Reduction Effect of CO₂ and Runoff by Green Infrastructure Application - Case Study of the Chungbuk National University -

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Abstract

Green Infrastructure (GI) approach provides significant benefits to cities and communities. GI applications would provide multi-benefits such as the reduction in building energy demand, stormwater management, urban heat island reduction, habitat creation, etc. GI is nowadays considered as a multi-benefit best management practice (BMP) at diverse levels of government. The purpose of this study is to find out the positive effects of GI application, and Geographic Information System (GIS) is used for the accurate and efficient analysis. Two polygon data, 'GreenRoof' and 'ParkingPlace' are produced with a satellite imagery extracted from Google Earth Pro. These data are used to calculate total available spaces for green roof and permeable pavement in the campus of Chungbuk National University. After GI application in the campus, 13.2% of landcover is converted to green spaces and this change results in expanding the green network of Cheongju city. The result of this study shows that green roof application can absorb 4576.95 kg/yr of Carbon Dioxide and possibly reduce maximum 1,497,600L urban runoff. This study proves how GI is valuable for the city environment with quantitative analyses.

Key words : *geographic information system (GIS), green roof, permeable pavement, stormwater management*

I. Introduction

Green infrastructure (GI) can be fundamentally categorized into two important concepts: the first one is to connect parks and other green spaces for the benefits of humans; and the second one is to prevent the destruction of habitats, and connect and protect natural areas in order to secure the diversity of species (Benedict and McMahon, 2006). Also, outdoor spaces for GI are designed in different ways from those used in the past, which is attributable to the fact that GI seeks to plan land development and growth management together (Benedict and McMahon, 2002). GI, as an interconnected network of green spaces, conserves natural ecosystem values and functions and provides human populations with associated benefits (Randolph, 2004). Green spaces are an essential element in establishing GI in urban areas, and they are natural resources to maintain and restore healthy ecosystems, and also the most eco-friendly

resources to change microclimate in urban areas. These factors can also contribute to the improved quality of urban dwellers as well as energy saving. Green surfaces can also reduce ambient temperature through the radiation of solar energy and the transpiration of plants. As rainwater is stored or permeates to groundwater, GI plays a pivotal role in restoring the function of the hydrological cycle in urban areas (Choi, 2013). Due to the increase in population and rapid urbanization, however, the reduction rate of green area per person continues to rise, and according to a study conducted in the United States, the reduction rate between 1945 and 1992 was 0.5 acres, but the figure jumped to 1.2 acres between 1992 and 1997 (DeCoster, 2000). Even though the population growth rate starts to slow down and decrease, green areas in cities continue to decline (Choi, 2013). Thus, it is essential to consider the resilience of nature in urban development plans to prevent the further decrease in green areas in cities, to secure more green spaces in urban areas, and thus to enable people to lead a sustainable life. For this reason, GI has emerged as a new alternative and started to be applied to cities globally, and in Korea, it has been

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also discussed in various fields (Choi, 2013; Kim and Son, 2012).

The United States is planning to enact regulations on green infrastructure, and the Environmental Protection Agency has also started to secure the budget and offered support for GI systematically. Local governments in the United States offers guidelines and design standards according to their circumstances, indicating that green infrastructure has been already recognized as the center of infrastructure development. Despite the global economic slowdown, advanced countries such as Canada, Australia and the European Union have set GI as one of the key policy priorities and continued to expand support for GI projects (Baietti and Shlyakhtenko, 2012; Goldman Sachs, 2014). Given the amount of the budget that has been secured and executed for GI so far, there is no doubt that GI has emerged as the center in expanding the national infrastructure (Baietti and Shlyakhtenko, 2012). However, associated areas such as developing technology and materials, and securing and educating a labor force specialized in this field such as planners and designers are still at the early stage, which is highly likely to grow as a new blue ocean. There have been already many studies conducted on the feasibility of GI (EPA, 2013; Raucher and Clements, 2010; Vandermeulen, 2011; Wolf, 2003), and different fields have each researched how to approach GI in their way.

The concept of construction had taken the largest part of the process of establishing infrastructure in cities, and designs that highlighted the strength of structures and their original function only had been adopted without putting much attention on their aesthetic values or shapes at all. Infrastructure that was established that way in the past is called “grey infrastructure” and the word “grey city” had often been used to express the negative images of a city surrounded by concrete structures. However, as the demand for quality life has increased over time, and it has become more difficult to handle an enormous amount of money spent to maintain the existing infrastructure, discussions to search for new alternatives were initiated by advanced countries in the 1990s, and based on the results of the discussions, the concept of GI was introduced. The introduction of GI has pioneered a new market by converging two opposite pillars, economy and environment, and created new types of jobs so-called “green jobs.” Two parallel lines—economic

growth and environmental conservation that would never meet—were adequately converged to make GI, and this, in turn, was applied to urban areas, bringing about innovation in the landscape of cities embroidered with green waves (Choi, 2013; Randolph, 2004; Wise, 2008). For instance, green roofs can play a pivotal role in circulating water in the process of establishing green infrastructure in urban areas. This study aimed to calculate spaces available for green roofs and permeable pavements on the campus of Chungbuk National University using Google satellite and GIS images, to quantitatively analyze the positive effects of green infrastructure on the urban environment based on the calculated results, and to provide concrete grounds for the results.

II. Research Methods

1. Selection of target areas and digitization of satellite images

Changes in land usage and land coverage are often compared to use them as the base data in observing changes in the environment and making policy decisions, which has been recognized as the most effective method (Kepner et al., 2004). High-definition satellite images were extracted to analyze the current status of target sites (Badrudin, 1995; Caldas et al., 2007; Lambin and Geist, 2008; Randolph, 2004; Stephenne and Lambin, 2001) using Google Earth Pro. Satellite images extracted by setting the coordinate system on ArcGIS ver. 10.x, a GIS software, were used as the base map to identify structures and impermeable pavements such as asphalt within the target site. The boundary of the campus of Chungbuk National University was digitized, and polygons were created using the base map.

To select roofs of buildings that are available to create green roofs, all the roofs of the buildings within the target site were primarily digitized using the extracted satellite images and a file of polygons titled as “GreenRoof” was generated. Based on the data, any shaded areas that are difficult to distinguish from the satellite images or other areas that are difficult to accurately identify their purposes were selected to rule out any obstacle to the application of green roofs. On-site surveys were conducted to assess the actual conditions and availability of

the areas, and persons in charge of the buildings were interviewed face-to-face and over the phone. The final candidates for green roofs were selected, and based on that; GIS data were updated.

To select spaces that can be transformed into permeable pavements such as parking lots paved with impermeable materials such as asphalt, and main and arterial roads were excluded because they were not suitable for permeable pavements due to their large traffic flows. Among pedestrian walkways, those that were covered by trees were also excluded as it was difficult to identify the type of pavements on the extracted satellite images. By applying these criteria, parking lots and spaces paved with impermeable materials on the campus of Chungbuk National University were digitized and a file of polygons titled as “ParkingPlace” was generated. Boundary areas between buildings that could not be identified on satellite images or shaded areas or other areas that needed to be checked further were selected, and after conducting on-site surveys, their data were revised and updated (Fig. 1).

2. Application of green infrastructure

Spaces available to create green roofs were selected, and the total area of the spaces was calculated using the “GreenRoof” polygon file. Out of the two green roof systems—intensive green roof system and extensive green roof system—it was assumed to apply the later type and herbal plants in this study in consideration that most of the buildings on the campus of Chungbuk National University were built long ago. Under the assumptions, the absorption amount of carbon dioxide was calculated. Using the “ParkingPlace” polygon file created to analyze the effect of reduction of runoff, the total area available

for permeable pavements was calculated. Among relevant studies, the results of three studies that directly conducted rainfall experiments outdoors (Collins et al., 2008; Dreelin et al., 2006; Gilbert and Clausen, 2006) were referred to in this study, and the total reduced runoff volume of one year was calculated. By combining the “GreenRoof” and “ParkingPlace” polygons, the total area available for green infrastructure (GI) on the campus of Chungbuk National University was calculated, and the total area available for green roofs and permeable pavements, and the total area available for GI were calculated using the GIS file. Changes in land coverage before and after applying GI to the spaces were compared (Fig. 1).

3. Analysis of the absorption amount of carbon dioxide and the reduced runoff volume

Among the several benefits of GI, the absorption amount of carbon dioxide and the reduced runoff volume that could be quantitatively analyzed based on the results of earlier studies (Collins et al., 2008; Dreelin et al., 2006; Gilbert and Clausen, 2006; Lee, 2003) were calculated. The absorption amount of carbon dioxide was found to have the largest impact on climate change, and this study analyzed how effective GI is to absorb carbon dioxide to secure green spaces and respond to climate change by using the total green roof area and the amount of carbon dioxide absorbed by herbal plants. The absorption amount of carbon dioxide was calculated by referring to the results of studies published in Korea on the geographical and environmental characteristics of plant growth. Two methods are usually used to calculate the absorption amount of carbon dioxide: First, the relative growth method is to calculate the biomass amount based on plant species, population number,

Fig. 1. Digitizing and GIS application flow.

plant age, breast diameter, and root collar diameter that were measured through thorough on-site investigations, and to calculate the absorption amount based on the calculated biomass amount (Park and Kang, 2010). The second method is to calculate the green coverage area using high-definition satellite images and calculate the absorption amount of carbon dioxide compared to the area (Moss et al., 2008). In this study, the second method was adopted, and the total absorption amount of carbon dioxide was calculated using the area available for green roofs that were calculated using the GIS above.

According to a study on the plants on green roofs created in Seoul (Ahn, 2010), the ratio between trees and bushes was 1:5, and depending on the methods of creating green roofs and the conditions of structures, green roofs were created either for the basic purpose of green roofs or roof gardens, or for multiple purposes such as storing and purifying rainwater, absorbing pollutants, reducing runoff, and improving the landscape of urban areas. Thus, green roofs are designed mainly considering the safety of structures and the proper amount of load, and it is difficult to plant trees and bushes on roofs since most of the roof spaces were not originally designed to create green roofs. Against this backdrop, in this study, it was assumed to plant grass, the most widely used herbal plant in extensive green roof systems, on the entire area, and the absorption amount of carbon dioxide was calculated using the following equation (Lee, 2003).

$$C = 0.0471 \text{ kg/m}^2 \times \text{Green area (m}^2\text{)} \quad (1)$$

where, C = the amount of carbon dioxide absorbed by grass.

The daily precipitation data in Cheongju in 2015 and the effects of permeable pavements on the reduction of runoff that were found in earlier studies were applied to analyze how much amount of runoff produced in the city was reduced by calculating the maximum and minimum values. The spaces

that can be replaced with permeable pavements on the campus of Chungbuk National University were calculated using the GIS program, and the total runoff volume caused by rainfall was calculated by multiplying the rainfall volume in Cheongju by the area available for green roofs and permeable pavements as shown in equation (2). The maximum and minimum values (%) suggested in the three studies mentioned above were multiplied to calculate the total runoff volume as shown in equation (3). The reduced runoff volume was obtained by subtracting the runoff volume from the rainfall runoff volume before constructing permeable pavements (asphalt surface) using equation (4).

$$\begin{aligned} &\text{Rainfall(mm)} \times \text{Area(m}^2\text{)} \\ &= \text{Rainfall Runoff Volume(FRV)(L)} \end{aligned} \quad (2)$$

$$\text{FRV(L)} \times \text{Max/Min(\%)} = \text{Runoff Volume(RV)(L)} \quad (3)$$

$$\text{FRV(L)} - \text{RV(L)} = \text{Reduced Runoff Volume(L)} \quad (4)$$

III. Results and Discussion

1. Effects of the installation of green infrastructure

The digitized satellite images showed that buildings were broadly distributed across the campus, and most of the buildings had flat roof surfaces, and thus the area that can be used to create green roofs was large (Fig. 2). In particular, except some spaces on which other equipment and solar panels were installed for research purposes, most of the roof spaces were empty, and people's access was restricted to safety issues. The total area available for green roofs, except some areas that cannot be utilized due to issues associated with structures and safety, was 97,175.18 m², and the total area available for permeable pavements, among parking lots, access roads, and impermeable pavements, was 49,125.74 m². The total area available for green infrastructure was 146,300.92 m², 13.2% of the entire campus area (Table 1, Fig. 3). If they are connected

Table 1. Green infrastructure applicable spaces in Chungbuk National University (CBNU).

CBNU campus (Unit: m ²)	Green roof applicable spaces	Parking spaces for GI	Total GI applicable area	Possible change
1,107,243.47	97,175.18	49,125.74	146,300.92	13.2%

to the existing green spaces and farm areas used for academic purposes, greenhouses and wetlands, connectivity, recognized as an important element in the networks of GI, can be significantly improved (Fig. 4). Also, GI (green roofs, permeable pavements) on the campus of Chungbuk National University

can improve the environment of the campus itself, and also increase the expandability of the green networks in Cheongju. Satellite images of areas surrounding the campus showed that a large part of the green network in the southern part was destroyed due to development activities, and buildings were

Fig. 2. GIS data creation (a) 'GreenRoof' polygons (b) 'ParkingPlace' polygons.

Fig. 3. Comparison of GI application (a) current campus, (b) after GI application.

Fig. 4. Green infrastructure extension effect in Cheongju City (a) present, (b) after GI application.

densely packed due to urbanization. The share of green spaces on the campus was relatively high, but newly added buildings disconnected green spaces. Each of the disconnected green spaces was isolated on the campus (Fig. 3). The share of green spaces can be increased only by 13.2% by creating green roofs and replacing asphalt pavements with permeable materials, but by connecting green spaces, the campus can be restored not as land for buildings, but as the core of the green spaces. This can also bring about positive effects such as expanding the green network in the southern part of the campus to the center of Cheongju City (Fig. 4).

2. Calculation of the absorption amount of carbon dioxide

When the area available for green roofs is substituted to equation (1), about 4.58 tons (4,576.95 kg/yr) of carbon dioxide can be absorbed annually, and here the amount of carbon dioxide absorbed by herbal plants used for permeable pavements was excluded due to difficulties in planting and managing herbal plants.

Considering that trees absorb the largest amount of carbon dioxide, followed by bushes and herbal plants, planting trees and bushes, rather than herbal plants (grass, etc.) will increase the effect on intensive and semi-intensive green roof systems. Thus, it will be reasonable to view the result calculated in this study as the minimum value.

3. Effect on the reduction of runoff

The precipitation data in Cheongju in 2015 (National Climate Data Service System, 2016) were used to calculate the runoff volume that can be reduced and the amount of rainfall that can be stored in soil by referring to the results of earlier studies on the changes in the runoff volume before and after replacing asphalt pavements with permeable materials. Since the results of earlier studies referred to in this study were obtained using different pavement materials, it would be slightly difficult to apply the results to this study. However, they can be used to calculate the maximum and minimum values of runoff that can be reduced by installing permeable pavements within the target site, to predict the range of effectiveness, and to use them as criteria before applying green infrastructure.

According to the data released by the Korea Meteorological Administration, the number of days when 5 mm rainfall or more was recorded in 2015 was a total of 42 days. The daily precipitation values and the maximum and minimum runoff volumes presented by earlier studies were applied to calculate the total runoff volume that can be reduced by installing permeable pavements on the campus of Chungbuk National University. Here, based on the results of earlier studies that showed that asphalt pavements produced 100% runoff (Collins et al., 2008; Dreelin et al., 2006; Gilbert and Clausen, 2006), the runoff volume of asphalt pavements was calculated using equations (2) and (3). In Case A, the results of a study that found that permeable pavements produced 37-61% runoff regardless of the amount of rainfall were applied, and in Case B another study's results were applied as follows: 93% of rainwater is absorbed by permeable pavements in 20 mm or fewer rainfall events, and thus they produced only 7% runoff. In Case B, however, rainfall events of 20 mm or more cannot be applied, and thus some spaces were left blank in Table 2. Considering the results that showed permeable pavements were highly effective in the rainfall events of 20 mm or less, it is predicted that Cheongju can expect the runoff prevention effects of permeable pavements for 356 days except nine days only. Case C showed the reduced runoff volume when the rainfall volume was 50 mm or less. In this case, no rainfall event of 50 mm or more was observed in Cheongju in 2015, and thus the results were applied to 365 days.

The total area available for permeable pavements on the campus of Chungbuk National University was calculated to be 49,125.74 m² (Table 1, Fig. 2, 3) using the GIS program. The total runoff volume was calculated by multiplying the minimum and maximum values (5) of each case, and the volume was subtracted from the runoff volume before installing permeable pavements (asphalt pavements) to obtain the reduced runoff volume by installing permeable pavements (Table 2). In Cheongju, the highest precipitation value (45.5 mm) in 2015 was recorded on June 26, and in this case, 1,497,600 L at the maximum can be prevented from directly running off to rainwater pipes when installing permeable pavements. When converting 1L to 1 kg, a whopping 1,497.6 tons of rainwater can be prevented from running off in the city. The yearly-based maximum and minimum values in Case A, the runoff volume

Table 2. Simulation results of projected runoff volume reduction based on rainfall data of Cheongju city in 2015.

(Unit: 1,000 L)		Rainfall discharge volume						Reduced runoff volume						
Date	Precipitation	Asphalt	Case A ^z		Case B ^y		Case C ^x		Case A		Case B		Case C	
		100%	Max. 61%	Min. 37%	93%	Max. 67%	Min. 36%	Min.	Max.	Min.	Max.	Min.	Max.	
1/6	5.0	245.6	154.7	95.8	17.2	157.2	81.1	90.9	149.8	228.4	88.4	164.6		
2/16	17.5	859.7	541.6	335.3	60.2	550.2	283.7	318.1	524.4	799.5	309.5	576.0		
2/21	5.5	270.2	170.2	105.4	18.9	172.9	89.2	100.0	164.8	251.3	97.3	181.0		
3/18	36.5	1,793.1	1,129.6	699.3	-	1,147.6	591.7	663.4	1,093.8	-	645.5	1,201.4		
4/2	8.5	417.6	263.1	162.9	29.2	267.2	137.8	154.5	254.7	388.3	150.3	279.8		
4/3	15.0	736.9	464.2	287.4	51.6	471.6	243.2	272.6	449.5	685.3	265.3	493.7		
4/4	10.0	491.3	309.5	191.6	34.4	314.4	162.1	181.8	299.7	456.9	176.9	329.1		
4/14	8.0	393.0	247.6	153.3	27.5	251.5	129.7	145.4	239.7	365.5	141.5	263.3		
4/19	20.5	1,007.1	634.5	392.8	-	644.5	332.3	372.6	614.3	-	362.5	674.7		
4/20	15.0	736.9	464.2	287.4	51.6	471.6	243.2	272.6	449.5	685.3	265.3	493.7		
4/29	13.5	663.2	417.8	258.6	46.4	424.4	218.9	245.4	404.6	616.8	238.8	444.3		
5/11	8.0	393.0	247.6	153.3	27.5	251.5	129.7	145.4	239.7	365.5	141.5	263.3		
5/12	11.0	540.4	340.4	210.7	37.8	345.8	178.3	199.9	329.6	502.6	194.5	362.1		
6/20	13.5	663.2	417.8	258.6	46.4	424.4	218.9	245.4	404.6	616.8	238.8	444.3		
6/24	10.5	515.8	325.0	201.2	36.1	330.1	170.2	190.9	314.7	479.7	185.7	345.6		
6/25	8.5	417.6	263.1	162.9	29.2	267.2	137.8	154.5	254.7	388.3	150.3	279.8		
6/26	45.5	2,235.2	1,408.2	871.7	-	1,430.5	737.6	827.0	1,363.5	-	804.7	1,497.6		
7/8	9.0	442.1	278.5	172.4	30.9	283.0	145.9	163.6	269.7	411.2	159.2	296.2		
7/9	16.0	786.0	495.2	306.5	55.0	503.0	259.4	290.8	479.5	731.0	283.0	526.6		
7/12	11.5	564.9	355.9	220.3	39.5	361.6	186.4	209.0	344.6	525.4	203.4	378.5		
7/22	14.0	687.8	433.3	268.2	48.1	440.2	227.0	254.5	419.5	639.6	247.6	460.8		
7/23	37.5	1,842.2	1,160.6	718.5	-	1,179.0	607.9	681.6	1,123.8	-	663.2	1,234.3		
7/24	30.0	1,473.8	928.5	574.8	-	943.2	486.3	545.3	899.0	-	530.6	987.4		
7/29	15.0	736.9	464.2	287.4	51.6	471.6	243.2	272.6	449.5	685.3	265.3	493.7		
8/8	10.0	491.3	309.5	191.6	34.4	314.4	162.1	181.8	299.7	456.9	176.9	329.1		
8/25	35.0	1,719.4	1,083.2	670.6	-	1,100.4	567.4	636.2	1,048.8	-	619.0	1,152.0		
9/11	10.0	491.3	309.5	191.6	34.4	314.4	162.1	181.8	299.7	456.9	176.9	329.1		
9/12	5.0	245.6	154.7	95.8	17.2	157.2	81.1	90.9	149.8	228.4	88.4	164.6		
10/1	42.0	2,063.3	1,299.9	804.7	-	1,320.5	680.9	763.4	1,258.6	-	742.8	1,382.4		
10/10	14.5	712.3	448.8	277.8	49.9	455.9	235.1	263.6	434.5	662.5	256.4	477.3		
10/11	8.0	393.0	247.6	153.3	27.5	251.5	129.7	145.4	239.7	365.5	141.5	263.3		
10/27	25.0	1,228.1	773.7	479.0	-	786.0	405.3	454.4	749.2	-	442.1	822.9		
11/7	17.5	859.7	541.6	335.3	60.2	550.2	283.7	318.1	524.4	799.5	309.5	576.0		
11/8	17.0	835.1	526.1	325.7	58.5	534.5	275.6	309.0	509.4	776.7	300.6	559.5		
11/13	25.0	1,228.1	773.7	479.0	-	786.0	405.3	454.4	749.2	-	442.1	822.9		
11/16	12.5	614.1	386.9	239.5	43.0	393.0	202.6	227.2	374.6	571.1	221.1	411.4		
11/23	9.0	442.1	278.5	172.4	30.9	283.0	145.9	163.6	269.7	411.2	159.2	296.2		
11/25	10.5	515.8	325.0	201.2	36.1	330.1	170.2	190.9	314.7	479.7	185.7	345.6		
12/2	7.5	368.4	232.1	143.7	25.8	235.8	121.6	136.3	224.8	342.7	132.6	246.9		
12/3	8.8	432.3	272.4	168.6	30.3	276.7	142.7	160.0	263.7	402.0	155.6	289.6		
12/10	8.7	427.4	269.3	166.7	29.9	273.5	141.0	158.1	260.7	397.5	153.9	286.4		
12/14	9.2	452.0	284.7	176.3	31.6	289.3	149.1	167.2	275.7	420.3	162.7	302.8		
Total	660.2	32,432.8	20,432.5	12,649.1	1,248.8	20,756.6	10,702.9	12,000.1	19,784.1	16,593.6	11,676.1	21,729.8		

^zApplication of the method of Gilbert and Clausen (2006).^yApplication of the method of Dreelin et al. (2006). Case B cannot apply to 20 mm or more precipitation.^xApplication of the method of Collins et al. (2008).

from 12,000.1 up to 19,784.1 tons can be reduced; in Case B, 16,593.6 tons; and in Case C, from 11,676.1 up to 21,729.8 tons. Combining the results of the three cases, as much as 11,676.1~21,729.8 tons can be reduced.

IV. Conclusions

The effect of green infrastructure (GI) has been already proven around the world, and the United States is planning to enact a federal law on GI to create a new urban environment. However, there are only a few studies on GI, and it is still difficult to apply their results directly to actual sites since environmental conditions in laboratories and locations of experiments do not coincide with those in actual sites. It is still expected that more efforts will be made to achieve various benefits such as economic development, environmental improvement, and reestablishment of infrastructure simultaneously, and to address issues witnessed across the entire city or in some urban areas by introducing GI with limited amounts of resources. This study analyzed the status of land usage and land coverage using satellite images, and based on the results, measured the amount of carbon dioxide absorbed by green roofs, which can be quantitatively analyzed among multiple benefits from the introduction of GI, using the GIS program to back up these efforts. The maximum area available for green roofs on the campus of Chungbuk National University was applied to calculate the absorption amount of carbon dioxide, and it was found that at least 4.58 tons (4,576.95 kg/yr) can be absorbed. When installing permeable pavements on parking lots and arterial roads except some main roads with high traffic flows, even in rainfall events of 45.5 mm or more, a significant volume of runoff can be reduced by installing permeable pavements, and in turn contribute to the prevention of flood damage in low-lying areas surrounding the campus. This study is significant in that it quantitatively analyzes some part of benefits of GI and suggest them with predictable values, and quantifies the applicability of GI in urban areas. The quantified results and analysis techniques used in this study can be used as the base data in the process of making policy decisions. However, there are many variables involved in the process of implementing GI, such as diverse complexity and connectivity, and the importance of forming efficient networks. Factors such

as LID techniques and materials can also have a significant impact on the expected effects. The results of this study suggest methods calculate data required to make policy decisions, but they are only to present the expected range roughly, not to guarantee the accuracy of data. Therefore, it will be necessary to conduct follow-up studies to accumulate more data and improve the accuracy of data by monitoring for a long period.

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