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Exploring the Relationship between Prior Knowledge on Rain Gardens and Supports for Adopting Rain Gardens Using a Structural Equation Model

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Abstract: The objective of this study was to determine the effect of prior knowledge and visual evaluation on supports for rain garden installations. To achieve this objective, a survey was conducted to obtain prior knowledge of rain gardens, rain garden implementation support ratings, and visual evaluation of rain gardens in 100 visitors of three rain garden sites. Results of the analysis revealed that users' visual evaluation of rain gardens played a role as a moderator in the relationship between prior knowledge and support for rain garden installations. In other words, education and publicity of rain gardens alone cannot increase support for rain gardens. However, if rain gardens are visually evaluated positively, the effects of education and publicity of rain gardens can be expected. Therefore, to successfully apply a rain garden policy in the future, basic consideration should be given to aesthetics in order to meet visitors' visual expectations prior to education and publicity of rain gardens.

Keywords: rain gardens; prior knowledge; supports; structural equation model; environmental policy

1. Introduction

Due to the seriousness and urgency of water cycle and water ecosystem pollution as a result of climate change and the urbanization of watersheds, related studies are continuously being carried out in various public and private organizations internationally. In particular, sustainable land use and environmentally-sound water cycles such as the Sustainable Urban Drainage System (SUDS), Water Sensitive Urban Design (WSUD), and Low Impact Development (LID), are being actively researched [1]. A rain garden is a planted depression designed to infiltrate runoff. It is commonly known as a bio-retention facility [2]. Rain gardens are effective in terms of landscape, ecology, and economy because of its low installation costs and easy maintenance, as well as long-term use [3]. Moreover, they are a typical biofilter as a low-energy water treatment technique for both quality and quantity, consisting of a vegetated overlaying layers of porous media [4].

Previous rain garden studies have focused on its chemical effects (such as the removal of non-point source pollutants), physical effects (such as the reduction of rainfall runoff), field application, and vegetation that can be applied to rain gardens. Most of these studies on chemical effects of rain gardens have been conducted under laboratory conditions, focusing on the removal efficiency of oil, heavy metals (such as lead, cooper, and zinc), and nutrients (such as phosphorus and nitrogen) [5–7]. Studies on the physical effects of rain gardens have also been carried out in a similar way by using model experiments based on the principle of rain gardens to compare inflow and outflow of artificial rainfall [3,8]. Studies on the effects of rain gardens according to planting conditions in laboratory conditions have shown that removal efficiencies for heavy metals, suspended matter, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrogen (TN), and phosphor (TP) are high for rain gardens with herbaceous plants and shrubs. Muthanna and Vikland [9] have demonstrated seasonal hydrological efficiency of rain gardens. Yoo et al. [10] have developed a predictive model of rain garden infiltration and runoff based on field experiments.

To enhance the effectiveness of rain gardens, various rain garden techniques have been developed, including the increase of pollutant adsorption effects of rain gardens through saturated zones [11], the development of hybrid rain garden systems [12], and the development of natural adsorption media by controlling the degree of peat moss carbonization to increase the removal of pollutants [13]. Kim and Sung [14] have determined the concentration of nutrients and heavy metals accumulated in plants and soils of rain gardens. Park et al. [15] have analyzed growth characteristics of 20 species of plants for rain gardens depending on the type of filter media.

Another study has explored users' perceptions on how government subsidy schemes affect their willingness to have rain garden installations [16]. In that study, they analyzed household responses to a supposed rebate program as an incentive to adopt rain gardens using household survey data. The results of the study revealed that the willingness to pay (WTP) of participants was up to about 75% of the average cost of a rain garden installation, which was $6.72 per square meter.

On the other hand, another study scrutinized perceptual processes associated to the aesthetics of rain gardens, proposed five perceptual lenses (landscape aesthetics, ecological aesthetics, management-related aesthetics, aesthetics depending on topophilia and identity, and functional aesthetics). The results revealed that the four rain garden sites rank second through fifth places in the preference survey, showing that users had a stronger preference for streets with rain gardens [17].

Where plant selection to improve stormwater treatment for rain gardens is implemented, the following should be considered: native species are recommended because of their capability of survival in the rain gardens' environment (water- and drought-resisting qualities); using various species and plant types; root characteristics as good indicators of performance, while above-ground appearance generally provides a poor guide; and plant density and effective maintenance of rain gardens in the long-term [2,4]. Additionally, at least 50% of species for rain gardens' effective performances or species with required traits for effective removal of the pollutants should be included, therefore, comprising of herbaceous plants like reeds and other plants in the *Poaceae*, *Cyperaceae*, and *Poa* families [4,17]. For this reason, the public may be dissatisfied with the potentially 'messy-looking' plants if they are not recognizable with the concept and function of rain gardens [17].

As discussed above, the majority of studies on rain gardens were focused on physical and chemical functions of rain gardens, such as runoff management, pollutant removal [3,5–7,18], and technical and structural design methods based on these studies [11,12,19]. However, a rain garden is a multidisciplinary facility involving engineering, hydrology, water quality, soil, horticulture, and landscape [20]. Thus, research on rain gardens needs to be discussed from various academic perspectives. In addition, community supports for rain gardens are essential for the successful implementation of rain gardens, and for integration into local streetscapes and neighborhoods [4]. Considering recent efforts to increase the participation of residents in the installation and development of public facilities, and to actively reflect opinions of residents on government policies, a systematic plan is urgently needed to raise public awareness and support for rain gardens.

Therefore, the first objective of this study was to analyze the relationship between prior knowledge and support for rain gardens. If the public's prior knowledge about rain gardens can increase their support for implementation of rain gardens, it can be assumed that education and publicity of rain gardens play an important role in the expansion of rain gardens. Conversely, if prior knowledge of rain gardens does not show a significant relationship with support for rain garden implementation, education and publicity of rain gardens will not contribute to the expansion of rain gardens. The second objective of this study was to analyze the role of visual evaluation in the relationship between prior knowledge of rain gardens and support for rain garden installation. In other words, the second research objective was to verify the role of visual evaluation as a moderator between prior knowledge and support for rain gardens.

2. Methods

This paper aims to analyze the relationship between prior knowledge and support for rain gardens and to scrutinize the role of visual evaluation in the relationship between prior knowledge of rain gardens and support for rain garden installation. To achieve the purposes, case studies were employed as the research methodology. A total of three existing rain garden sites were selected for the case study: one in front of Jangan-gu Public Health Center, Suwon (Site A); one on a street near Unhyeongung, Seoul (Site B); and one near the swimming pool of the Jamsil Sports Complex, Seoul (Site C). These selected locations where rain gardens had been installed and were available for public use included a public building (Site A), a street (Site B), and a park (Site C).

Site A, close to a public building, was composed to assist infiltration actions in a relatively smaller area where rain gardens were formed beside benches (Figure 1). *Zelkova serrata* was planted as a canopy. Shrubs, such as *Buxus koreana* and *Rhododendron indicum*, and herbaceous species, such as *Pennisetum alopecuroides*, *Liriope muscari*, *Zoysia* spp., and *Carex boottiana* were also planted.

Figure 1. Picture of case study site A.

Site B could be categorized as a typical urban streetscape area. It was constructed on the limited size of existing street flowerbeds. *Platanus* and *Lagerstroemia indica* were planted as a colonnade, where shrubs such as *Kerria japonica*, *Kerria*, and *Euonymus alatus*, and herbaceous species such as *Liriope muscari*, *Platycodon grandiflorus*, were planted (Figure 2).

Figure 2. Picture of case study site B.

Site C was constructed in a comparatively large area, including places for walking and relaxing. Site C was composed with trees, such as *Quercus variabilis* and *Pinus strobus*. *Rhododendron indicum* and a variety of herbaceous species, such as *Hosta*, *Liriope muscari*, *Convallaria majalis*, *Mukdenia rossii*, *Penniseum alopecuroides*, and *Iris ensata*, were also planted under the existing trees (Figure 3).

Figure 3. Picture of case study site C.

Participants who visited any of these three case study sites were interviewed about their prior knowledge of rain gardens, the visual evaluation of rain garden, and support for rain garden implementation in urban open spaces (Table 1). This survey was conducted on 100 rain garden visitors. At least 30 rain garden visitors were surveyed for each site, and a total of 100 respondents were surveyed for the convenience of analysis. Sampling of the participants was performed in a random manner. As the concept of rain gardens was considered comparatively unknown to the public, face-to-face surveys were conducted at each site to obtain more accurate results. The survey was performed from 28 October 2016 to 30 October 2016.

Table 1. Questionnaire list.

Sections	Questions
Prior knowledge of rain garden	• prior knowledge of rain garden • differences (open-ended response)
Visual evaluation	• visual evaluation of rain garden • visual evaluation compared to normal gardens
Support	• support for rain garden implementation • reason (open-ended response)
Basic information	• gender, age, job

To analyse elements that might affect supporting the rate for rain garden facilities adaptation, structural equation model (SEM) analysis was performed. AMOS, established by Arbuckle [21], is a variety of SEM combined with factor analysis and regression analysis. It can analyse statistical data proficiently by way of a graphical method. Based on theoretical discussions, the following research hypotheses were established in this study (Figure 4):

Hypothesis 1. *Prior knowledge of rain gardens has a positive effect on support for rain garden implementation.*

Hypothesis 2. *Prior knowledge of rain gardens has a positive effect on visual evaluation.*

Hypothesis 3. *Visual evaluation as a moderator influences the relationship between prior knowledge of rain gardens and support for rain garden implementation.*

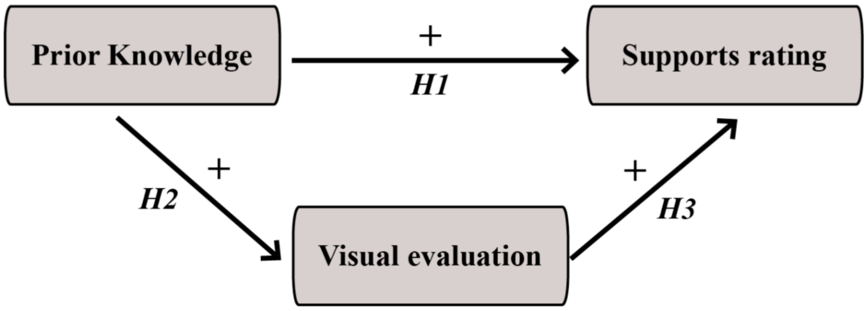

Figure 4. Research hypothesis diagram.

3. Results and Discussion

Concerning respondents' demographic characteristics, 49% were males and 51% were females. Those in their 20's, 30's, 40's, and $\geq$ 50 accounted for 24%, 29%, 19%, and 28%, respectively, showing a relatively uniform distribution by age. By occupation, these participants represented diverse occupational clusters, including office-based workers (33%), manual labour workers (25%), self-employed (19%), housewives (17%), and students (5%) (Table 2).

Table 2. Demographic characteristics of interviewees.

Sections		***n***	**%**
Total		**100**	**100.0**
Site	A	33	33.0
	B	34	34.0
	C	33	33.0
Gender	Male	49	49.0
	Female	51	51.0
Age	20's	24	24.0
	30's	29	29.0
	40's	19	19.0
	Over 50	28	28.0
Full time	Office based	33	33.0
	Manual labor based	25	25.0
	Self–employment	19	19.0
	House wife/Husband	17	17.0
	Student	5	5.0
	Unemployed/Other	1	1.0

The results of the survey are shown in the Table 3. In the visual evaluation scores of the rain gardens, the percentage of respondents who gave the positive response 'Very good' or 'Good' was 85.0%, which is high when compared to 14.0% of those who responded 'Bad' and 1% of those who answered 'Very bad'. The degree of prior knowledge of rain gardens was low. Most of the respondents (66%) answered, 'I never heard of it'. Only 3% of respondents answered that they have 'accurate knowledge' about rain gardens, and a total of 31% of respondents answered, 'I have heard of it'.

The survey requested information as to whether respondents would support a future urban open space to be a rain garden. It was revealed that 82.0% of respondents support a 'rain garden'.

Table 3. Survey results.

Questions	*n*	Response	Total (%)
Visual evaluation (Very bad 1–Very good 4)	100	1 2 3 4	3 82 14 1
Prior knowledge (Never heard about 1–Accurate knowledge 3)	100	1 2 3	3 32 66
Support rating (Not Support 1–Support 2)	100	1 2	18 82

To analyze elements that might affect support for rain garden facilities adaptation, SEM analysis was performed. Descriptive statistics for all variables are displayed in Table 2. The number of cases with the same variables was 100. Average visual evaluation, prior knowledge, and support for rain garden scores were 2.13 ± 0.442, 2.63 ± 0.552, and 1.18 ± 0.860, respectively (Table 4).

Table 4. Descriptive statistics results.

Variables	*n*	Min.	Max.	Average	S.D
Visual evaluation	100	1	4	2.13	0.442
Prior knowledge	100	1	3	2.63	0.522
Policy support rating	100	1	2	1.18	0.386

Results of the correlation analysis revealed positive correlations among prior knowledge, visual evaluation, and support rating. Visual evaluation showed statistically significant correlations with prior-knowledge ($r = 0.286$, $p < 0.01$) and support rating ($r = 0.513$, $p < 0.01$) (Table 5).

Table 5. Correlations among visual evaluation, prior knowledge, and support rating.

	Visual Evaluation	Prior-Knowledge	Support Rating
Visual evaluation	1	-	-
Prior-knowledge	0.286 *	1	-
Support rating	0.513 *	0.176	1

* $p < 0.01$.

Prior to analyzing the hypothetical relationship between constructs, confirmatory factor analysis of each measurement variable was performed. There are two methods to evaluate a model's goodness of fit: χ^2 and fitness index. In this study, the goodness of fit of the model was evaluated through Akaike information criterion (AIC), the root mean square residual (RMR), goodness of fit index (GFI), comparative fit index (CFI), and normed fit index (NFI) that was not sensitive to sample size. The standard of the fitness index was established in consideration of the model's interrelation. CFI and GFI have a value of between 0 and 1, with a value of 0.9 or higher indicates a goodness of fit [22,23]. The fit of the research model was judged to be appropriate, as displayed in Table 6.

Table 6. Confirmatory factor analysis.

AIC	RMR	GFI	CFI	NFI
12.00	0.00	1.00	1.00	1.00

Since the research model's goodness of fit was verified, the hypothesis of this study was verified through the path coefficient estimated through the research model (Figure 5).

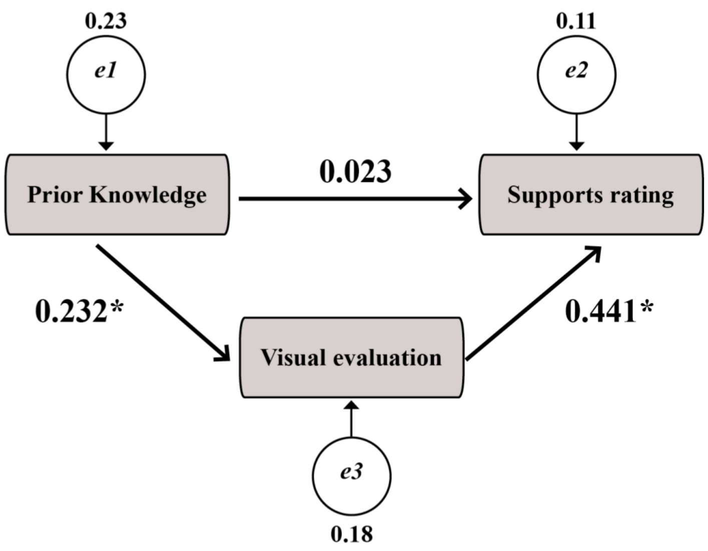

Figure 5. Structural equation model. * $p < 0.01$.

As a result of hypothesis verification, the first hypothesis, "Prior knowledge of rain garden has a positive effect on support for rain garden implementation", was not supported. On the other hand, prior knowledge of rain gardens showed a statistically significant positive relationship with visual evaluation. Therefore, the second hypothesis, "Prior knowledge of rain garden has a positive effect on the visual evaluation of rain gardens", was supported. In addition, visual evaluation of rain gardens had a positive effect on support for rain garden implementation. Therefore, the last hypothesis, "Visual evaluation of rain gardens is a significant moderator in the relationship between prior knowledge of rain gardens and support for rain gardens" was supported (Table 7).

Table 7. Result of SEM analysis.

	Estimate	S.E.	C.R.
Prior knowledge → Visual Evaluation	0.232 *	0.078	2.973
Prior knowledge → Supports Rating	0.023	0.064	0.353
Visual Evaluation → Supports Rating	0.441 **	0.079	5.600

* $p < 0.01$, ** $p < 0.001$.

It is generally known that, to build support for a policy, broad public knowledge must take precedence. Therefore, the current rain garden policy has been expected to require more efforts in offering information to the public about the benefits of rain gardens, including information about the concept, specific functions and expected effects of rain gardens. However, the result of SEM analysis, prior knowledge of rain gardens could not affect support for rain garden implementation directly. Therefore, education and publicity of rain gardens alone cannot contribute directly to the expansion of rain gardens. The study of Newburn and Alberini [16] also showed that the level of education or prior knowledge of rain gardens did not appear to have any effect on WTP.

Prior knowledge of rain gardens does not show a significant relationship with support for rain garden implementation, however, it could increase the visual evaluation of rain gardens. In addition, visual evaluation of rain gardens had a positive effect on support for rain garden implementation. In other words, visual evaluation was verified as a moderator between prior knowledge of rain gardens and support for rain garden installation. Additionally, it was reveal that the most common reasons for visitors not to support the installations of rain gardens were associated with the physical appearance, such as aesthetics or maintenance status, implying that diversification of rain garden planting types, along with the addition of further visual elements. Among those who do not support the installations of rain gardens (18% of total respondents), 38.9% answered 'lack of neat and clean-cut appearance' as a reason for their response, followed by 22.2% claiming the 'lack of harmony and relaxation with the urban setting', 22.2% saying the 'lack of potential for more elaborate landscape planting schemes', and 16.7% saying the 'easier installation and maintenance'.

Hence, if rain gardens are visually positive, prior knowledge can affect the support for rain garden through education and publicity of rain gardens. Therefore, in order to successfully apply rain garden policy in the future, rain gardens should be constructed in consideration of aesthetics in order to meet visual expectation of users prior to education and publicity of rain gardens.

4. Conclusions

Climate change and rapid urbanization are global phenomena that damage the water cycle system and aquatic ecosystem in urban areas. Rainwater, such as erosion of urban lowlands, are causing serious damages. Due to rain garden's effectiveness, such as preventing disasters caused by floods, reducing non-point source pollution, providing urban green spaces, and improving urban landscapes, they are gradually becoming important.

The purpose of this study was to analyze the influence of prior knowledge on public support for rain garden implementation and to verify the role of visual evaluation as a moderator in the relationship between prior knowledge and support for rain gardens. To achieve this purpose, a literature review was carried out to analyze previous research on rain gardens. A survey on users' prior knowledge about rain gardens, visual evaluation, and support for rain garden implementation was then conducted at three rain gardens in Korea.

Results of the survey indicated that prior knowledge of rain gardens did not have a direct effect on the support for rain garden implementation. However, it did have a positive influence on users' visual evaluation, which had a positive influence on support for rain garden implementation. In summary, visual evaluation of rain gardens can act as a moderator in the relation between prior knowledge and support for rain garden implementation policy. Hence, to increase support for rain garden implementation policy in the future, it is necessary to meet users' visual expectations of rain gardens prior to education and publicity about rain gardens.

This study has several limitations. First, the measurement methods for prior knowledge and visual evaluation of rain gardens were simple. The number of cases was small due to the lack of rain garden facilities in Korea. In addition, the survey was only conducted on weekends from Friday to Sunday. In future research, it will be necessary to conduct research on weekday users. Further research also needs to focus on detailed factors that affect support for rain garden policy, such as visual and aesthetic considerations.

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