Establishment of a Master plan for promoting the systematic building-greening

Ⅰ. Introduction

The demand increase of urban space according to industrialization resulted in the high-density development of urban area as well as the expanded urban areas. As a result, the high pavement rate, the destruction of green area and the increased energy use in urban areas have strengthened the concern with regard to urban flood, urban heat island phenomenon and the global warming. The strengthened heat island phenomenon resulted in the increase of the mortality in the elderly and the infirm and the deterioration in the living conditions of low income community, so it is being recognized as one of the severe social problems. In addition, the recent urban flooding caused by the localized heavy rain and the resulting natural disasters show the needs for improving the urban water cycle function.

In these growing concerns, considering a practical alternative to secure the green living area in the urban area where it’s hard to secure green space due to insufficient land, high land-price and economic logic, the interest in green building has been enhanced. Building-greening means to cover with plants through constructing the planted foundation on the artificial ground including roof, wall and indoor of building. The effect with regard to building-greening has been verified through various domestic and international researches. The greening on the roof of buildings resulted in the lower surface temperature compared to the concrete surface (Kim *et al*. 1999; Song, 2001; Washington, D.C., 2004; Cummings *et al*., 2007) and it showed the better temperature reduction effects depending on the thickness of soil and the planting types, namely the effect in mitigating the heat island (Lee *et al*., 2005; Oh, 2007). In addition, the temperature reduction effects resulted from roof-greening were also reported through simulations (Liu and Bass, 2005; Rosenzweig and Solecki, 2006). The studies regarding the CO_2 reduction effect resulted from the greening (Urban Greening Technology Development Organization, 1995) as well as the temperature reduction effects and those regarding the stormwater reduction capacity of roof-greening (Geiger, W., Dreiseitl, H., 1995; Ministry of Environment, 1998) were also conducted.

Thanks to the positive effects from the building-greening, the support and projects for the building-greening centering on the metropolitan cities in Korea, USA and Japan were now under the progress. Because the building-greening projects are being prompted separately depending on local governments, however, the methods to enhance the efficiency for building-greening projects are needed for securing the urban improvement projects and the systematic urban greening spaces in the long-term perspective.

Accordingly, this study, in order to select the targeted areas for building-greening reflecting the local features and to conduct the projects step by step, purposed to develop a model to establish the fundamental plan to present a guideline for concrete building-greening.

II. Research method and contents – a process to establish the master plans

1. Research methods

The basic plan for building-greening is to present the policy goal and direction in the unit of local government as a basic plan for local greening, to analyzed the various factors including the building-greening effects, local features and greening demand level and then to propose a process to select the optimal areas applying the building-greening.

The basic plan for building-greening in this study identified the preferred greening areas and recommended greening ones to promote the greening projects step by step with 6 perspectives including heat island reduction, water cycling improvement, carbon reduction, biodiversity promotion, green space increase and landscape improvement, recovering the comfort, healthy urban environment and improving the beautiful urban environment with local identity.

As for the basic plan establishment process for building-greening: 1) it conducts the status analysis to analyze the various individual statuses depending on the 6 viewpoints and to create the thematic maps. 2) It analyzes the viewpoint-specific building-greening targets though creating the viewpoint-specific comprehensive thematic maps. 3) It presents the building-greening basic plan suitable to targets and selects the preferred greening areas and the recommended greening ones through separating the 6 viewpoints by the basic analysis types and the specialized analysis types. Based on the above results, 4) it prepares the guidelines to apply by the building-greening types and 5) progresses a process to verify the quantitative effects of targeted building-greening areas though simulation analysis.

As for the 'heat island reduction', the areas with locally higher temperature compared to surrounding areas were identified. The temperature distribution maps for targeted areas were created through using the ACM(Air City Model)_static[1] analysis tool for the

[1] ACM is a model dedicated to the greening effect analysis developed in Korea Institute of Construction

distribution of average temperature, daily highest temperature and daily lowest temperature. Then, the above-mentioned daily highest temperature means the average value of peak temperatures of day by season and the lowest temperature the average value of lowest temperatures at dawn before sunrise by season.

Location factors		Location criteria	
Classifications	Detailed contents	Criteria (%)	Grade
Highest temperature in summer	To calculate after classifying the heat environment analysis results of CM regarding the highest temperature in summer into 10 grades To select the preferred greening areas sensitive to the temperature crease change caused by air conditioners	90~100 80~90	1st place* 2nd place**
Lowest temperature in summer	To calculate after classifying the heat environment analysis results of CM regarding the lowest temperature in summer into 10 grades To select the preferred greening areas targeting the tropical night-curring areas (the relatively high areas in the lowest temperature of air nditioners)	90~100 80~90	1st place* 2nd place**
Average temperature in summer	To calculate after classifying the heat environment analysis results of CM regarding the average temperature in summer into 10 grades To select the preferred greening areas targeting the relatively high eas in air conditioner temperature	90~100 80~90	1st place* 2nd place**
* preferred greening areas; ** recommended greening areas			

Table 1. The standard to select the areas targeting the 'heat island reduction'

As for the 'water cycle improvement', the direct runoff and evapotranspiration amount, or the major components of urban runoff, were analyzed through using a WEP model[2]. In order to identify and evaluate quantitatively the water-cycle status before and after building-greening, the areas with excessive direct runoff and low evapotranspiration amount were identified.

Location factors		Location criteria	
Classifications	Detailed contents	Criteria (%)	Grade
Direct runoff	To calculate it after analyzing the excessive direct runoff with the WEP model and classifying the results into 10 grades (compared to the yearly rainfall)	83.2~86.5 79.7~83.2	1st place* 2nd place**
Evapotranspiration amount	To calculate it after analyzing the low evapotranspiration amount with the WEP model and classifying the results into 10 grades (compared to the yearly rainfall)	13.0~15.5 15.5~18.0	1st place* 2nd place**
* preferred greening areas; ** recommended greening areas			

Table 2. The criteria to select the areas targeting the 'water-cycle improvement'

As for the 'carbon reduction', the lowest temperature in winter and the city gas consumption were considered in order to identify the areas with a high volume of heating

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Technology in order to calculate the temperature change caused by building-greening; through the ACM_static analysis mode, the various statistics regarding the temperature change before and after greening can be calculated easily as the form to express on maps from land cover information and meteorological data.

[2] The WEP (Water and Energy transfer Processes) model is a physically based spatially distributed (PBSD) rainfall-runoff model developed for quantifying the water/heat cycle on urban watersheds under the complicated land uses.

energy. The ACM_static model was used for the lowest temperature in winter and the Seoul City's statistical yearbook was used for the city gas consumption.

Location factors		Location criteria	
Classifications	Detailed contents	Criteria (%)	Grade
Lowest temperature in winter	To calculate after classifying the lowest temperature in winter into 10 grades according to the heat environment analysis results of Air City Model considering heating consumption	0~10 10~20	1st place* 2nd place**
City gas consumption	To calculate after classifying the city gas consumption by Dong shown in Seoul City's statistical yearbook into 3 grades according to the City's legends	0-33 33-66	1st place* 2nd place**
* preferred greening areas; ** recommended greening areas			

Table 3. The standard to select the areas targeting the 'carbon reduction'

As for the 'biodiversity increase', the key influential zones and buffering zones were identified as the stepping-stone greening areas in the perspective of city greening network and landscape ecology. The key influential zone was classified into Grade I in Biotope type evaluation and the buffering zone Grade II in Biotope type evaluation through using the city ecology map (Biotope map); the former includes large forest, national and local rivers and city's national park areas and the latter includes neighborhood parks, children's parks, small parks, cemetery parks, sport parks, waterside parks, cultural parks, history parks, mitigated greening spaces, linkage greening areas, public spaces and small rivers. The influential zone was identified through distance-weighting analysis on the influential zone according to certain distance after setting buffering zone centering on each source using Arc GIS 9.3.

Location factors		Location criteria	
Classifications	Detailed contents	Criteria	Grade
Key influential zone	Grade I in the Biotope type evaluation	125m 250m	1st place* 2nd place**
Buffering zone	Grade II in the Biotope type evaluation	125m 250m	1st place* 2nd place**
* preferred greening areas; ** recommended greening areas			

Table 4. The standard to select the areas targeting the 'biodiversity increase'

As for the 'greening promotion', the greening-alienated zones were identified in order to solve the imbalance in urban imbalance and to secure the urban comfort. According to the standard regarding the park area and location distance in the 'Urban Park Act', in the greenbelt less than 10,000 ㎡ and more than 10,000 ㎡ the park service area less than 250m and less than 500m were set respectively, and the zones excluded from buffering zone through conducting the distance-weighting analysis in Arc GIS 9.3 were identified as the greening-alienated zones.

Location factors		Location criteria	Note
Park	Natural park (National, county, provincial park)	In the area less than 10,000 ㎡ and more than 10,000 ㎡, the area less than 250m and less than 500m are designated as the greening-alienated zones respectively.	Natural Parks Act
	Urban park (livelihood park, theme park, urban natural park zone)		Act on Urban Parks, Greenbelts, etc。
Greenbelt	Greenbelt (reserved greenbelt, production greenbelt, natural greenbelt)		National Land Planning and Utilization Act
	Installed greenbelt (landscape greenbelt, buffering greenbelt, linkage greenbelt)		Act on Urban Parks, Greenbelts, etc。
Plaza			Urban planning facilities
Public area			
Amusement park			

Table 5. The standard to select the areas targeting the 'greening promotion'

As for the 'urban landscape improvement', the legislative aspect and non-legislative one were considered in order to create the various, beautiful greenbelt landscape within urban zone. In the legislative aspect, the buildings belonging to the landscape zone and beauty zone designated in the National Land Planning and Utilization Act and the landscape zone presented in the local government's urban planning ordinance were selected as the preferred greening areas while in the non-legislative aspect, the prospect right zones were considered as the areas targeting the building greening, so the targeted areas were identified through the landscape visibility analysis of Arc GIS 9.3. The common zones out of the targeted areas in the legislative aspect and non-legislative one were selected as the preferred greening areas and the other zones were classified as the greening management areas.

Location factors			Location criteria		Note
Classifications	Detailed contents		Criteria	Grade	
Legislative aspects	Landscape zone	- Natural landscape zone - Waterside landscape zone - Urban landscape zone	Relevant area	Out of the analyzed areas in the legislative aspect and the non-legislative one, the common areas was designated as the 1st place and the other ones as the 2nd place	National Land Planning and Utilization Act
	Aesthetic area	- History and culture aesthetic area - General aesthetic area - Central aesthetic area			
	Local government-specific landscape-related detailed ordinance		Relevant area		Local government's urban planning ordinance
Non-legislative aspects	Landscape visible area analysis		Prospect right area		GIS analysis utilization

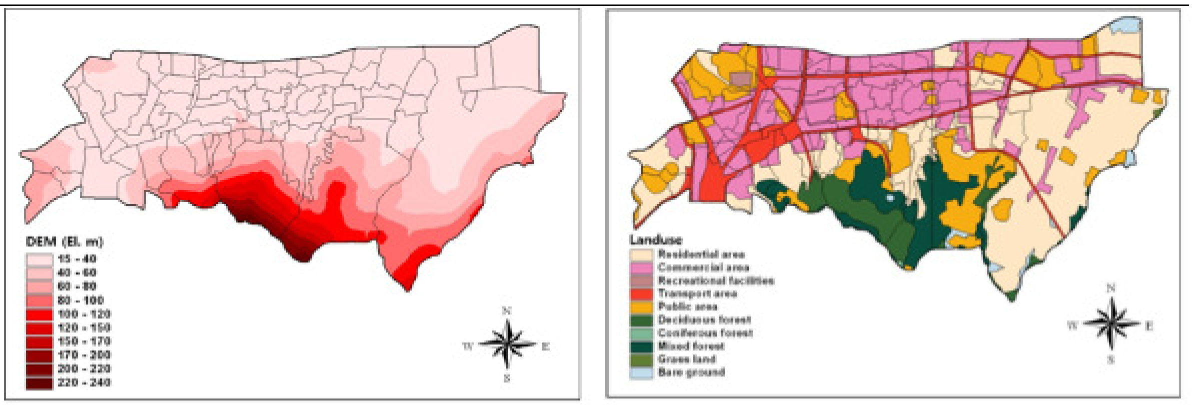
Table 6. The standard to select the areas targeting the 'urban landscape improvement'

In order to establish the basic plan of building-greening reflecting the local features, it's necessary to meet the 6 viewpoints-specific greening areas to the policy goal and direction of local government's basic plans for building-greening. This study, in order to build the pleasant, healthy urban environment, or the goal to establish the basic plan for building-greening, classified the basic analysis type for building-greening into the 'water cycle improvement', 'heat island reduction' and 'carbon reduction' related to the urban climate aspect. In addition, in order to improve the beautiful urban environment reflecting the local identity, it classified the biodiversity improvement and urban landscape improvement into the specialized analysis type, identifying the basic plan for building-greening suitable and specialized to the targeting areas.

2. Research-targeting areas

This study targeted the Jung-gu in Seoul City, which includes all the general urban types including residential areas and commercial ones as a central part in Seoul City. In addition, it is mixed with the existing conventional houses and modern high-rise buildings, is required to be continually repaired due to deteriorated urban infrastructure and has a high usability of the basic plan because it is designated as the preferred district for promoting the rooftop-greening project within a visible region from Nam Mountain in the City.

The area of this zone is about 10 ㎢, showing the maximum altitude (240m EL) around Nam Mountain; less than 40m (EL) in the most areas including commercial and residential areas. As for the land use status, the commercial areas, residential ones, forest and grassland, public facility areas, traffic facilities and other idle areas account for 27, 34, 13, 16, 9 and 1% respectively, and the impervious area rate of 86% (Figure 1).



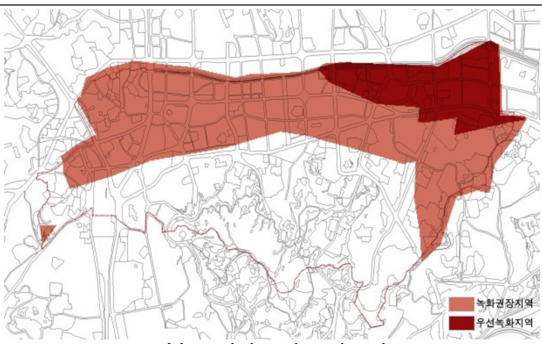
a. Altitude model of Jung-gu (DEM) (1:5,000) | *b. Land use status of Jung-gu (1:25,000)*

Figure 1. Status of Jung-gu in Seoul city

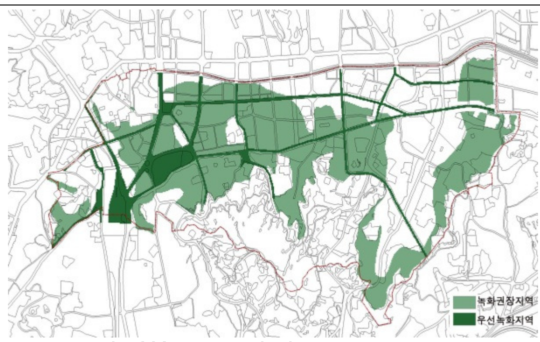
Ⅲ. Pilot application of the basic plan for building-greening: Jung-gu in Seoul City

1. Viewpoint-specific greening area selection

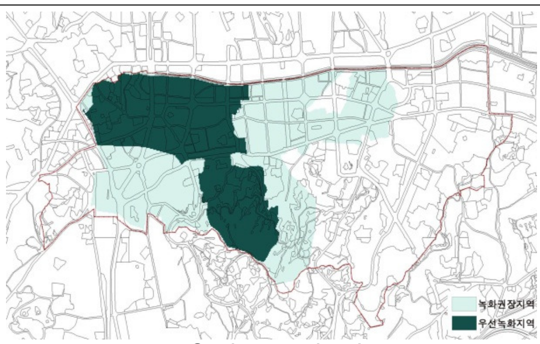
In the perspective of urban heat island reduction, the commercial zone located on the north of the targeted area was identified as the preferred greening area and recommended greening one (Figure 2. a). In the perspective of water cycle improvement, the direct runoff was shown high at the areas with high impervious area rate including road, commercial area and residential one and the evapotranspiration was shown high centering on the forest area (400-600 ㎜) and park (about 470 ㎜); the preferred greening areas were identified centering on the high direct runoff and low evapotranspiration area (Figure 2.b). In the perspective of carbon reduction, the preferred greening areas and recommended greening ones were identified as the below figure (Figure 2.c) and in the perspective of biodiversity, the south-north axis linking Bukhan Mountain and Nam Mountain, or the major greening axis, and the east-west axis centering on Cheonggyecheon were identified as the greening management areas (Figure 2.d). In the perspective of greenbelt promotion, the areas concentrated with central commercial zones and residential ones were identified as the greening-alienated areas (Figure 2.e). In the perspective of urban landscape promotion, Nam Mountain and Bukhan Mountain designated as a view point were identified as the preferred greening area and recommended greening one (Figure 2.f).



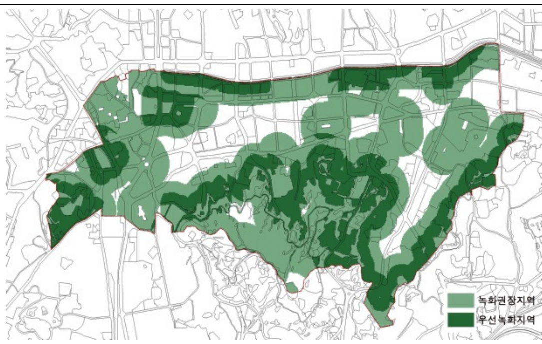
a. Heat island reduction



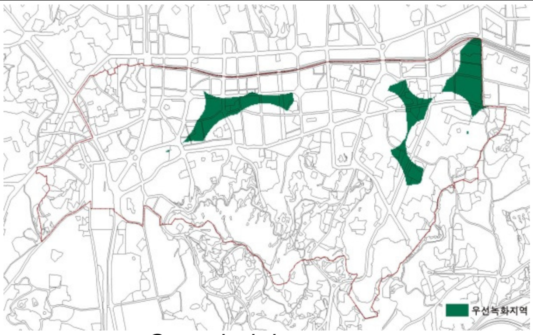
b. Water cycle improvement



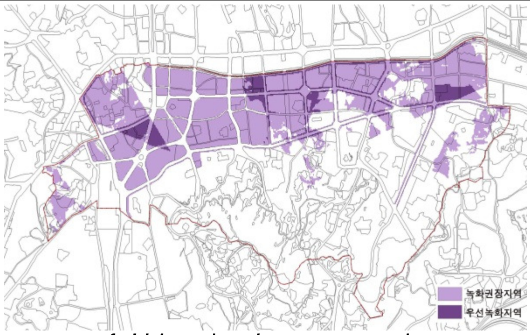
c. Carbon reduction



d. Biodiversity improvement



e. Greenbelt improvement



f. Urban landscape security

Figure 2. Viewpoint-specific greening area – Jung-gu in Seoul City

2. Selection of greening areas by specialized analysis types

The targeted area was selected as the important one to establish the greenbelt network in the ecology network plan (Seoul City, 2007) and, considering the components of greenbelt network including key area and base one are distributed around or within Jung-gu, it was found that it would be desirable to consider the biodiversity improvement as a basic plan specialized to Jung-gu.

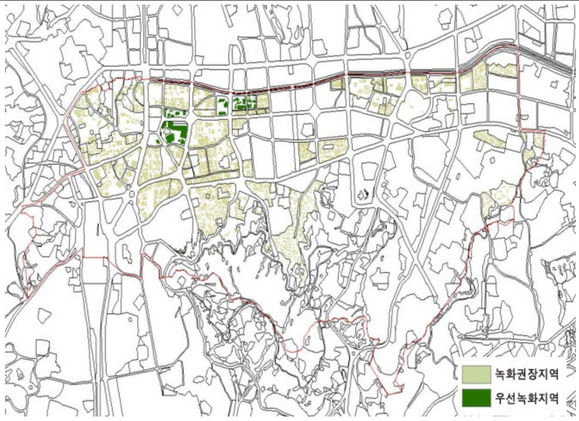
In order to analyze the urban climate aspect (water cycle improvement, heat island reduction and carbon reduction), or the basic analysis type of building-greening, 2 points and 1 point were given to the preferred greening area and recommended greening one and then, after adding up the points, 5 and 4 points of greening index and 3 points of greening index were re-classified as the preferred greening area and the recommended greening one respectively. The preferred greening areas in the urban climate aspect account for about 7.48% (746,128 ㎡) out of the total area (99,600 ㎡) and the greening management areas about 16.50% (1,675,350 ㎡) (Table 7, Figure 3-a).

The biodiversity aspect, in addition to the urban climate aspect, was also considered for the specialized building-greening of Jung-gu. 1-7 points of greening index were identified through adding up the totaling 1-5 points of greening index in the urban climate aspect (water cycle improvement, heat island reduction and carbon reduction) and the 1-2 points of biodiversity aspect; the areas with the greening index of 7 and 6 points and the areas with 5 points were reclassified into the preferred greening area and the greening management area respectively. In the building-greening basic plan specialized to the biodiversity, the preferred greening areas are mostly distributed at the central commercial areas and accounted for about 1.48% (147,365 ㎡) of the total area (99,600 ㎡). The greening management areas were located at commercial and residential areas and accounted for about 23.73% (2,366,448 ㎡) (Table 7, Figure 3-b).

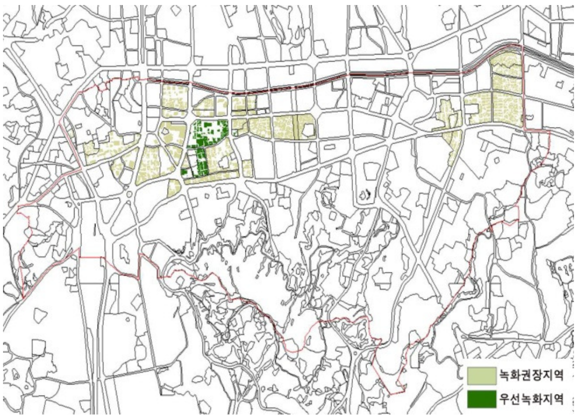
	Preferred greening area				Recommended greening area			
	Area (㎡)	%	Building area	Building-to-land ratio	Area (㎡)	%	Building area	Building-to-land ratio
Urban climate	746,128	7.48	318,951	42.75	1,675,350	16.80	635,113	37.91
Urban climate + Biological diversity	147,365	1.48	54,758	37.16	2,366,448	23.73	822,710	34.77
Urban climate + greenbelt improvement	145,526	1.46	57,638	39.61	1,144,157	11.48	543,262	47.48
Urban climate + landscape	157,863	1.58	77,688	49.21	2,252,213	22.59	910,239	40.42

Table 7 . Type-specific greening area-identified area

a. Basic type_urban climate



b. Specialized type_urban climate+bio-diversity



c. Specialized type_urban climate+greenbelt improvement

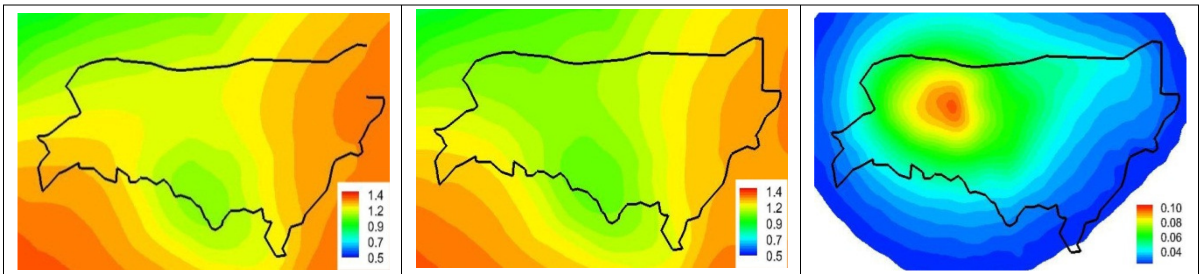
d. Specialized type_urban climate+landscape improvement

Figure 3. Viewpoint-specific greening area – Jung-gu in Seoul City

3. Analysis on the estimated effects of building-greening

This study analyzed the effects before and after building-greening on the preferred greening area and recommended greening one identified as the specialized type considering the aspect of ‘urban climate change’ and ‘biodiversity’ aspect for Jung-gu in Seoul City, or the study-targeted area. The effect analysis was observed through the heat environment for urban heat island reduction and the water environment for water cycle improvement.

As for the heat environment effect analysis, each temperature distribution map was created through classifying pre-greening and post-greening of buildings through ACM_static analysis mode used before. As for the daily lowest temperature influencing the tropical night phenomenon in summer, the daily lowest temperature change was calculated (Figure 4-c) in order to know the effect resulted from the greening after calculating (Figure 4-a; b) the temperature distribution of pre-greening and post-greening of building. Here, the temperature change means the figure subtracting the daily lowest temperature after greening from the daily lowest temperature before greening; in case the figure will be positive, it means that the temperature was lowered due to greening. It's expected that the daily lowest temperature after greening will be lowered by up to 0.1℃, and by about 0.05℃ and more in the total area of Jung-gu.



a. Pre-greening_daily lowest temperature	*b. Post -greening_daily lowest temperature*	*c. Pre- and post-greening_daily lowest temperature*

Figure 4. Estimated effect on heat environment after performing the basic plan for building-greening

As for the water environment effect analysis, the change of evapotranspiration amount and direct runoff were evaluated through performing the analysis at the one-hour interval between 1999 and 2008 in the WEP model. In case of greening the preferred greening areas, the pre-greening average direct runoff of 1,255㎜ out of the total rainfall of 1,481㎜ was reduced to 899㎜ by about 28% after building-greening and the average evapotranspiration amount increased from 226 to 578㎜ by about 2.5times. In addition, in case of greening the recommended greening areas including the preferred greening areas, the pre-greening average direct runoff of 1.253㎜ was reduced to about 915mm by about 27% after building-greening and the average evapotranspiration amount increased from 222 to 563㎜ by about 153%. It can be thought that the effect was resulted from the impervious area reduction in the building-greening area. The Figure 5 shows the space distribution according to the water cycle change before and after building-greening for the direct runoff and evapotranspiration amount.

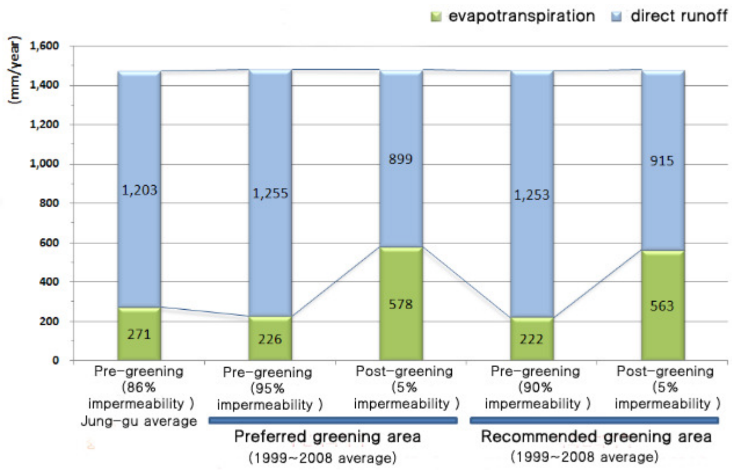


Figure 5. The change of average evapotranspiration and direct runoff according to building-greening

Ⅳ. Recommendations and utilization prospect

This study purposed to identify the preferred greening areas reflecting the local features as one of the methods to make cities eco-friendly and ecological and to present the basement to promote the local government-leading systematic greening projects. As a result, centering on the various themes including the urban heat island reduction, water cycle function improvement, urban carbon emissions reduction, urban biodiversity improvement, security of greenbelt deficient within city and urban landscape improvement, this study can provide the basement to establish the promotion plans for various building-greening types and secure the utilization possibility.

The basic plan for building-greening can develop to more specialized plans for greening projects through adding and changing the detailed analysis items at the level of local government based on the basic frame identified in this study. Based on the results from this study, it's found that the local governments can set the promotion direction for the systematic, efficient greening projects and it's expected that the effect resulted from the various building-greening, in addition to the urban climate improvement, can be maximized.

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