey of existing green roof sites and identified the degree of management intensity, including the manager, irrigation type, fertilizer used, weeding, and supplemental planting, and the sites' various planting types that determine the overall green roof type. In the case of classifying different types of management intensity, theses were differentiated into Intensive greening, Extensive greening, and no greening. Planting types of the green roof were differentiated into herbs only (unit box, soil spread type), the combination of herbs and shrubs, and the combination of herbs, shrubs, and trees to investigate the visible landscaping changes. Next, we selected existing green roof sites that appropriately meet the criteria for the respective management intensity types identified in the present study. We also selected measurement sites with each of the three aforementioned planting types (herbs only, combination of herbs and shrubs combination, and combination of herbs, shrubs, and trees) for each management intensity type. From March 2013 to October 2013, we photographed the landscaping changes at each measurement site at identical angles and positions each month. The photographs were taken using a CANON 450D and an 18–55-mm standard lens. The index of Greenness, which is the proportion of plant leaves occupying the human

visual field, was calculated using the Auto CAD ver.2010 program.

RESULTS AND DISCUSSION

Classification by Management Intensity Type

Green rooftop guidelines of the German(2002, hereafter FLL) classifies green roof systems into the following three categories: intensive greening, simple intensive greening, and extensive greening. Intensive greening involves planting grass, shrubs, and trees and affords great flexibility in design. In order to implement the management type, the building load must be preemptively designed to allow tree planting. Furthermore, maintenance practices including irrigation and fertilization are considered, even in the early planning stages. Another management intensity type, simple intensive greening, also involves planting grass, shrubs, and other ground-covering plants. Unlike intensive greening however, simple intensive greening does not offer flexibility to users and designers compared to intensive greening. Furthermore, simple intensive greening requires lower building load demand and maintenance. Extensive greening minimizes management and involves planting primarily herb species including moss, grass, and sedum. The premise of implementing extensive greening is to minimize landscaping costs and management.

Unlike the practice in Germany, where classification types are based on management intensity, South Korea classifies green roofs based on weight and soil depth into the following three categories: heavy-weight, mid-weight, and light-weight. Consequently, there has been a tendency for the importance of management to be neglected in the respective green roof types. In short, the classification based on the soil depth and weight is prioritized, and the considerations of green roof management, which has the most significant influence on the sustainability and aesthetics of green roofs, are relatively reduced. The side effects, caused by a lack of a clear management plan for each green roof type, as well as detailed terms and conditions, include dead vegetation layers, complete discard the green roof system due to management burdens, and bias towards the mid-weight category for its stable maintenance capacity.

Before categorizing the detailed management intensity types, which have the greatest influence on green roof sustainability, we examined the detailed specifications of the green roofs. The classification of such included the presence of a designated or temporary manager, a planned irrigation cycle, the type of irrigation equipment, planned fertilization and weed management, supplemental planting, and miscellaneous facility management. The result of such classification is shown in the following table.

Table 1. *Management type of green roof in this study*

Management Type	Primary management specifications and intensity	Monitored Planting Type
Intensive Management	・ Intensive management is provided by a dedicated manager ・ Equipped with an automatic or manual watering system ・ Regular irrigation management is conducted in accordance with specified management instructions ・ Regular weeding and supplemental planting and fertilization on a need-basis are performed	herbs (Soil spread type)
		herbs + shrubs
		herbs + shrubs + arbor
Extensive Management	・ A managing staff in charge of temporary management is present	herbs (Unit box)
		herbs (Soil spread

	· Conducts irrigation management on a need-basis · Performs weeding on a need-basis	type)
		herbs + shrubs
		herbs + shrubs + arbor
No Management	· No dedicated manager · No weeding, irrigation, or fertilization	herbs (Unit box)
		herbs + shrubs

Index of Greenness analysis

Following monthly measurements of the index of Greenness, and analysis of the results, each planting type was found to differ based on the management intensity. Furthermore, we found that the difference in the index of Greenness was evident between not only the simple presence or absence of management, but among the varying detailed management specifications and intensity. In the case of planting herb plants primarily constituted by perennial Korean native wild herbaceous plants and sedum, even the construction of simple and convenient Unit Box type and the general soil spread type exhibited an index of Greenness difference. As the herbs are planted and cured prior to construction in the case of Unit Box, it is a system based on minimal management. Measurement results found that the index of Greenness of Unit box varied depending on the presence or absence of the minimum level of management, and irrigation. In other words, a Unit box that had been meticulously planted and cured is expected to secure a high index of Greenness simply through irrigation management during the dry season. In the case of planting herbs in soil spread type, there was no significant difference in the index of Greenness between intensive and extensive management conditions. In fact, the present study results showed that the increase in the index of Greenness was actually lower under the intensive management condition. Such a result is considered to have occurred due to overly intensive management including the trimming of male plants and by artificially securing the planting area to prevent inter-plant competition.

With respect to the herbs+shrubs planting type and trees+shrubs+herbs combination type, we were able to observe a clear difference in the index of Greenness between intensive management and extensive management. The two landscaping types began with a similar pattern of an increasing index of Greenness in March and April, which is the initial growth stage. However, in the high temperature and dry conditions of summer, a difference in the index of Greenness began to emerge. Planting type under an extensive management consisting of irrigation management only exhibited a lower index of Greenness than under intensive management. Such a difference indicates that planting the combinations of herbs+shrubs or herbs+shrubs+trees results in better growth in the case of intensive management including regular irrigation management, fertilization, and weeding. Furthermore, this difference was more evident between summer and fall rather than in the initial growth stage.

Table 2. *Overall Index of Greenness change pattern by type (%)*

Type	Management Intensity	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Unitbox (herbaceous)	Extensive	11.4	27.8	77.8	84.9	85.3	84.5	79.8	7.7
	None	16.1	45.0	82.1	80.1	84.9	75.5	76.4	15.8
Soil spread Type(herbaceous)	Intensive	10.2	25.8	68.3	71.4	68.8	69.3	49.2	46.5
	Extensive	4.9	69.7	76.5	86.0	90.5	85.8	34.4	12.8
shrubs + herbs	Intensive	3.8	40.0	88.8	72.6	97.5	89.3	75.3	19.3

	Extensive	8.1	62.3	80.9	57.4	61.0	56.5	65.4	39.8
arbor+shrubs+herbs	intensive	12.4	44.6	57.1	71.8	72.1	73.4	58.5	0.0
	Extensive	9.6	47.7	57.7	66.8	58.4	52.9	49.1	24.8

The Unit Box system is maintained under the low management concept from green roof designing stages such that, even in a site with intensive management capacity, the site was extensively managed. Consequently, the Unit Box type was differentiated and compared according to extensive and no management subtypes. When the extensive management condition of dry season irrigation management and no management condition of Unit Box type were compared, the former management type exhibited an overall difference in the index of Greenness change for the duration of the monitoring period. Unit box, which is based on a low management concept, was found to exhibit differences in the index of Greenness even with minimum irrigation management.

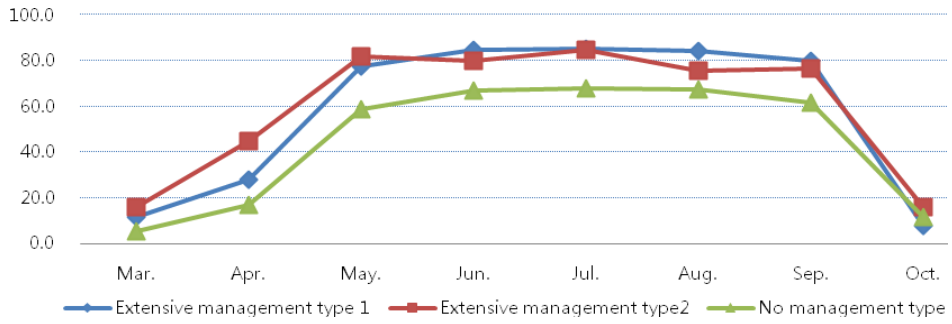

Figure. 1 The changing Index of Greenness pattern in Unit Box by management intensity

In the case of Soil spread type, there was no significant difference in the index of Greenness between intensive and extensive management. According to the index of Greenness analysis, the intensive management type actually exhibited a slower speed or increase in the value of the index of Greenness compared to the extensive management type. This is thought to be the result of intensive management involving the removal of invasive plants and trimming of planted plants for aesthetic reasons. Consequently, an optimal index of Greenness can be realized with extensive management involving only minimum irrigation management in the case of Soil spread type.

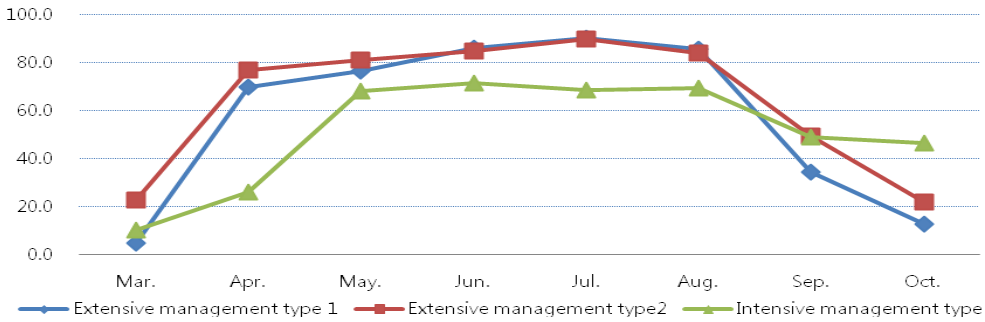

Figure 2. *Changing index of Greenness pattern of Soil Spread type herbs by management intensity*

The herbs+shrubs combination exhibited the following index of Greenness based on intensive and extensive management, respectively. The index of Greenness of this type, involving intensive and extensive management, is produced in the following figure. In the initial stages of growth, there was no difference in the index of Greenness between the two management intensity types. From May, however, a significant difference in the index of Greenness was exhibited. Intensive management involving fertilization, weeding, and regular irrigation secured a high index of Greenness in July, August, and September, which are the peak months of growth. The reason for a relatively lower index of Greenness for intensive management in October is the difference in plant composition.

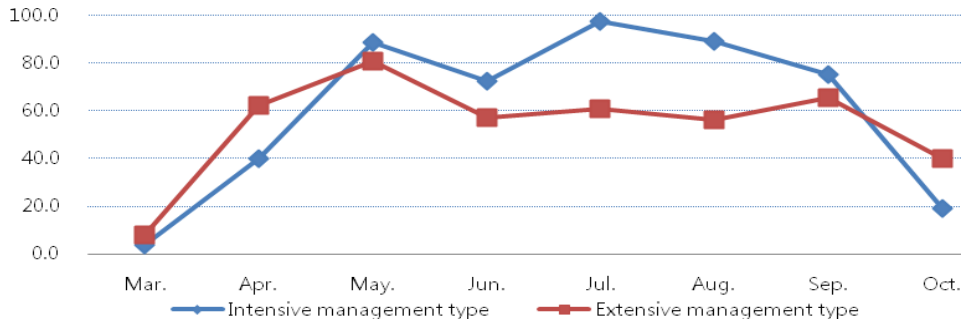

Figure 3. *Changing index of Greenness patterns of shrubs + herbs combination type by management intensity*

Like the shrubs+herbs combination, the three-layer combination of herbs, shrubs, and trees did not exhibit much difference in the index of Greenness during the initial growth stage. By the summer season with predicted high temperature and dryness damage, the index of Greenness of the intensive management type exhibited a stable increase compared to that of the extensive management type. Under the extensive management involving irrigation only, the summer season resulted in a gradual decrease in the index of Greenness. As the extensive management type was composed of an evergreen, *Taxus cuspidata*, the extensive management type exhibited a higher index of Greenness in October.

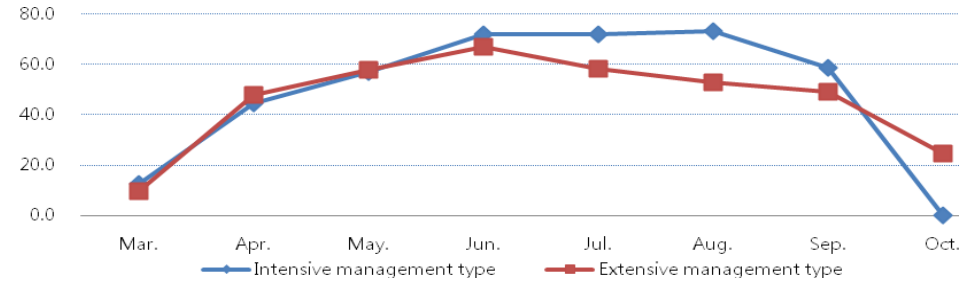

Figure 4. *Changing index of Greenness patterns of trees + shrubs + herbs combination type by management intensity*

CONCLUSIONS

When the index of Greenness results were aggregated, we were able to confirm that

management specifications and intensity applications differentiated by planting types can effectively and economically maintain the green roof system. In the case of the Unit Box, the presence or absence of irrigation management demonstrated a significant difference in the index of Greenness and growth. Consequently, even the use of just planned irrigation management can facilitate the maintenance of a sustainable green roof system (Zhao and Kang, 2013). However, it must be noted that as Unit Box was designed for convenient construction and elimination of management burdens associated with supplemental planting and weeding, uniformity in pre-planting quality including ratio of green coverage and good growth conditions must be secured.

In the case of the soil spread type, a large index of Greenness difference based on management intensity is not apparent. This observation demonstrates that, rather than extraneously intensive management, economical low-key management is sufficient to maintain a sustainable green roof system (Lee *et al*., 2003; Lee *et al*., 2007). It should be noted in the case of soil spread type that removing the potential for invasive plants as much as possible at the planting stage would play a big role in maintaining a good green coverage and relieving management burdens. The combination of herbs+shrubs, and the herbs+shrubs+trees landscaping type were shown to exhibit a significant index of Greenness difference in the late growth season based on intensive and extensive management types. In short, as the summer season approaches, the exposure to an unfavorable roof environment, including high temperature and dryness, requires variable maintenance management including regular irrigation, appropriate weeding, and fertilization to be of any influence. Furthermore, monitoring the results showed that the sustainable planting pattern of herbs+shrubs and herbs+shrubs+trees landscaping types not only depended on appropriate maintenance and management but also on the composition of plant species. Among the monitoring sites, those areas with *Taxus cuspidata, Rhododendron indicum,* and *Pleioblastus fortunei* demonstrated good index of Greenness results due to the excessive growth of *Pleioblastus fortunei* However, Pleioblastus encroached upon other plants through overpopulation and eventually crowded out other plant species. In the long term, such dominance by *Pleioblastus fortunei* is expected to affect the sustainability of the index of Greenness and the green roof system itself. Consequently, an appropriate combination of plant species should be studied in detail in the future. The sustainability of greenery is ultimately determined by management specifications and intensity. The intensity of management may be directly linked with landscaping design and the growth condition for plants. Consequently, the degree of management burdens can be addressed effectively and economically based on a reasonable landscaping design and the condition of planted greenery(Derek and Jeremy, 2008). Furthermore, such results suggest that plant community research and landscape aesthetic research with respect to rooftop greenery should be conducted in tandem.

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