Master's Thesis of Landscape Architecture

Predicting Heat Island Mitigation from Green Infrastructures in Vacant Building Demolition Areas

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Graduate School of Seoul National University
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Yoonsun Park

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Under the Direction of Adviser, Prof. Dong Kun Lee

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Graduate School of
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Yoonsun Park

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Yoonsun Park

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Chair	______________________	(Seal)
Vice Chair	______________________	(Seal)
Examiner	______________________	(Seal)

Abstract

Rapid urbanization and decaying downtown areas have caused mass gains in vacant houses in large cities, such as Seoul, and mid-sized cities, such as Incheon and Daejeon. Vacant land and houses lower land prices and can trigger crime, causing negative externalities to adversely affect their surroundings. More cities have been gradually introducing green spaces in vacant land as a means of redevelopment to improve the city and reduce negative externalities. In addition to this societal value, the physical evaporation and shadow effects of green spaces can mitigate the urban heat island effect, which is a serious problem due to the artificial heat of the city.

In Korea, quantitative figures for the mitigation of the urban heat island phenomena are derived only for individual sites, and there has been insufficient research on the effects of introducing green spaces into vacant land and housing sites. In particular, it is important to evaluate the potential temperature reduction effect in the planning stage before implementing greening in the vacancies. This is important data that provides baseline data at the decision-making stage. Therefore, it is

necessary to quantitatively study the effect of greening vacant land and houses.

The purpose of this study is to derive the quantitative effects of urban infrastructure mitigation using meta-analysis to predict the regional effects of green infrastructure on vacant land. First, quantitative figures are derived from the meta-analysis on the impact of a Green Infrastructure Strategy on reducing urban decay. Second, based on the results of the meta-analysis, we quantitatively derive the green infrastructure effect obtained in two selected high-density areas in Sungui-dong, Nam-gu, Incheon. Nam-gu is the second largest city in Incheon and its residential area is the target of urban regeneration. Third, we examine the environmental benefits and opportunity costs of greening.

The study was conducted as follows. To understand the quantitative effect of green infrastructure, we derived a regression equation and used meta-analysis to determine the effect of temperature reduction when green space was introduced. Then, the extent of urban decay was evaluated using a previous study and sites A and C, with available ground surface temperature data, were selected in Nam-gu, Incheon.

The appropriate type of greening for Sites A and C were selected and the effect of temperature reduction was estimated using meta-analysis results.

The results of the study indicate that Sites A and C should be transformed into a Neighborhood Park and pocket park, respectively. These changes would result in a temperature reduction up to 2.751 ° C within the park at Site A, and a temperature reduction of ~1.507 ° C within a 62-m radius outside the park. The projected performance at Site C was similar, a temperature reduction of up to 2.269 ° C internally and ~0.92 ° C outside the park. In deriving the results, we considered that various previous studies obtained results from different situations, including climate zones and geography. In addition, the opportunity cost due to greening and the added value to the surrounding area are discussed.

Green infrastructure is an effective environmental practice tool to add social, economic, and cultural value. Furthermore, it facilitates the adoption of environment-friendly policies, such as the introduction of green spaces rather developing additional buildings to public places.

Keyword : green infrastructure, urban heat island, vacant land, vacant house, urban park, pocket park, shrinking cities
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Chapter 1. Introduction

Rapid urbanization and decaying city centers have gained public notice and publicity in some cities in Korea. These issues have arisen in large cities, such as Seoul, relatively mid-scale cities, such as Incheon and Daejeon, and small cities, such as Naju. The presence of vacant land and houses cause damage to cities (Branas et al., 2011), and these negative externalities adversely affect their surroundings (Accordino and Johnson, 2000). Local governments have become interested in redeveloping or managing vacant land to mitigate these problems. For the past half-century, scholars have been investigating the best practices for vacant land use (Bowman and Pagano, 2000); various solutions can result in the decline or growth of cities.

More cities have been increasingly introducing green spaces to vacant land as a means of redevelopment and to reduce negative externalities (Schilling and Logan, 2008). For example, Cleveland in the United States, in response to vacant land areas produced in the city due to social change, introduced greening to strengthen the natural environment of the city. Their aim was to stabilize the region, build green infrastructure, and create a productive landscape. In the case of Detroit, which thrived as an industrial city, greening initiatives developed efficient planning, implementation, and management strategies that would benefit the community. In Korea, Busan City is in the process of improving abandoned resources and create walking trails by greening idle land from an abandoned railroad. The Seoul Railroad 7017 Project, a green project that converted Seoul Station highway overpass to a green walking path, is popular because it created beautiful scenery and positively affected the surrounding real estate market.

Greenfields, serving as green infrastructures, have proven versatile in rainfall mitigation, reduced social vulnerability, increased access to greenery, mitigation of the heat island effect, and air quality, and have improved biodiversity through landscape connectivity (Lovell et al., 2013). The last benefit is often linked to ecosystem services. In addition, Mell (2009) highlighted that green infrastructures include niche spaces that have little value otherwise. In the context of this study, green infrastructures have emerged as a suitable substitute for components of 'gray infrastructure' (Benedict & McMahon), suggesting that urban sustainability can be promoted by providing a flexible development method that can modify the basic structure of the city. Green spaces, which preserve natural ecosystem values and functions and provide human-related benefits, have significant impacts because of their potential to improve resilience to social and natural environments (Benedict & McMahon, 2002). Above all, green infrastructures are important for addressing climate change, and its severe present and future impacts. However, green infrastructure has been criticized as having benefits limited to rain storm management (Newell et al. 2013). Therefore, other physical functions, including evaporation and the shadow effect, should be noted; greenery can mitigate the urban heat island effect, which is a serious problem due to excess heat from cities. Evaporation absorbs the surrounding heat and reduces the temperature. The shadow effect can prevent surface temperatures from rising due to tree shadows. An urban green area can reduce the inside of the green area by about 2-3 °C on average by mitigating the heat island effect. Sustainable public interest and public awareness are taken into consideration to address social, economic, cultural, and environmental aspects of urban decay because interest in preventing urban decline increases at the time of urban renewal (Sung Eun Young and others, 2015). That is, developing a green renewal strategy to implement green infrastructures in downtown areas and public announcements is necessary to realize sustainability.

However, in Korea, quantitative figures that can contribute to mitigating the urban heat island effect are derived only for individual sites, and there is insufficient research on the effects of introducing them to public sites. In particular, the potential temperature reduction effect should be evaluated at the planning stage before implementing a greening project at a public site. This type of important data can serve as the basis for decision-making; therefore, a quantitative approach to address the effects of greening on public space is necessary.

The purpose of this study is to derive the quantitative effects of urban infrastructure mitigation using meta-analysis to predict the regional effects of green infrastructure using existing data and predict the effects of greening.

Chapter 2. Literature Review

2.1. Greening strategies case study

Decaying cities are characterized by the decline of the primary city industries as society becomes unstable, with suburbanization marking the beginning of city decay. In the case of Cleveland, the declining manufacturing industry caused abandoned buildings and land in the city as the population was halved. In Detroit, industrial restructuring and decline of the automobile industry resulted in a significant decline in the population and a shrinking city. In Milwaukee, residential moves to newly developed areas outside the city resulted in a declining population and abandoned industrial sites. Changes to Philadelphia were characterized by similar factors. However, the subsequent success of these cities has been driven by the pursuit of a greener strategy that enables sustainable development.

Philadelphia has exploited the effects of parks and other green vegetation in mitigating the urban heat island effect (Cao et al., 2010; Li et al., 2013, Wong et al., 2011). In particular, the "clean and green" program maintains and manages abandoned lots with trees and plants trees, thereby stabilizing public landscapes, public sculptures, and the limited green space. Generally, these goals have been met (PHS, 2016). This greening strategy has already proven to aid in preventing crime and improving economic value (Branas et al., 2011; Heckert & Mennis, 2012). However, there has been no research on the amount of greenery required for the well-being and mental health of local residents (Garvin et al., 2013)

In Cleveland, green infrastructures were constructed as a public recycling plan for land use strategy, and recreational resources were provided to provide various functions, such as rainstorm management and ecological function. These will contribute to the restoration of the overall ecosystem and storm reserves.

The Southeast Michigan Council of Governments (SEMCOG) in Detroit has developed long-term strategies for introducing green infrastructure to Detroit. With a land-use model, SEMCOG predicted that large-scale green infrastructure would reduce 10 to 20% of the rainfall flowing into the sewage treatment plant. SEMCOG's notification plan can be divided into three areas: notification of greening next to main roads, notification of individual greening, and consolidation of notice for massive greening. They work with the non-profit organization “The Greening” to manage the greening plan. In particular, “The Greening” has planted more than a thousand trees through urban reforestation programs. Since 1989, more than 400 community gardens have been developed, and in doing so, has served the public interest in providing jobs for young people.

In Japan, encouragement for various green areas has been revealed in policies. Urban agriculture has been institutionalized since the 1980s, and in the 1990s, the Citizen's Farm Improvement Promotion Act for urban residents was enacted and open land facilities other than farmland were included for recreational purposes. City parks have been managed efficiently. In addition to developing greenery to prevent city flooding, the increase in the demand for graves from an aging society has been inevitable, but the development of cemeteries in the form of paddy fields using trees as grave markers has enabled sustainable land use. This is an example city sustainability that neutralizes the negative connotations of graves grave, prevents the decline in land prices, and helps maintain stability.

In Korea, the 'Gyeongui Line Forest', which was modified from above ground to partially below ground, has been transformed from idle abandoned railway land to walking paths for new communication and exchange. The project merged cultural elements and ecological values into a basic plan; this project serves as an example that verifies the versatility of green space that provides diverse ecosystem services. A similar project transforming idle railway land into a forest walkway has been implemented in Busan. In addition, the Seoul Station 7017 project has transformed an abandoned highway into a walkway with planted trees to show the benefits of pursuing cultural and ecological values rather than development oriented ones. This is similar to the high line in New York, which is a successful example of greening. It is hoped that these greening projects in Korea will also have such a successful result.

2.2. Case studies of greening vacant land

Zhang (2017) highlighted that in developed cities it is impractical to improve urban landscape connectivity due to environmental constraints. However, scholars have conducted research to provide practical conservation methods for detecting the fragmentation of green spaces and improving the landscape connectivity through connectivity analysis. The city of Detroit has become a popular research area because it is likely to reassess existing plans. The program FRAGSTATS has been used to identify structural and functional connectivity, select core patches in ArcGIS, minimize cost pathways, and evaluated corridors using a gravity model. As a result, the proposed corridors provide a way to develop vacant land and other available land through a green infrastructure network that benefits both humans and wildlife.

A study on the value of ecosystem services (Hasse et al., 2014), based on a literature review, discussed declining cities and ecosystem services. The value of various ecosystem services was estimated using classified indicators and type of vegetation planted. Among indicators, considering that the impacts of the cooling effect are developed for traffic information, the effect of traffic information is 0, urban green space is 2.9K in consideration of different usages of the vegetation, urban agriculture is 1.3K, and urban forest is 3.3K (Bowler et al., 2010; Hasse et al., 2014). In addition, the value of regulation services, such as air quality purification, carbon storage, storm management, and cultural service items are also presented, which suggests that known greening induces versatility.

Rajabi and Abu-Hijleh (2014) found that Deira, which is an old city in the structure in Dubai, and Bur Dubai, a densely populated city, had high contributions from greening to temperature reduction. In general, tree planting was better than rooftop greening and lawn planting. Furthermore, they found that to apply a greening plan to Deira, which is an old city structure, would require medium density planting. In addition, for Bur Dubai, dense city, they proposed a way of planting trees with moderate density.

A study using indicators to predict the value of ecosystem services modeled the effects of temperature reduction, and predicted the effect of introducing Green Infrastructure based on LCZ[①] (Emmanuel et al., 2015). Using Lidar data, the shape of the zone was identified and Envi−met was used to derive the temperature reduction results obtained when introducing green infrastructures to different LCZs. Based on the assumption that the value of the research is in the future, a scenario for introducing green zones in different ratios in 2050 was proposed. This scenario was used to propose a regression equation with high fitness for deriving the obtainable temperature reductions at different locations. In addition, it allowed the selection of different types of green infrastructures, such as roadside trees, permeable vegetation zones, and roof gardens.

[①] LCZ (Local Climate Zone): Each type of LCZ comes from a combination of surface structures, pavement, and human activity. Categorizing sites with appropriate LCZ requires basic metadata and landmark characteristics. The zone definition provides a standard framework for reporting and comparing site sites and temperature observations. The LCZ system is designed primarily for urban heat island researchers, but is now widely used in other disciplines.

Chapter 3. Methods

3.1. Scope of the study

3.1.1. Contents

The scope of this study is as follows. First, quantitative numbers were derived from a meta-analysis of the impact of green infrastructure strategies for reducing urban decay. This includes the results obtained from a literature review on the effect of green space on the urban heat island effect. Second, based on the results of the meta-analysis, we quantitatively derived the green infrastructure effect for two selected densely populated areas in Sungui-dong, Namgu, Incheon. We examined the environmental benefits gained and the opportunity costs generated due to greening.

3.1.2. Spatial context

The spatial area of Incheon is the oldest city in metropolitan Incheon, and has the second highest number of dongs. (2016). Namcheon, Incheon occupied a large portion of the city center in the past; however, the declining role of the city center, increase in population outflows, and relocation of major institutions led to declining neighborhoods. Sungui-dong is located in the vicinity of Jaemulpo Station on the Gyeongin Railway. It is the area where the port industry was once active, but according to recent statistics, it ranks first in Nam-gu in population decline and population decline for three consecutive years. Old buildings account for 84% of the total dwellings in the southern region (Incheon Urban Regeneration Strategy, 2016). Therefore, Sungui-dong is an area where the residential environment is the weakest. Sungui-dong is made up of four dongs, with a population of about 40,000 and an area of 2 km2. Among them, Sungui 1 and 3 Dong, with an area of 7,400 m2, are locations for the implementation of the 'Landscape Maintenance Project of Incheon Seok jeong District', and the project is in progress to construct an apartment building with 15 floors and happy homes. More than 130 landowners, 98% of residents, have already agreed to redevelopment agreements. It is the first 'mini reconstruction' project in which the Korea Land and Housing Corporation (LH) have participated. While these proposals have proceeded, the development business has suffered setbacks due to the complicated interests of owners, such as explanations for funding the project given the small scale of business, unsold housing and land, and difficulties in the legal process. Nonetheless, the plan is to rebuild 283 dwellings and revitalize demand-oriented maintenance projects that will increase the resettlement rate of the indigenous people and save local communities (Business watch, 2017).

Figure 1. Study Sites A and C in Sungui dong (Sungui 1,3 dong and Sungui 2 dong) (source: naver aerial view)

3.2 Methods

3.2.1 Study flow

The infrastructure of the study flow was based on the Sungui−dong vacant land site in Nam−gu, Incheon. First, in order to determine the quantitative effect of green infrastructure, a regression analysis of the temperature reduction value and reduction distance after introducing green space was derived using meta−analysis. Second, urban decline was evaluated using a previous study, and the ground surface temperatures at sites A and C in Nam−gu, Incheon were obtained. Then, we selected appropriate types of greening for Sites A and C. Third, the meta−analysis results were used to estimate the temperature reduction effect at each site (Figure 2).

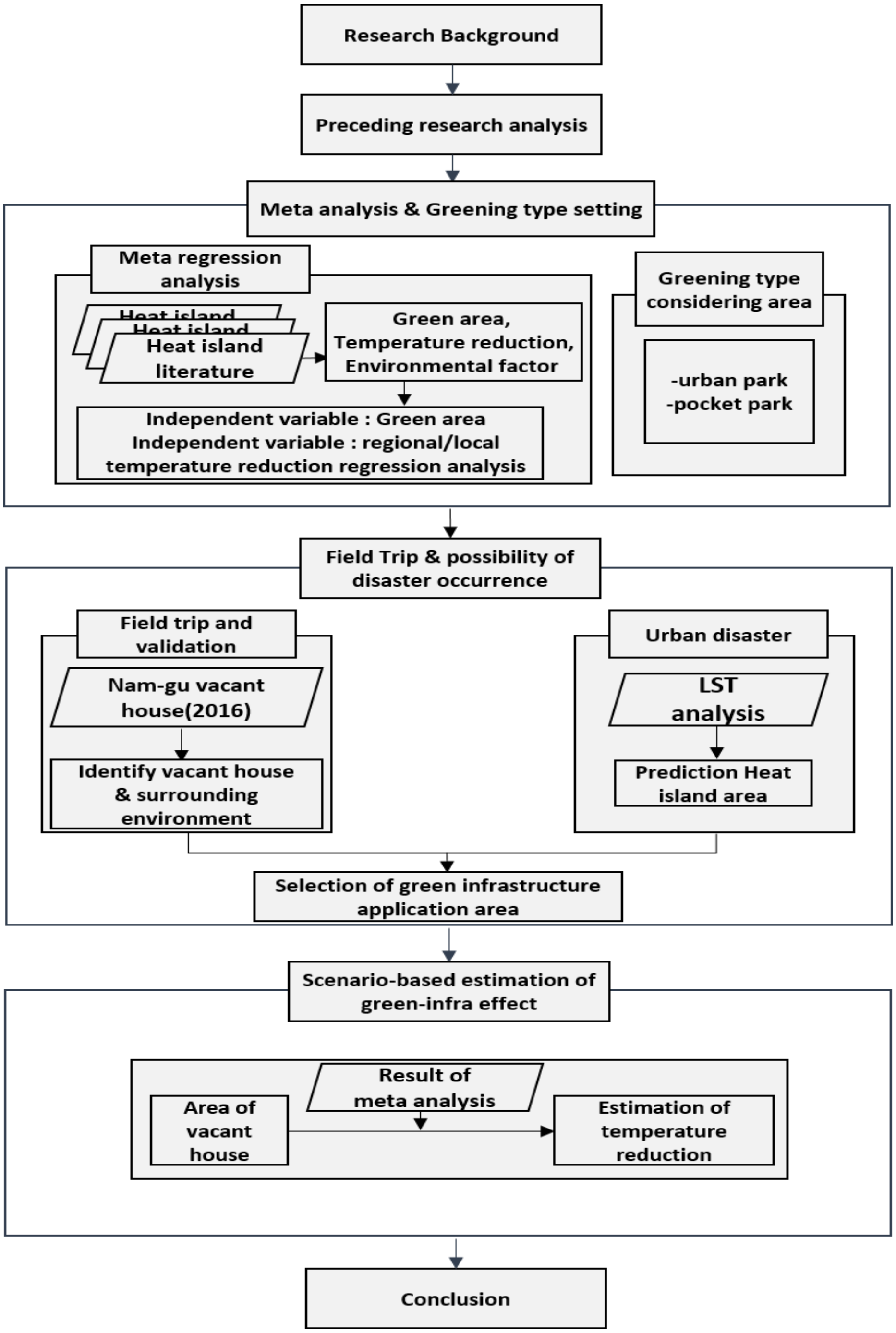

Figure 2. Method flow chart

3.2.2. Estimation of green infrastructure effect using meta-analysis

In this study, we derived potential heat island mitigation using a meta–regression analysis method (Glass, 1997), an analytical method that systematically and quantitatively analyzes previous studies on the same subject and derives comprehensive results. Existing individual studies have their limitations, including low statistical verifiability, neglecting alternative methods or models due to focusing on expected results, and suggesting different models based on individual data. These result in inconsistent or conflicting results. The traditional method for analyzing results is systematic in that it extracts samples at the convenience of the researcher, or there is a possibility that the subjectivity of the researcher will interfere with errors. However, meta–analysis ensures systematic sampling and objectivity (Hwang Seong–dong, 2015). It should be noted that the meta–analysis is a synthesis of a number of studies into a single summary measure, which can lead to errors resulting from the synthesis of heterogeneous studies with different characteristics.

1) Search and selection of related documents

The literature used for the meta-analysis was selected using same steps in Table 1. To investigate the effect of reducing the heat island effect due to greening, we reviewed published papers addressing the regional and global effects of green areas. For this study, we extracted the area, temperature reduction effect, and reduction distance of each type of greenery. Papers addressing regional effects of green spaces mainly presented temperature measurements and GIS analysis. Literature addressing local effects had the largest number of measurements, and analysis methods included GIS and CFD Envi-met. The studies reviewed were limited to studies involving atmospheric temperature (Table 1). The temperature reduction effects in the reviewed studies were expressed as Park Cool Intensity (PCI), which is the minimum value of temperature measured by 'walking by man' or 'by means of transportation' within park green spaces. This method indicates differences within the same city area, which can be used to measure the strength of a green area’s cooling effect.

Table 1. Selection of research for meta-analysis

	research inclusion/exclusion criteria
Phase1	Search related research -search engine: scopus -keywords: “(urban) heat island/heat/green infrastructure “ AND ” greening/mitigation/urban park/pocket park “ (Search to include one word in each group, ex)” urban heat island “ AND ” urban park “)
Phase2	Excepting studies involving “mitigation of heat island by green spaces”
Phase3	If related to the green area size or temperature mitigation and range of mitigation, select them. However, exclude those that do not present quantitative values.
Phase4	When searching for studies on temperature reduction, limited to studies involving atmospheric temperature.
Phase5	Reviews of 14 PCI-related papers (Regional) Reviews of 39 PCI-related papers (Local) Reviews of 8 PCI-related papers (Range of mitigation)

2) Heat island reduction estimation equation

Based on the selected studies, quantitative numbers for heat island effects were derived. The regression equations were derived such that the independent variable was the green area and the dependent variables were, 'reduction temperature of internal green space', 'reduction temperature of outside green space', and 'reduction temperature range of outside green space'. The value of each variable was obtained from the literature sources. In addition, the 'Park Cool Island Intensity (PCII②)' value, which is used as an indicator for the mitigation of the heat island effect due to the greenery, is generally the temperature difference between the urban area and urban area. Scatter maps representing the quantitative values derived from the literature were created and appropriate trends were derived using the regression fitting function in SPSS.

The effect of temperature reduction due to greenery is not limited to the area of greenery; it is also influenced by various factors, such as humidity, wind speed, albedo, and SVF (Oliveira et al., 2011) Clearly, it is unreasonable to estimate the entire effect of the virtual temperature reduction with only

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② PCII (Park Cool Island Intensity): means the maximum temperature difference between the inside and outside of the park when measuring the temperature of the park (excluding the effect of the shadow or sun). This can provided in formation on the maximum value of the greening effect for temperature redu ction (S. Oliveira et al., 2011). For the temperature outside the park, which is the reference point, the built-up area temperature is used in most studies.

the green area. However, the nature of this study suggests is not site−specific, but rather an integrated study of the literature to provide an environmental impact prediction based on applying green infrastructure to a site. The numbers extracted from the literature were used to derive the descriptive statistics in this study.

3.2.3 Selecting the study site and greening type

1) Study site

(1) Selecting the ‘dong’ needing green infrastructure

In this study, we selected Nam − gu in Incheon Metropolitan City as the target area for green infrastructure due to the increasing public interest rate, high urban decline index, and the urgent need for a solution to prevent risks. To derive a region with high vulnerability due to climate change, which is a factor that adversely affects the residential environment even in the southern part of the country, we conducted a ground surface temperature analysis using satellite imagery. We used this to limit the study to areas where introducing green infrastructure has the highest priority. The analysis method for determining the surface temperature was as follows. First, we conducted an

LST (Land Surface Temperature) analysis, which is often used because of its high explanatory power for temperature (Schwarz et al. 2012) Through the southern provinces, we sought heat island vulnerable areas.

(2) Vacant house sites needing green infrastructure

A preliminary study (Jeon & Kim, 2016) classified the public service provided by the Nam-gu office in Incheon and crowded area of Sungui-dong into four areas from cluster 1 to 4 according to cause and type. To understand the types of possible green infrastructures, it is necessary to determine the degree of building aging and area of public land. To determine the degree of building aging, such as the robustness of roofs and windows, the public areas of Sungui-dong, Nam-gu near Jeemulpo Station were visited. For the purpose of determining the various green infrastructural elements appropriate for crowded areas, we photographed the residents, notice, surroundings, corridors of dense housing, and waste situation. We compared the data obtained from Nam-gu and the state of public acreage to determine potential public interest in an existing site or if redevelopment is taking place. In this case, the survey data and survey results were different. In addition, we evaluated the current state of buildings located in the surrounding area to select an appropriate type of greenery in anticipation of the demand for green space. In this study, dense areas were termed areas A to D (Table 2).

Table 2. Sungui–dong field survey method

Place	Object	Method	evidence of age	Conditions for possible green infrastructure deployment	Whether Photos taken
Sungui 1,3-Dong	Vacant house	field investigation, supported by Nam-gu cheong	-robustness of house -status of waste disposal	-Density of nearby residents -Building Age	O
	Vacant land	field investigation	-		O
	Surrounding apartments	Naver aerial view, field investigation	-Apartment construction period		O -expected demand for green space after evaluating surrounding buildings
Sungui2-dong	Vacant house	field investigation, supported by Nam-gu cheong	-Rust on the roof -Cramped hallway	- Size and Building age	O
	Surroundings	field investigation, Naver Roadview	-	-Percentage of greening	-Same as Sungui 1,3-dong

2) Select greening type

In this study, to estimate the reduction effect of the heat island effect obtained through the installation of green infrastructures, we proposed the creation of a pocket park in Sungyeon 2 dong. The primary proposal was to make the selected public site 100% green. This study predicted the effect of reducing the heat island effect due to greenery.

Chapter 4. Results and discussion

4.1 Estimation of green infrastructure effect using meta-analysis

4.1.1 Results from the search and selection of related documents

1) Temperature reduction of the internal green space

The table in Appendix 1 lists the literature used to determine the effect of global ambient temperature reduction due to greenery. As shown in the table, the set of samples with various climatic zones is represented with values obtained from the meta–regression analysis. The types of samples collected were diverse: specimens were collected from a wide range of climatic zones ranging from hot and dry desert areas to rain–rich tropical regions. Samples were also collected with different velocities, measurement methods, measurement locations, tree species, albedo, and SVF. Atmospheric temperatures measured at too high an altitude result can result in poor measurements of the temperature reduction effect due to turbulence. Therefore, most studies measured at height above ground < 2 m at wind speeds < 2 m/s. The temperature reduction effect (PCI) ranged between 1 and 7 °C. Most research was conducted in urban parks or gardens (Appendix 1).

2) Temperature reduction of outside green space

Appendix 2 provides the list of publications that studied the effects of global atmospheric temperature reduction due to greenery. Notably, there were few publications with available data; more data was available for sites > 50 ha because the external temperature reduction effect is meaningful when the size of green space is large. However, this study has sites that are < 1 ha. Therefore, the number of studies used in the meta-regression analysis was very small. The temperature reduction effect was about 1–2 °C (Appendix 2).

3) Temperature reduction range for outside the green space

The publications in Appendix 3 examined the cooling effect due to the greenery for areas outside the green area with radii up to several meters. The size of the green area ranged from

0.24 to 60 ha, and the reduction effect ranged from 15 to 1000 m (Appendix 3).

4.1.2 Derivation of Heat Island Reduction Effect and Trend Equation

We predicted the effect of green infrastructure reduction based on the appropriate types and sizes of green spaces for the public areas of Sungui – dong using the derived PCI from meta−analysis. In general, the effects of urban greenhouse gas reduction due to greenery are divided into regional and global temperature reduction effects. The global effects include the extent of the actual temperature reduction and its influence. In this study, we obtained regression analysis by setting the independent variables as 'green space size', dependent variables as 'temperature reduction effect', and 'temperature reduction range', as indicated previously.

1) Sample selection

We attempted to standardize the PCI values to remove anomalies from the collected samples and then to remove the samples whose values were outside the absolute values. However, no anomalies were found in the analysis, and regression analysis was performed using all the collected samples. We note that all collected samples were measured as daytime temperatures. In deriving the external temperature reduction formula, only the rooftop greening study was removed and the regression analysis trend formula was derived using the limited number of samples. Finally, to study the range in external temperature reductions, a trend equation was derived for six samples, excluding the two studies with insufficient information.

2) Derivation of regression equation and trend equation

(1) Interior temperature reduction

The simple linear regression model showed that 'the area of the green space' accounts for about 11% of the 'reduction of the internal temperature of the green space', which is relatively high. The significance level is not more than 0.05. It is generally known that the relationship between green area and internal temperature reduction is expressed as a logarithmic relationship (Cheng et al., 2014, Ren et al., 2013). Accordingly, the samples were fit to the logarithmic expression, and the results are shown below (Figure 3). The area of the study site is small, but a large sample (for example, one publication with 20 ha green area) was used to obtain a more accurate log graph.

Table 3. Regression analysis Result

Model	R Square	F	Sig.
Linear	0.107	6.773	.042

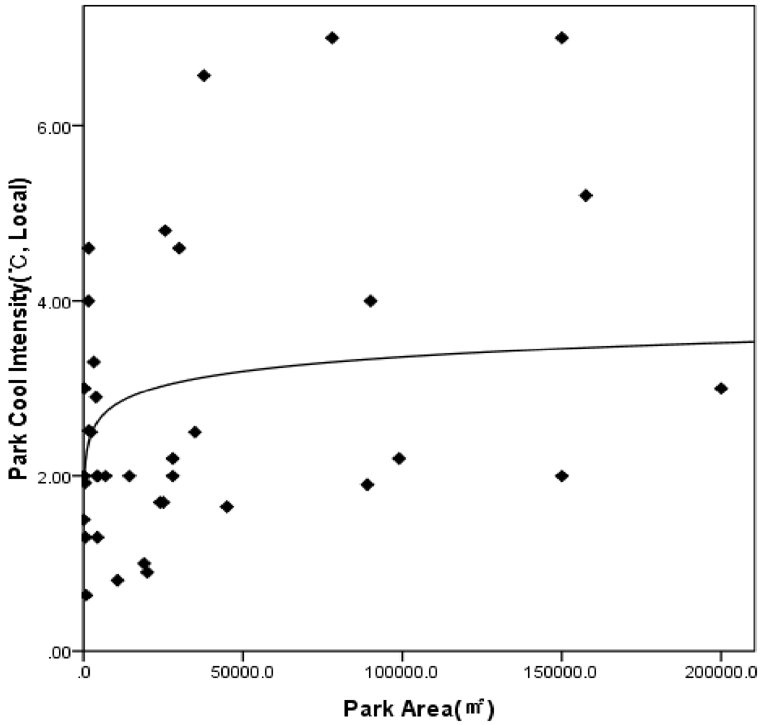

Figure 3. Relationship of area & Local temperature reduction

(2) Outside temperature reduction

Regression analysis of the effect of external temperature reduction due to greenery indicates a logarithmic trend equation. In the sample collection process, the external temperature reduction effect for small green area was relatively large (2–3 °C). In contrast, many studies have shown that the reduction effect for green areas exceeding ~150 ha is only 3–4 °C. Therefore, when these values are included, a formula with a negative linear relationship is derived, which is somewhat difficult to explain. However, we hypothesize that this relationship is due to the temperature reduction effect having a limit. The inclusion of all large areas of greenery and outliers suggests that there is an optimal green area that maximizes temperature reductions (Figure 4).

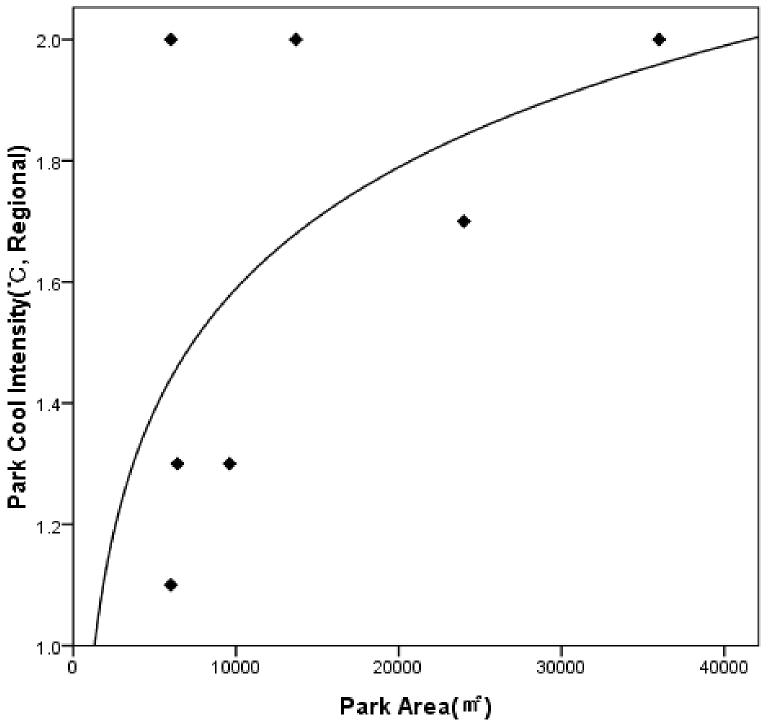

Figure 4. Relationship between area and regional temperature reduction

(3) Outside temperature reduction range

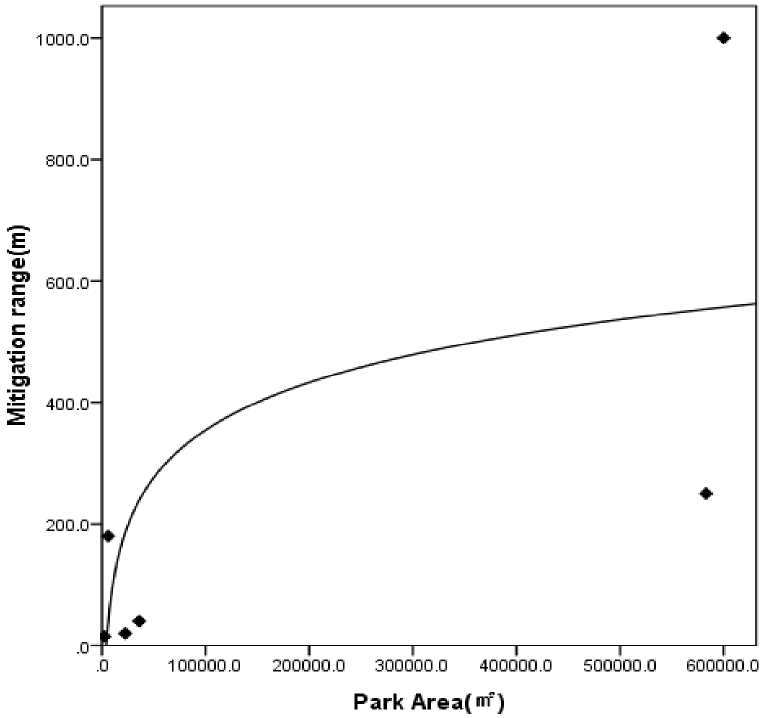

Figure 5. Relationship of area & Regional temperature reduction range

Regression analysis indicated that the range in external temperature reduction due to greenery was small. To obtain a significant reduction range outside the green area, it is necessary to have a specifically sized green area. The logarithm of the trend formula is shown in figure 5.

$$y = 0.634 + 0.237\ln x \quad (1)$$

$$y = -1.074 + 0.289\ln x \quad (2)$$

$$y = -946.427 + 112.992\ln x \quad (3)$$

Equations (1), (2), and (3) were used for the metric regression analysis. The internal reduction temperature versus area was derived using (1) and 40 samples. The temperature reduction effect is evident within the greenery. Next, a trend formula for obtaining the reduction temperature outside the green zone according to the area was derived as (2). Finally, equation (3) determined the extent of the external temperature reduction effect obtained from equation (2). In this case, the distance reduction decreased as the distance increased, however further discussion of this point is beyond the scope of this study. Using these regression results, it is possible to predict the temperature reduction effect from greening a public area in Sungui-dong, Incheon.

4.1.3 Equation accuracy

1) Explanation of the reliability of the trend equation

From the perspective that meta-regression analysis is the synthesis of various data, it is difficult to expect a good fit between the trend line and sample. However, the greatest advantage of meta-regression analysis is that scientific results and objectivity can be guaranteed because the results are derived from various publications. The purpose is to propose new hypotheses from the analyses. For environmental reasons, each sample is different, which can be explained as follows.

First, we relied on the credibility of peer-reviewed published studies. The Park Cool Intensity (PCI) of collected studies may not be accurate, which would suggest that there is no regular relationship with area.

Low explanatory power in a similar study (Chang et al. 2007) was explained as due to the meteorological network measuring the reference temperature based on location convenience and rather than representing true rural temperature. We do not have confidence in this explanation. Another reason for the uncertainty is that it is inappropriate to apply the various criteria in each study, such as the proportional application of a reference temperature to both a large park and small park. However, when measuring the reference temperature, the same distance application for large or small parks should be applicable given that air moves from high temperature to low temperature, irrespective of park size. Clearly, the reliability of the study varies due to the uncertainties that may arise in the methodology.

Second, while each climate zone has unique characteristics, they are unclassified, so there is a limitation in trends. Other 'meta-analytic' studies on the effect of greenhouse depletion on heat sinks have yielded different mitigation ranges, which are explained as due to different climate zones. For example, Bowler's meta-analysis in 2010 concluded that the mean value of green cooling intensity (GCI) was 0.97 K, but Skoulika's 2014 study defined the range as 0.3 K to 6.9 K. The former researched the subtropical region and the latter studied Mediterranean climate. Based on these results, the reduction in the heat island is likely specific to the climate zone.

Third, geomorphological differences have a great influence on the urban heat island effect and its reduction. Although the importance of the climate zone has been emphasized earlier, the reduction results are different for varying measurement time even for the same climate zone. Furthermore, if the other parameters are identical, then the results are noticeably different for different geometries. For nighttime samples, the reduced temperature is proportional to the loss of long-wave radiation, which in turn depends on the quantity of heat allowed to escape (Lee et al., 2009). This is the same mechanism for varying sky view factor (SVF) values. Therefore, geometry plays a large role in temperature reduction. The relative impact has been studied in Hong Kong, and it was concluded that geometry accounts for 25.4% (S.S. Lau et al., 2012) based on a regression equation between SVF and temperature reduction. As a result, the SVF factor can be used for other temperature reduction values given the same conditions.

A combination of the second and third factors result in a fourth factor. The effects of the wind and arrangement of buildings can balance. As mentioned previously, moderate winds help maximize the heat island effect. However, an unplanned building layout in a city can block the passage of the wind, eventually offsetting the role of wind to mitigate the heat island effect. Various combinations of wind speed and building layouts must be distinguished for different studies, which is virtually impossible. Therefore, it is difficult to deduce an exact equation between area and temperature reduction.

Fifth, there are other external factors that result in differences in temperature, such as altitude, cloudiness, and tree composition. Temperature differences due to elevation can be a factor for deriving different temperature values even under the same conditions. Similarly, the same area of greenery has different evapotranspiration ability due to differences in tree structure, which can make a big difference in temperature reduction effects.

In summary, the uncertainty in the regression equation is reasonable given the variations in these five factors; these conditions limit the research and should be studied further.

2) Limitations and implications of this study

Despite the limitations, this study has merit. The meta-analysis and its application provide a mechanism to propose new hypotheses and identify differences between individual study sites. In this study, we discussed the accuracy of the derived trends and explained the differences between individual studies. Because meta-regression analysis is not heterogeneous, it is difficult to achieve a high fitness value because it synthesizes individual studies with many specimens;

this results in a wide range of predictions for the heat island effect. Although the uncertainties are large, the general trends are meaningful.

A CFD can evaluate the differences and implications suggested from the regression equation derived from multiple measurements at one site. Using CFD is a task that requires many assumptions, so it has uncertainties, and there is room for overestimation or underestimation. This method should use measurements at one site because the uncertainty of having various environmental conditions makes a multi−site analysis useless. Although a site−specific regression equation is limited to the site, it can be argued that the fitness value of the formula generated for various sites can be applied to an unknown site. In other words, the CFD can be applied to a wide range of situations, and can be used to support the plan for a public green site.

4.2 Search and select target sites

4.2.1 'Dong' selection for green infrastructure

1) Derivation of thermal environmental vulnerability map

Figure 6 shows the surface temperature map (LST map). From the map, the vicinity of Sungui 1,3 and Sungui 2 are vulnerable to heat. LST is > 44 °C for Sungui 3, which includes Site A, and 44 °C for Sungui 2, which includes Site C, and 46 °C in Sungui. Sites B and D, included in Sungui 4, show relatively low LST at 41 to 44 °C (Figure 6).

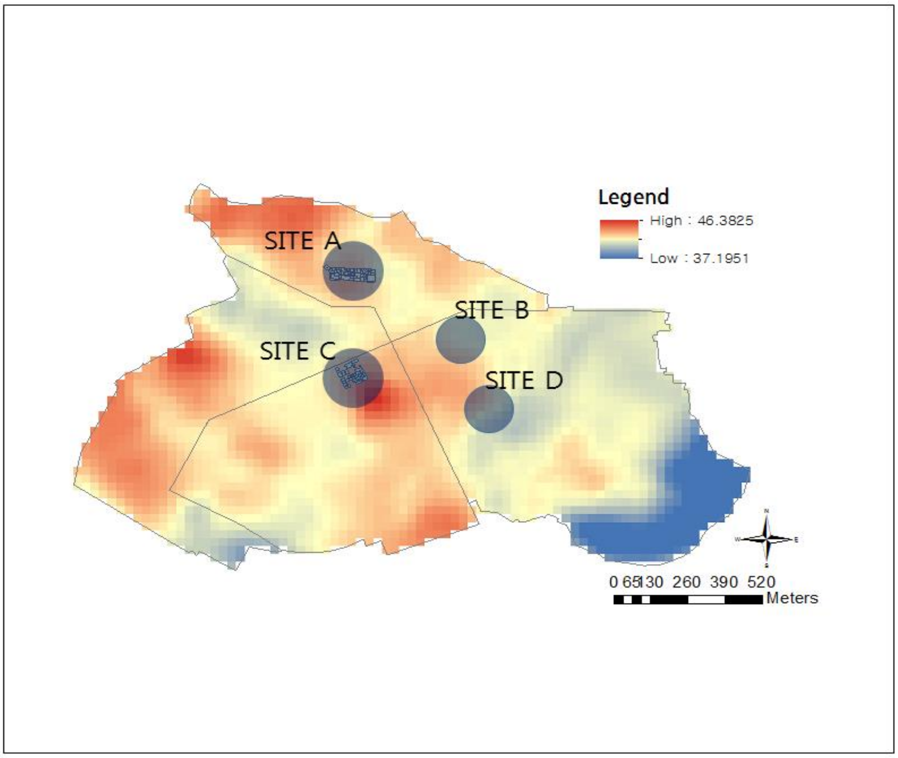

Figure 6. LST map(Land Surface Temperature Map) of Sungui dong

(by researcher, source: 2016.8.7. Landsat8)

2) Prediction of the heat island effect from site structure observations

Factors affecting the urban heat island (UHI) effect include solar energy to warm the surface and surrounding air, areas with limited greenery that reduce the cooling effect from shadows and evapotranspiration, and heat emissions from cooling machines that make the surrounding area hotter (US EPA, 2015; Wong et al., 2011; H. Pearsall, 2017). In particular, we predicted that Sung-ui II will have a significant heat island effect, considering that the low vegetation rate, impermeable surfaces made of concrete, arrangement of dense houses affecting solar radiation, and heat emissions. is. The same predictions were made for Sungui 1, 3-dong.

Considering that the environmental factors, such as the high temperature distribution shown on the LST map, coincide with the environmental factors, such as the poor building layout, areas vulnerable to the heat island effect were predicted based on site structure observations. Furthermore, areas with strong UHI effects were identified.

4.2.2 Vacant land for green infrastructure

1) Sungui-dong exploration results

Figure 7. Study site

Figure 8 Sungui 1·3 dong study Site A(red boundary)(source: google map)

Figure 9 Sungui 2 dong study Site C (red boundary) (source: google map)

Surveys of Sungui−dong, Nam−gu, Incheon were used to divided the dong into Sites A and D. This study used research that divided the densely populated area of Sungui−dong into four types according to type and cause (Jeon & Kim, 2016). In this study, the focus was to identify the types of infrastructures and apply them to simulate UHI effects (Figure 8, 9).

Site A was judged to be an area that could not be redeveloped because aged buildings were too concentrated. The buildings had clear characteristics of decay; there were roofs mostly down and rusty, many pieces of household waste, broken windows, sculptures, and irreparable houses. It was concluded that a new plan was needed after demolition (Figure 8). Notably, this is the location where the low−rise residential management plan of Seokjeong village was established, and has become an issue for the redevelopment site. Due to the frequent change in development policy, the plan remains unsettled. However, due to the many apartment complexes in the surrounding area, it is expected that the demand for green space will be high and it will eventually lead to an improvement in the quality of life. Therefore, the benefits of introducing green spaces in this socio−economic and cultural context are significant.

In Site B, houses that had been designated as vacant land in previous research were demolished and turned into construction sites (Jeon & Kim, 2016). Many of the surrounding houses had quick-sale or lease markings and were newly built, while some existing houses were gradually declining in value. This area could be developed and rescued from urban decline with simple home remodeling.

Site C is a dense vulnerable class zone in a closed area near the Nam-gu office. Each building is small in size, and the corridors between buildings are so narrow that one person can barely pass (Figures 9).

Site D has a steep-sloping terrain, and the altitude is increasingly high. It is expected that when the heavy rain occurs, the slope will cause the ground to collapse. There was a crowded hall and a house showing visible decay. In addition, the plethora of abandoned cigarette butts suggests that people are not rare.

It was concluded that the public areas were likely to be the most vulnerable areas. If these areas are neglected, it is expected that the adverse effects will continue to spread over a wide area, as specified in the broken window theory.

In this study, Sites A and C were chosen as green infrastructure sites (Figure 10). For Site A, installation of green spaces for nearby residents would benefit many people environmentally and culturally, which indicates a balance between supply and demand. For B, the site can act as a cause (Kim, 2015). Site B was also a vulnerable area for the UHI effect, but it was excluded from greening because active development was taking place.

Figure 10 Study site in Sungui dong: Sites A and C (Sungui 1, 3 dong & Sungui 2 dong) (source: Naver aerial view)

Table 4 Results of Sungui-dong field survey

Place	Object	Method	evidence of aged	Conditions for possible green infrastructure deployment	whether install green-infra
SiteA Soongui 1,3-dong	Vacant house	field survey, supported by Nam-gu cheong	-almost every building(houses) was aged - waste disposal - abandoned area - a rare place	- very aged house, demolition recommended - Nearby apartment complex, Estimated demand for green space	O
	Vacant land	field survey	- vacant land around vacant house		
	Surrounding apartments	Naver aerial view, field survey	- mixture of old and new apartments.		
SiteB Soongui 4-dong (1)	Vacant house	field survey, supported by Nam-gu cheong	- existing vacant house location changed to construction site	-	X
	Surrounding	field survey	- Most houses come out for sale. - Shrinking region		
SiteC Soongui 2-dong	Vacant hous	field survey, supported by Nam-gu cheong	- a cramped and aged house - narrow aisle	- Housing is very small compared to other areas - aged housing	O
	Surrounding	field survey, naver roadview	- nearby Nam-gu office - Residential area - High density residential		
SiteD Soongui 4-dong (2)	Vacant hous	field survey, supported by Nam-gu cheong	- Unsafe areas	-	X
	Surrounding	field survey	- the place where the playground was located was formed as a large vacant land - nearby Soobong park& Juan park		

<Site A>

Figure 11 Sungui 1, 3 dong (image collected in this study, March 7, 2017)

<Site C>

Figure 12 Sungui 2 dong (image taken for this study, March 7, 2017)

4.3 Estimation of green infrastructure effect

In this study, Site A and C, which are designated as Sungyeong – dong, were planned locations for a neighborhood park and pocket park, respectively. This was in agreement with Incheon City's urban planning policy (Incheon Metropolitan City, 2016), which included the green area per capita increase policy. The regression equation and trend equation for the park area and heat island reduction effect were derived for these two sites. Site A showed a 2.751 °C temperature reduction effect inside the park compared to the outside, and 1.507 °C reduction at a radius to about 62 m outside the park. Site C showed a 2.269 °C temperature reduction inside the park and a reduction of about 0.92 °C outside; however, the reduction distance is negative in the calculation, meaning that it cannot be predicted because a meaningful value cannot be derived (Table 5).

Table 5 Sungui-dong temperature mitigation effect obtained from installing green infrastructure

	SiteA		SiteC	Total
area(㎡)	7559.5		992.1	8551.6
mitigation range(m)	62.655		-	-
regional PCI(℃)	1.507		0.920	-
local PCI (℃)	2.751		2.269	-

4.4 Impacts on the surrounding area

Installing green space in Site A area can be expected to bring many apartment residents from the surrounding area. As neighboring parks are created, they create various values, such as community, increase in biodiversity, and prevention of damage caused by heat island flood. It is also possible to predict that resident visits will revitalize the surrounding commercial area, revitalize the park, and raise land prices. Next, Site C is known as a concentrated residential area vulnerable to urban decay. All the houses are very small and corridor widths between buildings are too small for one person to pass. Densely populated areas are usually considered as having serious heat island effects. Therefore, installing a pocket park on one side of such a narrow space would likely bring a temperature reduction to the entire residential block. For example, Park et al (2017) found that small green space has an excellent effect in reducing the unit block temperature; when the green area occupied by the block is large, the results show that the temperature reduction effect is > 1 °C even if the area is as small as about 200 m2. This shows that the presence of a small green space can play a large role in reducing urban temperatures.

4.5 The opportunity cost of greening

We also derived the numerical value of the urban heat island effect reduction effect from greening of public areas. However, there are numerous examples of urban regeneration, including the introduction of residential facilities, construction of energy generation facilities, and introduction of cultural facilities. As a known method of regeneration in Korea, there is a typical method of introducing a residential facility in a building, such as a toad housing or a news tee business. However, there are also street house maintenance businesses, which are a low-rise residential development projects, called mini-reconstruction. The construction of the street house in Geoje District 1, Yeonje-gu, Busan, has recently been disturbed due to financial problems that have not been resolved with loan guarantees. In the case of original redevelopment or reconstruction, the HUG (Housing Guarantee Corporation) guarantees the project cost because of the large size of the project, while the landscape housing project has not been supported by the HUG due to the small scales of the projects. As a result, the Seoul Metropolitan area has been working on the guarantee and expertise for LH, and as a result, HUG's New Urban Regeneration Support Team has been established, which will likely accelerate the activation of business. The 'New Urban Regeneration' policy, which will be pursued in the future, may be suitable for Seoul. It is different from that of the Seoul metropolitan area and Seoul New Town dislocation area, which is expected to be promoted as the subject of urban regeneration (MK News, 2017). It is also expected that the HUG 'Urban Renaissance New Deal Support Team' will reinforce the construction of vacant houses in rural areas. However, in the case of the provinces, considering the time, financial, and administrative efforts to solve the problem and demand for buildings, the installation of green infrastructure could be an advantageous financial, environmental, and cultural alternative.

With the confirmation of building development and guaranteed profit, economic profit from green space should be discussed. Although the population of Korea is gradually declining, city planning is proceeding assuming that population is increasing due, and there has been an error in the population estimation method. If this assumption is invalid, financial costs to management costs will result due to unused building space, which would not occur through the introduction of green spaces. It should not be overlooked that there are many apartment complexes and commercial opportunities formed when parks are introduced (Mohammed, 2006). Generally, the introduction of excessive buildings leads to wasted land resources.

Planning for future climate change and population decline suggests that greening infrastructure is more important than development. Green areas are worth more than the introduction of buildings given the values of ecosystem services and a reduction in the UHI effect from green space in the context of future climate change.

Chapter 5. Conclusions

The purpose of this study was to derive the quantitative effect of UHI reduction obtained from introducing green infrastructure to public land, and in particular, to the dense area of Sungui – dong, Incheon. Quantitative reduction values and ranges were summarized using a review of the literature on UHI reduction corresponding to green infrastructure. In addition, we classified the results to certain criteria in a previous study to select appropriate locations for public green sites.

To estimate the temperature reduction and range at each site, we derived regression and trend equations for the internal temperature reduction, external temperature reduction, and temperature reduction range according to green area. We found that introducing a neighboring park to vacant land in Sungui–dong would have environmental value that could reduce temperature 2.751 °C inside the park; expected ambient temperatures would be reduced 1.507 °C to a radius of 62 m. In addition, it was predicted that a relatively small area pocket park would reduce the inside of the park 2.269 °C, and outside the park 0.92 °C. In addition, this study predicted physical phenomena that would occur when green infrastructure is introduced through the synthesis of various researches. Therefore, in the literature analysis process, the temperature reduction effects in green areas were evaluated using various variables, such as humidity and wind direction. Because these are not independent variables, this is a limitation of the study. Deriving the equations to predict reductions in the UHI effect through synthesis of more sophisticated variables and more reliable data will result in improved accuracy in future studies.

In this study, there were no discussions on the problem of demolition of private property, development or conservation of urban regeneration projects such as road maintenance projects. However, this will be done flexibly in accordance with the 'Urban and Residential Environment Improvement Act' and the 'Empty House and Small House Improvement Act[③]', which were revised in 2017 to be effective in February 2018. In the

③ On May 17, 2017, the Ministry of Land, Infrastructure and Transport (MOTT) announced that it would reorganize the complex maintenance business system for the existing city and residential environment improvement law to make it easier to understand. The small-scale housing maintenance projects, which were partially removed from the Planning Act, autonomous home maintenance project, small-scale reconstruction, and house maintenance project were enacted as subordinate ordinances and concrete requirements were laid down for each piece of legislation. The legislation will be enforced in February 2018 (Ministry of Land Transport and Transportation, 2017).

situation where urban regeneration is attracting attention such as the budget allocated to urban regeneration by the regime change is increased to 66 times of the current budget, it is necessary to consider deeply the characteristics of each region in regard to how to regenerate in what direction.

The results of this study are evidence that environmental practices of green infrastructure are effective in addition to social, economic and cultural effects. It can contribute to the adoption of environmentally friendly policies such as the introduction of green spaces rather than development priority policies through the introduction of buildings to public places.

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Appendix

Appendix 1 : Local mitigation temperature

No.	Author	wind speed (m/s)	greenspace area(㎡)	city/country (temperature zone)	mitigation temperature (℃)	method	Site Features	green space type
1	Mueller&Day (2006)		67	Phoenix/ Arizona (temperate)	1.5		green roof	park
2	A.Dimoudi et al.(2003)	1	100	Athens/ (temperate)	2	CFD/1.5m	–	park
3			196		3			
4	Harazono et al.(1991)		140	Japan (temperate)	2	measured/ 0.2m	green roof	
5	Bacci et al.(2003)	-	200	Florence/ Italy (Mediterranean)	3	measured/2m	–	
6	Shashua-bar&Hoffman(2000)	0.5-2	1500	Tel Aviv, Israel (Mediterranean)	4	measured/1.8 m	Aharon Garden	garden
7	Z. Wu et al.	1.5	470	Beijing/China (subtropical)	1.92	envimet/2m	high−rise residential quarter, paved with asphalt, and	pocket park in

							sidewalks used concrete and cobblestone as pavement materials.	WCY
8	S.S. Lau et al.(2016)	0.4 m/s.	560	Hongkong (Tropical)	1.3	measured/	high rise−high density building geometry. its shading effect surpasses the effect of greenery	pocket park
9	Lin&Lin (2010)	-	804	Taipei city/ Taiwan (Tropical)	0.64	measured	The shading of U. parvifolia reduced air temperature by 2.52 ° C but that of C. fitula only by 0.64 ° C	park
10	Mayer&Hoppe (1987)	-	1600	Munich/ German (oceanic)	4.6	measured/ 1.75m walking man	grass and trees (height:18m)	backyard
11	Lin&Lin (2010)	-	1633	Taipei city/ Taiwan (Tropical)	2.52	measured (U.parvifolia)/	Shadow effect varies depending on plant species, so temperature reduction effect varies	park
12	Saito 1991	그림으로표기	2400	Kumamoto/ Japan	2.5	measured/ 1.5m	broad−leaved trees residental area	pocket park
13	Barradas (1991)	light winds	30000	Mexico(AP)/ (Tropical)	4.6	measured/	small and humid island generated by cityparks	park
14	Shashua-	0.5-2	3920	Tel Aviv, Israel	2.9	measured/1.8	Meltz Garden	garden

	bar&Hoffman(2000)			(Mediterranean)		m		
15	F.Salata et al. (2015)	0.01	3240	Cloister/ Rome (Mediterranean)	3.3	CFD/2m	different albedo	square
16	N. Gaitani et al. (2011)	0.5-3.5	4160	Athens (temperate)	2	CFD/ 1.5&3.5m	surrounded by high residential buildings of an average height close to 20 m. & concrete pavement	park
17	Shashua-bar&Hoffman (2002)	-	4400	Tel Aviv, Israel (Mediterranean)	1.3	GreenCTTC/ 1.8m	SVF=0.721	Garden
18	Nichol. (1996)	0.5	4500	Singapore (Tropical)	2	measured	A dense area of high-rise residential buildings	green areas
19	Bacci et al. (2003)	-	6900	Florence/ Italy (temperate)	2	measured/2m	–	park
20	Chang et al. (2007)	2.1	10700	Taipei/ (tropical)	0.81	measured/ 2m	trees, shrubs, turf, parcel surfaces	park
21	Jansson et al. (2006)	1-2	14400	Stockholm/ Sweden (Subarctic)	2	measured/ 0.19, 1.16, 2.47m	Deciduous trees, grassy parks, buildings are rarely found	park

22	Barradas (1991)	light winds	19000	Mexico(temperate)	1.0	measured/	small and humid island generated by cityparks	park
23	Barradas (1991)	light winds	20000	Mexico(temperate)	0.9	measured/	small and humid island generated by cityparks	park
24	Upmanis (1998) (이상치 아님)	2.0	24000	Goteborg/ Sweden (Subarctic)	1.7	measured/2m	fissure valley landscape, dominated by a few broad and large valleys SVF=0.44−0.61 many decidious trees	park(Guberoparken)
25	Potcher et al. (2006)	0-1	25000	Tel Aviv, Israel (Mediterranean)	1.7	measured/2m	grass	park
26	B.Vidrih&S.Medved (2013)	0.1-4.5	25600	-	4.8	CFD/1.2m	LAI=3.8	park
27	Potcher et al. (2006)	1-2	28000	Tel Aviv, Israel (Mediterranean)	2	measured/2m	covered at the park center by high and wide−canopied Ficus microcarpa trees, well shaded (95% of the ground area), and located in the city center	park
28	P. Cohen et al. (2014)	~1.9	28000	Tel Aviv, Israel (Mediterranean)	2.2	measured	a variety of mature tree, shrubs and lawn well−developed Ficus microcarpa	park

							tree−lined avenue and was well shaded (tree cover 85%, SVF 0.077).	
29	Potcher et al. (2006)	calm	35000	Tel Aviv, Israel (Mediterranean)	2.5	measured/2m	medium trees residential neighborhood	park
30	M. Boukhahra(2012)	2.06 (empty situation)1.3 (current)	37772	Gothenburg/ Biskra (desert)	6.57	Envi-met	garden with the mature trees	garden
31	Armson et al. 2012	- measured by HOBO	78000	Manchester, UK (temperate)	7	measured/ 1.1m	mitigation effect: shading>surface	Park
32	Barradas (1991)	light winds	89000	Mexico (temperate)	1.9	measured/	small and humid island generated by cityparks	park
33	Erica Correa (2006)	-	90000	Mendozaa/ Argentina (temperate)	4	measured/ 3m	low construction density (1.96 m3/m2) mainly, with a mean building height of 3m.	park
34	Barradas (1991)	light winds	99000	Mexico (temperate)	2.2	measured/ -	(LGU)	park
35	Spronken-Smith	4.1	150000	Sacramento/	7	measured/	Wind speeds were	park

	(1998)			US (temperate)			higher in Sacramento than Vancouver. It is di" cult to know if this enhanced the magnitude of daytime PCI due to increased evaporation in Sacramento, but it probably did act to reduce the size of nocturnal PCI by increasing turbulent mixing	
36	Jansson et al. (2007)	park: 0.5-1.0 builtup: 1-2	150000	Stockholm/ Sweden (temperate)	2	measured/ 2.47m	–	park
37	Lu et al. (2012)	-	45000	Chongqing/ China (subtropical)	1.65	measured/1.5 m	with a complex assemblage of business districts, densely populated residential areas	park
38	cheng et al., (2014)	-	157600	Shanghai/ China (subtropical)	5.2	Land surface temperature	–	park
39	Sugawara	1.96-2.02	200000	Tokyo/Japan (temperate)	3	measured/2.5 m	deciduous forest & canopy height:14m	park

Appendix 2 : Regional mitigation temperature

No.	author	wind speend (m/s)	greenspace area(㎡)	city/country (temperature zone)	mitigation temperature (℃)	method	Site Features	green space type
1	Saito et al. (1991)		2400		2.5	measured/		park
2	박종화 외 (2016)		6000	Seoul/Korea (temperate)	2			park
3	Spangenberg et al. (2008)	0.8	6000	San Paulo/ Brazil	1.1	envi-met/-	H/W ratio:0.5 albedo:0.3-0.4	park
4	Younha Kim et al.(2016)	(AWS)	6400	Seoul/Korea (temperate)	1.3	envi-met/1.5	albedo:0.35-0.4	park
5	Paula & Denise (2012)	0.8	9600	San Paulo/ Brazil	1.3	envi-met/-	simulating changed LAI	park
6	Katayama et	2-3	13680	Fukuoka/	2	measured/-	seabreeze	park

	al.(1993)		(0.18-27ha)	Japan				
7	Upmanis et al. (1998)	2	24000	Goteborg/ Sweden (Subarctic)	1.7	measured/2m		park
8	Upmanis et al. (1998)	2	36000	Goteborg/ Sweden	2	measured/2m		park
9	Jim et al. (2013)	3	39000	Kowloon Tong/ Hongkong (tropical)	1.3-1.7	envi-met/ 1.2m above the roof	open-lowrise	green-roof
10	Jim et al. (2013)	3	39000	Kowloon City/ Hongkong (tropical)	0.7-1.3	envi-met/1.2	compact lowrise	park
11	Jim et al. (2013)	3	40000	Broadcast/Hongkong(tropical)	0.7-0.9	envi-met/1.2	open middlerise	park

12	Jim et al. (2013)	3	41000	Chun Man/ Hongkong(tropical)	0.8-1.0	envi-met/1.2	open highrise	park
13	Wong & Chen. (2004)	1.6	120000	Singapore/ (tropical)	1.1	envi-met	-	park
14	M.F. Shahidan et al. (2012)	7.5	420000	putrajaya/ Malaysia	2.7	envi-met	(cool matrial) albedo: 0.8	park

Appendix 3 : Regional mitigation temperature range

	Author	wind speed (m/s)	greenspace area(㎡)	city/country (temperature zone)	mitigation range (m)	method	green space type
1	S. Szegedi & R. Gyarmati	2-3	-	Debrecen/ Hungary	300-500	measured	park
2	K.Narita et al., (2002)	0.2	583000	Tokyo/japan	250	measured	park
3	H.UPMANIS et al., (1998)		36000	Vasaparken	30-40	measured	park
4	H.UPMANIS et al.,(1998)		24000	Gubberoparken	-	measured	park
5	Saito et al., (1991)		2400	Kumamoto/ Japan	15	measured	park
6	Saito et al.,(1991)		22500	Kumamoto/ Japan	20	measured	park
7	CA		600000	Tokyo/japan	1000	measured	park
8	박종화, (2016)		6000	Korea	180	GIS analysis	park

Abstract (Korean)

급속한 도시화의 진행 및 원도심의 쇠퇴는 서울과 같은 대도시뿐만이 아니라, 인천, 대전 등의 비교적 중규모에 속하는 도시에 공가를 양산하게 만들었다. 공지 및 공가의 존재는 지가를 떨어트린다거나 범죄를 유발하여 부정적 외부효과들이 그 주변에 악영향을 끼친다. 더 많은 도시에서는 점차적으로 공지에 녹지를 도입하는 방식을 그 해결책으로 이용하고 있는데, 이는 도시의 개선을 도모하는 재개발의 수단일 뿐만이 아니라, 부정적 외부효과를 감소시킬 수 있는 방법이기 때문이다. 녹지의 기능을 고려해 보았을 때 생리학적 기능인 증산효과와 물리적 기능인 그림자 효과는 도시의 인공열로 인하여 심각한 문제가 되고 있는 도시 열섬현상을 완화하는 기능으로 작용할 수 있다.

하지만 국내에는 개별 대상지에 한하여 녹지가 도시 열섬현상 완화에 기여하는 정량적인 수치는 도출되어 있지만, 이를 공가 · 공지 부지에 도입하였을 때 파생되는 효과에 대한 연구는 부족한 실정이다. 무엇보다도 녹지화 계획 단계에서 공가 · 공지 부지에 있어 실제 녹지화 이전에 온도저감 효과를 가늠할 수 있다는 장점이 있기 때문에 중요하다. 이는 의사결정의 단계에서 근거로 작용할 수 있는 중요한 자료가 될 것이므로 공가 · 공지의 녹지화가 줄 수 있는 효과에 대한 정량적인 접근 방식에 대한 연구가 요구된다.

따라서 본 연구의 목적은 공지를 활용한 그린 인프라의 지역적인 효과에 대하여 예측하기 위하여 메타분석을 활용하여 그린 인프라로 인한 도시재해 저감의 정량적 효과에 대하여 도출하고, 인천 남구 숭의동을 대상으로 공가 · 공지를 녹지화 시켰을 때 얻게 되는 효과를 예측하는 것이다. 이를 위하여 첫째, 그린 인프라 전략이 도시의 재해를 저감하는데 미치는 영향에 대하여 메타 분석을 통해 정량적 수치를 도출한다. 둘째 메타 분석의 결과를 바탕으로 인천 남구 숭의동의 공가 밀집지역 두 곳을 선정하여 얻게 되는 그린인프라 효과에 대해 정량적인 수치로 도출해 낸다. 셋

째 이로서 얻게 되는 환경적 이익과 녹지화를 함으로써 발생하는 기회비용에 대하여 고찰하였다.

본 연구의 공간적 범위가 되는 인천 남구는 구도심으로서 공가 발생이 계속 증가하며 공가 수가 인천 내에서 두 번째로 많은 지역으로, 남구 내 위치하는 많은 동들은 도시재생사업의 대상이 되고 있다.

본 연구에서는 인천 남구 숭의동 공가 부지를 활용하여 그린 인프라를 도입하였을 때의 정량적 효과를 제시하고자 하였다. 첫 번째로 그린인프라의 정량적인 효과를 알고자, 메타분석을 통해 녹지가 도입되었을 때의 온도저감 효과를 도출하고 회귀식을 도출하였다. 두 번째로는 도시쇠퇴 진행사항, 선행연구를 고찰하여 인천 남구 일대를 선정하고, 지표면 온도(LST), 현장답사 자료를 파악하여 그린 인프라 도입이 필요한 공가부지 Site A, C를 선정하였다. 그리고 Site A, C에 알맞은 녹지화 유형을 선정하였다. 셋째로 메타분석 결과를 활용하여 대상지의 온도저감 효과를 추정하였다.

연구결과는 다음과 같다. SiteA에는 그 면적에 알맞게 근린공원, SiteC에는 포켓파크를 조성한다는 가상의 계획을 수립하였다. 결과적으로 SiteA의 PCI는 내부로는 최대 2.751 까지 온도저감 효과를 보이며 외부로는 약 1.507도를 62m까지 온도 저감 효과를 보여준다. SiteC의 PCI 는 내부로 최대 2.269도 온도저감 효과를 나타낼 수 있고 외부로는 약 0.92도의 온도 저감 효과를 보여준다. 결과를 도출하는 과정에서 다양한 문헌들이 서로 다른 상황에서 측정된 결과임을 고려하였다. 더불어 녹지화로 인하여 발생할 기회비용에 관하여 논의해보았고 공가 주변 부지에 미칠 영향에 대한 고찰도 덧붙였다.

본 연구의 결과는 그린 인프라의 실천이 사회 · 경제 · 문화적인 파급효과 이외에 환경적으로도 효과가 있음을 증명해주는 근거자료에 해당 한다. 공가 부지에 건축물의 도입 등을 통한 개발우선적인 정책보다 녹지의 도입이라는 환경 친화적인 정책을 도입하는데 기여할 수 있을 것으로 판단된다.

키워드 : 그린인프라 스트럭쳐, 도시 열섬 현상, 공가, 공지, 도시공원, 포켓공원, 쇠퇴도시
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