How Should Green Infrastructure with Diverse Functions Be Evaluated?

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Landscape and Ecology Division, Research Center for Infrastructure Management

Research officer (DAg) KIM Bohyun Head OISHI Tomohiro

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1. Introduction

Green infrastructure (GI) is expected in the Fifth Priority Plan for Infrastructure Development to be used in "disaster prevention and mitigation leveraging rainwater collection and infiltration and ecosystems, conservation of the natural environment that considers ecosystem networks, healthy, relaxed community-building suited to new lifestyles, environmentally friendly regional development in line with the SDGs, conservation and sustainable use of biodiversity, [and] realization of regional development, etc. through tourism," and the plan is moving forward as a means capable of handling a variety of challenges.

GI planning requires quantitative evaluations that can show how well the GI functions as infrastructure, and NILIM is conducting research into these evaluation methods, based on investigations of systems in other countries that are introducing GI and case examples of functional evaluation.

Photo. Examples of green infrastructure (Machida, Tokyo)

2. The definition of GI

A commonly used definition of GI is shown in the 2015 National Spatial Strategy: "making use of the diverse functions of the natural environment in both tangible and intangible aspects, such as the development of social infrastructure and land usage, to build a country and regions that are sustainable and attractive."

GI as introduced in this initiative is diverse, consisting of parts and green spaces made up mainly of trees, grasses, and soil cover, as well as rain gardens (photo: top) and bioswales (photo: bottom), which add stones, gravel, crushed rock, and the like to planted areas, and rooftop gardens and wall greening installed on buildings.

3. GI evaluation methods in regional planning

As shown above, GI takes many forms, some of which exhibit functions and performance that differ depending on the type and are uncertain, so it is difficult to move forward with planning while quantitatively demonstrating the effects of GI introduction.

Liverpool and London in the UK, which this study investigated, have regional planning that evaluates how well the current GI is functioning across the region as a whole and introduces the necessary GI in areas where it is lacking. This appropriately resolves the issues facing each area in the region and has the targeted effects of adapting to climate change, health and welfare, and economic growth, among others.

This is one method of planning to evaluate and introduce GI, but the ideas of setting targets for functions and effects and evaluating the current situation is a valid method when effectively planning and distributing GI, including making use of existing GI and other infrastructure.

4. Example of a GI function evaluation method (rainwater collection and infiltration function)

GI, with its diverse functions, is often hoped to be effective in mitigating urban flooding in recent years, and there is demand for computations of the amount of rainwater collected and infiltrated to contribute to prevent it from flowing out. However, the quantity that green spaces made up of trees and other greenery can handle is difficult to compute because it is affected the state of the soil and other conditions.

This study investigated examples from other countries of evaluations of green spaces as GI (table 1) and summarized their thinking about evaluation, computation methods, etc. One of these, GI-Val, is used by many countries and local governments, mainly around the UK, and it computes different rainwater outflow volumes according to land coverage and soil class in GI planning (table 2). In this way, it evaluates the reduction in rainwater entering the combined sewerage system and converts it into monetary value by estimating the energy-saving effects pertaining to sewerage treatment.

Table 1. Example of evaluation method (mitigating urban flooding)

Evaluation method		Evaluated function
I	GI-Val	Rainwater collection and infiltration function of green spaces (Reducing rainwater flowing into combined sewerage, lowering construction costs of conventional infrastructure)
	i-Tree Eco	Rainwater collection and infiltration function of green spaces (Reducing rainwater outflow)
II	LEED ND	Floodplain avoidance functions Rainwater management functions
	Eco Districts	Resilience (Proportion of land area of 100-year floodplain)
III	TESSA	Flooding control functions
	InVEST	Flood risk mitigation functions

* I: GI evaluation tool II: Accreditation system III: Ecosystem service evaluation tool

Table 2. Coefficients to evaluate the mitigation of rainwater outflow (GI-Val)

Land coverage class	Soil class			
	A	B	C	D
Buildings	98	98	98	98
Other impermeable land	98	98	98	98
Treed land	25	55	70	77
Shrubbed land	45	66	77	83
Land with mowed lawn or grass	39	61	74	80
Land with lawn or grass	30	58	71	78
Farmland	67	76	83	86
Water surface	0	0	0	0
Bare land or graveled land (pavement, etc.)	74	83	88	90

* Green infrastructure valuation toolkit calculator v. 1.6 (created for reference)

In reducing the rainwater outflow by introducing GI, there are many examples of quantitative evaluations using the area occupied by green spaces, but GI-Val is characterized by the way that the soil class condition greatly affecting the evaluation outcomes. Evaluations by soil class like this have been used in the UK, as well as several local government areas in the US, and classes A to D have been created to make determinations from existing soil data or on-site measurements, based on table 3.

Table 3. Examples of soil classes for evaluating rainwater infiltration capacity

Class	Saturation infiltration coefficient (The right side is the standard when the distance to the impermeable layer exceeds 100 cm)	
A	> 40.0 μm/s (> 144 mm/h)	> 10.0 μm/s (> 36 mm/h)
	Low possibility of rainwater outflow. Soil consists of 10% or less of clay and 90% or more of sand, gravel, sand and gravel, etc.	
B	≤ 40.0 to > 10.0 μm/s (≤ 144 to > 36 mm/h)	≤ 10.0 to > 4.0 μm/s (≤ 36 to > 14.4 mm/h)
	Moderately low possibility of outflow. Soil consists of 10% to 20% clay and 50% to 90% sand.	
C	≤ 10.0 to > 1.0 μm/s (≤ 36 to > 3.6 mm/h)	≤ 4.0 to > 0.4 μm/s (≤ 14.4 to > 1.44 mm/h)
	Moderately high possibility of outflow. Soil consists of 20% to 40% clay and under 50% sand.	
D	≤ 1.0 μm/s (≤ 3.6 mm/h)	≤ 0.4 μm/s (≤ 1.44 mm/h)
	High possibility of outflow. Soil consists of over 40% clay and under 50% sand.	

* Hydrology National Engineering Handbook, 2007, NRCS (created for reference)

Japan is also establishing rainwater infiltration facilities and the like after examining the geology, soil qualities, groundwater level, and other factors when planning the facilities, and the standards and ideas concerning soil classes and the computation methods that are used when doing so can also be used when introducing GI. GI evaluations using land coverage and soil class can make rainwater collection and infiltration function clearer and can be expected to promote plans for higher-functioning GI. In addition, in plans covering an entire region, such as river basin flood control, this method shows the potential for use in establishing appropriate locations and scales for GI, such as in coordination with other infrastructure and considering target sites suited to the introduction of rainwater collection and infiltration functions.

5. Future research

In future, we will research and study methods for computing rainwater collection and infiltration function and on-site measuring methods, as well as examining easy-to-use evaluation methods with a view towards social implementation in Japan and conducting research with a view towards creating technical materials capable of supporting GI planning and maintenance.

☞See here for detailed information

1) Tech. Note of NILIM, No. 1166, pp. 19–20
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn1166pdf/ks1166_05.pdf