

Article

Exploring Psychological and Aesthetic Approaches of Bio-Retention Facilities in the Urban Open Space

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Abstract: Over the last decades, a number of bio-retention facilities have been installed in urban areas for flood control and green amenity purposes. As urban amenity facilities for citizens, bio-retentions have a lot potential; however, the literature on bio-retentions focused mostly on physiochemical aspects like water quality and runoffs. Hence, this paper aims to explore psychological aspects of bio-retentions such as perceptions and landscape aesthetic value for visitors. In order to achieve this purpose, the study employed on-site interviews and questionnaires in the chosen three case studies as research methodology. For the 3 different locations of bio-retention facilities, interviews and questionnaires were carried out. The surveys of 100 bio-retention users were conducted, investigating their general perceptions and landscape aesthetics of the bio-retention facilities. The paper found that only 34% of the interviewees recognised bio-retention facilities, illustrating that most visitors were not aware of such facilities and were unable to distinguish the differences between bio-retention and conventional gardens. On the other hand, the majority of interviewees strongly supported the concept and function of bio-retentions, especially those who recognised the differences in planting species with conventional urban open spaces. Such main findings also encourage further studies of seeking quantitative values by conducting a correlation analysis between the functions and aesthetics of bio-retention facilities.

Keywords: bio-retention; rain gardens; aesthetic value; perceptive response; Low Impact Development; Sustainable Urban Drainage Systems

1. Introduction

Internationally, there has been a global phenomenon of rapid climate changes and urbanisation, and because of those, urban flash flooding, drainage problems, and non-point source pollutions have become major concerns in our lives [1]. Hence, several studies have been conducted to find ways to reduce the impact of climate change and urbanisation on the water cycle.

Recently, a low proportion of green spaces has threatened an adequate supply of urban ecosystem services in urban areas. According to Artmann et al. [2], the concept of compact green cities is required to provide a systemic approach by reflecting the complexity of cities as socio-ecological systems. In order to achieve this concept, a combination of various sources and types of data are needed, such as spatial, quantitative (economic benefits of compact cities) and qualitative (preferences of green spaces by different population groups). Therefore, a study of bio-retention facilities is required to determine economics and users preferences.

The new concepts of a Sustainable Urban Drainage System, Best Management Practices, and Low Impact Development have already altered the management methodologies of drainage systems from conventional applications [3]. Similar to Sustainable Urban Drainage Systems, Low Impact

Development is storm water management that contains both soft and hard engineering solutions. The main purpose of Low Impact Development is to maintain original or existing hydrologic systems by introducing infiltration, filtration, and storage of rain water, unlike the conventional pipe and pond approach. Therefore, the Low Impact Development eliminates polluted water through networked and distributed systems of soft landscapes [4].

Within the Low Impact Development technologies, green infrastructures or bio-retention systems have played an important role in serving green cities for people. Numerous infiltration-based technologies are being introduced in order to minimise the volume of storm water runoff and to increase the quality of water [5]. Bio-retention is one of these Low Impact Development facilities. Bio-retention is a ‘planted depression’, such as a rain garden, method to infiltrate rain water runoff [4]. The physical and chemical effects of this facility, such as reducing peak flow by infiltrating storm water runoff and removing nonpoint pollutants in rainfall, were successfully demonstrated in many studies [6–12]. Furthermore, bio-retention is considered as one of the most effective Low Impact Development facilities from aesthetical, ecological, and economic perspectives, because bio-retention serves as urban green spaces that improve urban landscape values and are known for low cost installations and easy maintenance [13]. Those environmental effects resulted in a rapid increase in bio-retention installation throughout the world over the past few years, and bio-retentions have become the most preferred site practice for sustainable development [14].

Studies on bio-retention need to be considered from diverse perspectives, as bio-retention is an interdisciplinary technology among structural engineering, hydrology, soil and horticultural sciences, landscape architecture, built environment and sustainability [7,8,13–18]. Only few studies have focused on the other side of bio-retentions, such as urban amenity roles and aesthetic aspects of bio-retentions and users and their general perceptions of bio-retention facilities.

While a few studies have been conducted on such topics, this study aimed to explore users’ aesthetic and psychological perceptions and the expectations of urban open space and to assess the bio-retention facilities’ perceived values and potentials for further improvement. In order to achieve these aims and purposes, extensive literature reviews on Low Impact Development and bio-retention facilities were carried out. Then, the study employed survey interviews and questionnaires from visitors in the case studies as research methodology. Three bio-retention facility locations in South Korea were chosen, and a series of interviews were carried out for approximately 100 visitors on psychological perceptions and aesthetic opinions about the bio-retention facilities (Figure 1).

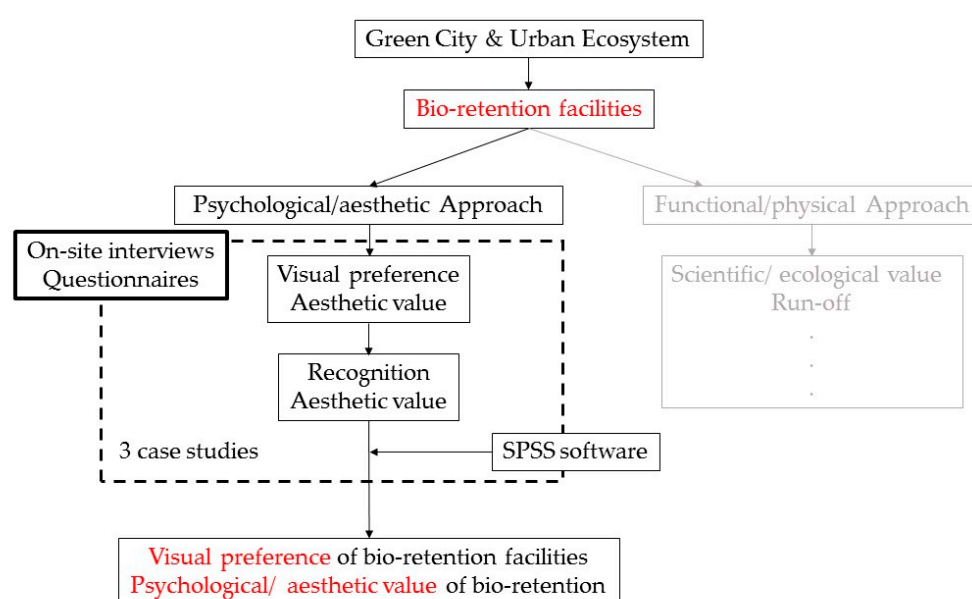


Figure 1. Research Work Flow.

2. Bio-Retention Systems within Urban Ecosystems

The majority of studies on green infrastructure and bio-retention focus on physical and chemical facets of hydraulic and hydrologic performances such as run off volumes and water quality. In terms of chemical effects of bio-retention facilities, a number of studies have illustrated that bio-retention facilities are highly effective for the retention of water, removal of heavy metal, and rain water control in urban areas [5,15,16]. Particularly, those studies analysed the performance of bio-retentions in eradicating or reducing oil, heavy metals like copper, lead, and zinc, as well as organic material like phosphorus, nitrogen, ammonium, and nitrate only within the controlled environment. Moreover, some research has been conducted to find out the physical benefits of bio-retention facilities such as retention capability and timed release of storm water by comparing in and out flows [13]. Some research was also conducted on-site evaluation of bio-retention facilities with respect to water quality and flow volume measurements [7,8,11,17], which proved the physicochemical capacities of bio-retention systems. However, other studies focused on the techniques and efficiency of the systems [16,18].

As an amenity facility, green infrastructure or bio-retention systems play a key role in providing a green better environment to citizens within urban areas, and such importance is well-recognised. In order to seek the function of amenity for bio-retentions, user-focused research is required. Another study explored users' perceptions as to how government subsidy schemes affect the willingness of rain garden installations [19]. Interviewees claimed they would spend up to 6.72 US dollars per square metre for bio-retentions, which was approximately 75% of the average cost of construction.

A study raised a concern about recent flooding and water contamination in the Red River in Canada [1]. As a solution, building bio-retention facilities in cities was suggested. Also, in order to persuade public understanding and perception, social feedback about bio-retention facilities was surveyed within elementary schools. As a result, it was found that the largest obstacles for installing bio-retention systems were funding and an ill-knowledged general public. First, the attitudes toward the behavior were associated with behavioral intention, suggesting that extension natural resource educators ought to work to increase the beliefs that bio-retentions would contribute to positive outputs they cherished, for instance, water quality, aesthetics of their home and contest beliefs that bio-retentions will contribute to outputs they do not want to happen such as attracting mosquitoes or standing water. Secondly, the use of endorsing social standards as a programme strategy to encourage acceptance of bio-retentions was supported [20].

On the other hand, Dobbie [21] inspected the perceptual processes related to the aesthetics of bio-retentions. This author explored the perceptive preferences of garden users by conducting a review in which imageries of four different bio-retention facilities were compared with imageries of four other similar sites without bio-retention systems. Dobbie's study showed that the four bio-retention sites ranked within top five in the preference survey, demonstrating that visitors had a robust preference for streets with bio-retentions. Simultaneously, the topophilia and satisfaction were proved to influence the preference: visitors preferred streets in their residential areas, regardless of the existence or absence of a bio-retention facility. The study also found that participants living in a street with bio-retention facilities did not influence their preference for the bio-retentions. In fact, the degree of satisfaction with a street was mostly influenced by individual elements such as vegetation trails, drains, and topophilia. The limits of the study show that it was an image-orientated survey and that it involved participants who have neither seen nor experienced the bio-retention facilities physically; that it completed a visual preference analysis by means of images taken at sole angles; and that it only focused on bio-retention facilities placed on the street; however, the study effectively scrutinised preferences for and responsiveness of the general idea of bio-retentions, and investigated landscape aesthetics, mostly concentrating on aesthetics grounded on topophilia and satisfaction with streets on the whole.

The examination of the trends in bio-retention literature illustrates that the majority of research includes the investigation of the physicochemical effects of bio-retentions, reflection of structural enhancements to improve these effects, in addition to evaluation of planting types.

Considerable research has been carried out on users' perception, but comprehensive research on landscape aesthetics and awareness of bio-retention facilities has seldom been carried out, in particular, among bio-retention users on site. However, where plant selection for bio-retentions is important, native species are often suggested due to their water and drought resistances and their suitability and resilience based on climate, soil, and humidity conditions, to the area where a bio-retention is to be constructed [4]. Therefore, no less than 50% of the planting for bio-retentions needs to include herbaceous plants such as reeds and other plants in the *Poaceae*, *Cyperaceae*, and *Poa* families. Hence, the general public using a bio-retention facility might not be fascinated by the possibly 'messy-looking' plants if they are not accustomed to the notion and function of bio-retentions [21]. Thus, an investigation of the aesthetic influence of bio-retentions, targeting to improve their functionality as urban open spaces and to reflect the users' requirements and the awareness of bio-retentions founded on the aesthetic and ecological differences from conventional gardens, would be an important step in future implementation. However, few studies have been carried out on the general perceptions and landscape aesthetics of bio-retentions among garden visitors.

3. Research Methodology

This paper aims to scrutinise the landscape aesthetics and perceptions of urban bio-retention facilities among garden visitors using the concepts that have been widely unexplored in previous studies. In order to achieve the aims and purposes, the research methodology employs survey interviews and questionnaires for three case studies. For the case study, a total of three existing bio-retention sites were selected (Table 1): one in front of the 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).

The selected three locations, where bio-retention facilities had been installed and the general public has a full access, for instance, an open space within a public building (Site A), a linear green strip with pedestrian access (Site B), and a recreational open space (Site C) support diversity in terms of geographic physical appearance, usage and layout categories. As a part of a public building, Site A was constructed by planting species such as *Rhododendron indicum* and *Zoysia* grass to facilitate infiltration actions in a relatively smaller area where ponds were formed alongside seatings. Site B could be classified as a typical urban streetscape area, constructed under existing street trees in herbaceous beds of limited size, where shrubs such as *Euonymus alatus* and *Kerria japonica* as well as herbaceous species such as *Liriope muscari* were planted. Site C was constructed in a relatively large area, which involved places for walking and relaxing, by planting *Mukdenia rossii*, *Pennisetum alopecuroides*, and *Iris ensata* together with existing trees such as *Quercus variabilis*, *Pinus strobus*.

Table 1. Case Study Locations.

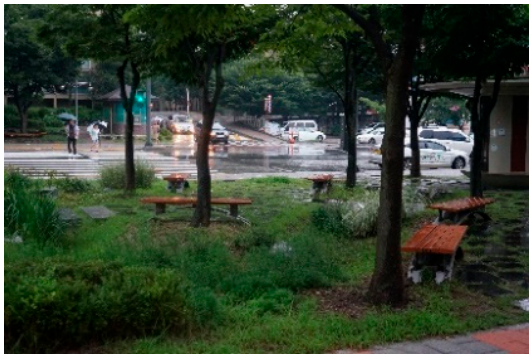
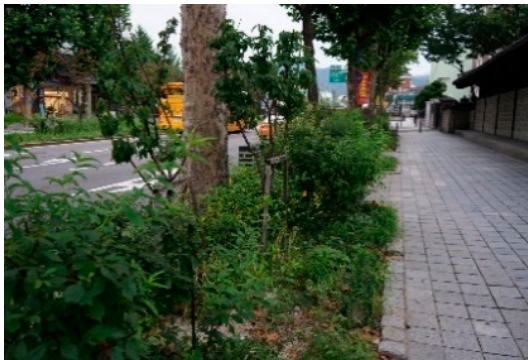
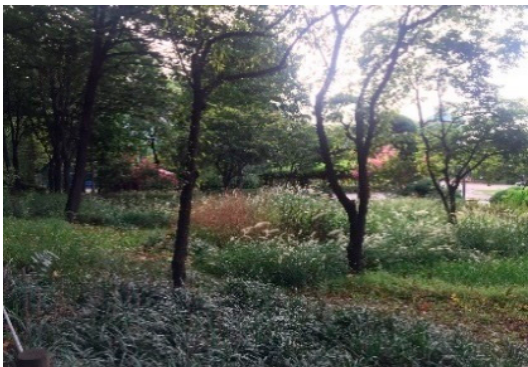
Site	Site Photo	Descriptions
A		<ul style="list-style-type: none"> • Jangan-gu public health centre, Suwon • Type: Open space serving public using health care • Area: 115 m² • Canopy: <i>Zelkova serrata</i> • Shrub: <i>Buxus koreana</i>, <i>Rhododendron indicum</i> • Herbs and Groundcover: <i>Pennisetum alopecuroides</i>, <i>Liriope muscari</i>, <i>Zoysia</i> spp., <i>Carex boottiana</i>

Table 1. Cont.

Site	Site Photo	Descriptions
B		<ul style="list-style-type: none"> • Street near Unhyeongung, Seoul • Type: Typical street linear open space • Area: 80 m² • Canopy: <i>Platanus</i>, <i>Lagerstroemia indica</i> • Shrub: <i>Kerria japonica</i>, <i>Kerria</i>, <i>Euonymus alatus</i> • Herbs and Grondcover: <i>Liriope muscari</i>, <i>Platycodon grandiflorus</i>
C		<ul style="list-style-type: none"> • Jamsil Sports Complex, Seoul • Type: Recreational open space serving sports complex • Area: 450 m² • Canopy: <i>Quercus variabilis</i>, <i>Pinus strobus</i> • Shrub: <i>Rhododendron indicum</i> • Herbs and Grondcover: <i>Hosta</i>, <i>Liriope muscari</i>, <i>Convallaria majalis</i>, <i>Mukdenia rossii</i>, <i>Iris ensata</i>, <i>Pennisetum alopecuroides</i>

4. Results and Discussion

In order to explore aesthetic and psychological roles of bio-retention in green cities, it is important to appreciate the existence of green open spaces within urban areas. Given that the case study is based on the bio-retention facilities in South Korea, the analysis sub-section in the following includes results of interviews and questionnaires. The participants who visited any of the three bio-retention sites in the previous chapter were interviewed and asked about their general evaluation of the bio-retention's landscape aesthetics, and the value as a green amenity facility. The questions were divided into four main categories: the perception of the bio-retention, landscape aesthetics, preference, and usage. Moreover, the questionnaires included multiple choice questions such as the difference between bio-retentions and conventional green spaces, or the reasons for visitors' preferences. Those questions had open-ended responses in order to carry out a thorough collection of public opinion. The general description about bio-retention was given to visitors when answering the questions. The descriptions were 'Bio-retention is designed to collect and infiltrate rainwater to reduce the urban flash flooding and improve water quality. It is a depressed area planted with various species such as grasses, herbaceous plants and trees and it also contributes to energy savings by lowering urban temperatures and creating a pleasant cityscape'. This survey was administered to 100 bio-retention facilities visitors, with sampling performed in a random manner (Table 2). As bio-retention facilities are considered relatively unknown to the general public, face-to-face interviews were conducted at each site to obtain more accurate responses. The survey was performed from 28 to 30 October 2016, and the data analysis was carried out using statistics software, SPSS, used for logical batched and non-batched statistical analysis.

Table 2. Characteristics of Interviewees.

Division		Frequency (%)
Site	A	33
	B	34
	C	33
Gender	Male	49
	Female	51
Age	20s	24
	30s	29
	40s	19
	50s and over	28
Full time	Office-based workers	33
	Manual labor workers	25
	Self-employed	19
	House wife/husband	17
	Student	5
	Unemployed/Other	1
Total		100

4.1. Recognition of Bio-Retention Facilities

The degree of awareness of bio-retention among interviewees was low. Only 3% responded ‘very familiar’. A total of 31% responded ‘somewhat familiar (I have heard of it)’, and the rest (66%) responded ‘unfamiliar (I never heard of it)’. Provided that some visitors may have been educated about bio-retention while visiting, it is highly possible that the degree of public awareness nationally is lower than these figures. A total of 34 interviewees who were aware of or had heard of bio-retentions were asked whether they knew the place they were visiting was a bio-retention; 67.6% answered ‘yes’. In particular, bio-retention visitors at Site A (73.3%) and Site C (100%) were found to be relatively well-informed in that they were using bio-retentions when compared to those who visited the one at Site B (30%). This can be explained by the fact that Site B users, with a comparatively short period of stay when compared to the other two bio-retention users, had fewer opportunities to identify the characteristics of the facility they were visiting. This can also be attributed to the absence of signage and the differences in the size of flower beds.

With regard to visitors distinguishing between the bio-retention and other conventional gardens, 51.0% of respondents answered ‘yes’ whereas, 49% claimed ‘no’. Judging from the fact that no substantial tendencies were conveyed among those who could distinguish any difference, ordinary users do not identify the characteristics of bio-retentions and their differences from other conventional gardens. While these findings cannot be measured statistically, more cases of positive recognition were observed at Site A and Site C than at Site B. For interviewees who recognised a difference between bio-retentions and other conventional gardens, 37.3% claimed a ‘more natural, less artificial feeling’ and 23.5% claimed the ‘wide variety of plants’ as reasons for their responses. The recognition of bio-retentions among the general public can be explained as follows: bio-retentions usually have an attractive appearance and make a natural, positive imprint; however, only about one in three visitors was aware of the notion of bio-retentions, and visitors often do not distinguish much difference between bio-retentions and conventional gardens, which shows that the current bio-retention policies should be more proactive, employing better campaigns. Thus, it is essential to provide the general public with information about the concept and function of bio-retentions and to recognize and highlight the benefits that distinguish them from conventional gardens (Table 3).

Table 3. Cognition of users about bio-retention.

Query	n	Response	Total (%)	Site (%)		
				A	B	C
Awareness of 'bio-retention' concept	100	Accurate knowledge	3.0	3.0	0.0	6.1
		Heard about	31.0	42.5	29.4	21.2
		Never heard about	66.0	54.5	70.6	72.7
		χ^2	-		5.478	
Whether they were aware that the place they were visiting was a bio-retention	34	Yes	67.6	73.3	30.0	100.0
		No	32.4	26.7	70.0	0.0
		χ^2	-		11.002 **	
Whether users distinguished between the bio-retention and other urban gardens	100	Yes	51.0	66.7	32.4	54.5
		No	49.0	33.3	67.6	45.5
		χ^2	-		9.215	

** $p < 0.01$.

4.2. Aesthetic Value of Bio-Retentions as Urban Ecosystems

As well as seeking evidence about visitors' overall perceptions of bio-retentions, the survey investigated some details about the landscape aesthetics of planting types. In the landscape aesthetic scores of tree types planted in the bio-retentions, the percentage of respondents who gave the positive response 'Good' was 78.0%, which is high when compared to 21.0% of those who responded 'bad' and 1% of those who responded 'Very bad'. Most respondents (32.1%) claimed a 'wide variety of plant species' as a reason why they responded that the planting types in the bio-retention were aesthetically attractive, followed by the 'natural, fewer artificial trees and grass (16.7%)', that the 'trees seem more vibrant (11.5%)', and that there were 'plenty of attractions from natural plant species (10.3%)'. In contrast, most of those who were negative about the vegetation (63.6%) criticized the 'poorly-managed, messy appearance', which can be regarded as a management issue rather than an indication of a strong disapproval of the types of species planted in the bio-retentions.

In the landscape aesthetic scores of bio-retention planting species and layouts, the proportion of respondents who gave the positive response 'Good' was 79.0%. Among those who found the planting species and structure of the bio-retentions to be aesthetically attractive, 63.3% answered the 'harmonious and natural design' as a reason for their answers, followed by 19.0% who answered 'efficient use of space' and 6.3% claimed 'well-designed for relaxation'. Alternatively, 52.4% of those who provided negative replies criticized the 'messy, poorly managed appearance', followed by the impression that the 'space seems too small', that there was 'a serious lack of resting space in a garden', and 'poor planting' (Table 4).

Table 4. Landscape Aesthetics Value of bio-retentions.

Query	n	Response	Total (%)	Site (%)		
				A	B	C
Planting and tree types	100	Very good	0.0	0.0	0.0	0.0
		Good	78.0	75.8	85.3	72.7
		Bad	21.0	24.2	11.8	27.3
		Very bad	1.0	0.0	2.9	0.0
		χ^2	-		4.476	
Planting structure and layouts	100	Very good	0.0	0.0	0.0	0.0
		Good	79.0	69.7	88.3	78.8
		Bad	20.0	30.3	8.8	21.2
		Very bad	1.0	0.0	2.9	0.0
		χ^2	-		6.569	

A majority of participants who recognised the bio-retentions provided positive opinions on their landscape planting aesthetics, whereas, 28.8% of the participants who did not recognize the

bio-retention provided negative views despite some positive responses. Amongst those who identified a general difference between bio-retentions and conventional gardens, 94.1% were positive about the landscape aesthetics, which is very high. On the other hand, a comparatively high percentage of the participants (36.7%) who described no substantial difference between bio-retentions and conventional gardens provided a negative view ('Bad') of bio-retentions' landscape aesthetic value. For those who were already aware of bio-retentions, a slightly higher number of participants were positive about the landscape aesthetic value of bio-retentions compared to those who were unaware of them. This result shows comparatively low statistical significance. In contrast, where respondents have knowledge of a general difference between bio-retentions and conventional gardens, the percentage of positive replies (96.1%) regarding planting species and structures was remarkably higher than the percentage of positive replies from those who were unaware (61.3%) (Table 5).

Table 5. Cross-tabulation analysis.

Query	n	Response	Awareness of 'Bio-Retention' Concept		Know the Differences	
			Y (34)	N (66)	Y (51)	N (49)
Planting and tree species	100	Very good	0.0	0.0	0.0	0.0
		Good	94.1	69.7	94.1	61.3
		Bad	5.9	28.8	5.9	36.7
		Very bad	0.0	1.5	0.0	2.0
		χ^2	7.837 *		15.834 ***	
Planting structure and layouts	100	Very good	0.0	0.0	0.0	0.0
		Good	91.2	72.7	96.1	61.3
		Bad	8.8	25.8	3.9	36.7
		Very bad	0.0	1.5	0.0	2.0
		χ^2	4.699		18.337 ***	

* $p < 0.05$; *** $p < 0.001$.

In terms of landscape aesthetic value, it was revealed that planting types and structures are the most valuable aspects of bio-retention systems. Moreover, a cross tabulation analysis of the recognition of bio-retention facilities illustrated that the visitors who were able to recognize a bio-retention and who were aware of difference between bio-retention and conventional gardens tend to rate the planting structures and types positively. On the other hand, the visitors who had a negative view of bio-retention's planting types and structures blamed poor maintenance as the reason behind the view. These results also suggest that sustainable maintenance is equally important as introducing new bio-retention facilities in order to increase users' satisfaction and convenience.

4.3. Support of Bio-Retention Installation

The survey sought information as to whether participants would prefer a future urban open space to be a bio-retention or a convention garden. It was discovered that 82.0% of participants preferred a 'bio-retention or rain garden' while 18.0% preferred a 'conventional garden', showing an overwhelming preference for bio-retentions. In most cases, even allowing for user characteristics, participants revealed robust support for bio-retention facilities over conventional gardens, illustrating that users might be more likely to answer positively to the extensive installation of bio-retention facilities and to suggest supporting them in the future (Table 6).

Table 6. Supporting bio-retention installation.

Query	n	Response	Total (%)	Site (%)		
				A	B	C
Whether respondents would prefer a future urban green space be a bio-retention or normal green space	100	Normal urban green space	18.0	18.2	14.7	21.2
		Bio-retention	82.0	81.8	85.3	78.8
		χ^2	-	0.481		

The main motive behind preferring bio-retention facilities appears to reflect visitors' understanding of their functional facets, rather than their aesthetic value. More specifically, 29.3% of participants claimed, in support of their responses, that bio-retentions were 'more effective in dealing with water scarcity'; this was followed by 28.0% who claimed they were 'more natural and environmentally friendly', 11.0% who claimed they were 'cost-effective', and 11.0% who commended 'water quality improvement'. Only 2.4% answered aesthetic value as a reason, claiming that 'rain garden planting schemes will look better than conventional garden'. On the other hand, a lot of respondents who preferred conventional gardens related their answers to aesthetic aspects or to the garden's appearance. Among them, 38.9% answered 'more neat, clean-cut appearance' as a reason for their response, followed by 22.2% claiming the 'more harmonious, relaxed with urban setting', 22.2% saying the 'potential for more elaborate landscape planting schemes', and 16.7% saying the 'easier installation and maintenance'.

Notwithstanding the favorable perceptions of bio-retention aesthetics, the functional facets of these gardens were claimed as the key reason why visitors preferred them, suggesting that the general public reveals a robust interest in the environment and that it has high prospects of the role that bio-retentions could play. Furthermore, the fact that respondents claimed aesthetic values as a reason for their strong support of conventional gardens suggests that their support for bio-retentions could increase if landscape aesthetic improvements to planting species, structure and maintenance could be made.

A binary logistic regression analysis was carried out within this study, where the dependent variable was the support for bio-retention facilities as urban open space of the future, and independent variables involved basic demographic characteristics, whether or not respondents were capable of identifying a bio-retention, and respondents' landscape aesthetic evaluations of the bio-retentions. The B value is the coefficient of each independent variable, which means the magnitude of the effect on the total value when the independent variable value increases by one. The results illustrated that the more visitors recognised that the bio-retention they were visiting was distinguished from conventional gardens, for instance, in terms of the trees species and grass planted, and the more positively they valued its landscape aesthetics, the sturdier their support for bio-retention installation. R^2 is the explanatory power of this model, which means that the above independent variables explain 52.9% (Table 7). This suggests that divergence of plant species, along with development of various designs accent aesthetic and landscape features, would gain more support from general public when implementing future policies related to bio-retentions.

In the improvement requirements for each bio-retention, the percentage of participants who answered the 'lack of waterscape facilities (pond, fountain etc.)' was 38.0%, followed by 27.0% citing the 'lack of plants diversity', 18.0% citing the 'Lack of amount of plants', 16.0% citing the 'lack of facilities for rest (benches etc.)', and 1.0% citing the 'Overabundant artificial facilities' (Table 8). In particular, the visitors at Site A answered the 'lack of amount of plants' was 36.4%, and the 'lack of waterscape facilities' was 30.3%. Most visitors at Site B cited the 'lack of waterscape facilities' (41.2%) and the 'lack of facilities' (26.5%). At Site C, the 'lack of waterscape facilities' and the 'lack of plants diversity' were the same (42.2%).

Table 7. Logistic regression analysis—supporting bio-retention installation.

Variables	B	S.E.
Gender	1.300 (3.671)	1.392
Age	−0.057 (0.944)	0.055
Awareness of ‘bio-retention’ concept (No 0, Yes 1)	−2.100 (0.122)	2.118
Planting and tree types-Know the differences (Very different 1~Not at all different 4)	−4.793 (0.008)	1.810 **
Planting and tree types-Landscape aesthetic value (Very good 1~Very bad 4)	−5.603 (0.004)	2.020 **
Planting structure and layouts-Know the differences (Very different 1~Not at all different 4)	1.987 (7.297)	2.503
Planting structure and layouts-Landscape aesthetic value (Very good 1~Very bad 4)	−2.460 (0.085)	2.145
Constant	29.885	8.680 **
N	100	
−2 Log likelihood	18.971	
Cox-Snell R^2	0.529	

** $p < 0.01$; Parentheses indicate the standardization factor; Since the correlation coefficient between independent variables is not large, multicollinearity is not a problem.

This can be explained by the geographical characteristics or size of each site. Attached to a public building, Site A seems to lack plants. It also seems to be worth more if waterscape facilities will be installed, such as a pond and fountain, as Site A is an open space in the middle of an urban area. In the case of Site B, a typical streetscape space, the size is very limited and plants are monotonous, so it can be seen that the responses demanding various facilities, such as waterscape facilities, are large. In addition, there is no facility to rest, such as benches, and it is necessary to install such facilities. It is judged that the diversity of plants in Site C is insufficient compared to a large space. It is expected that the use of Site C will increase if various facilities such as a pond or a fountain are added so that leisure facilities can be enjoyed as a family unit.

Table 8. Improvement requirements for bio-retention.

Query	n	Response	Total (%)	Site (%)		
				A	B	C
Improvement requirement for bio-retentions.	100	Lack of plant diversity	27.0	15.1	23.5	42.4
		Lack of number of plants	18.0	36.4	5.9	12.2
		Lack of waterscape facilities	38.0	30.3	41.2	42.4
		Lack of facilities for rest	16.0	18.2	26.5	3.0
		Overabundant artificial facilities	1.0	0.0	2.9	0.0
		χ^2	-	22.978 **		

** $p < 0.01$.

5. Conclusions

The role of bio-retention facilities as a part of urban ecosystems-encompassing the stoppage of flooding damages and reduction of nonpoint source pollution and the establishment of an attractive landscape and location for relaxation- would be more significant. However, most bio-retention studies have explored physicochemical effects, for instance, water quality enhancement and minimizing runoff, leading to a lack of literature on the aesthetic values and user perceptions of bio-retention as urban green open spaces. Therefore, this study aimed to explore the landscape aesthetic values and user perceptions of bio-retentions in an attempt to improve their landscape values as urban open spaces with the potential for extensive application in the future. In order to achieve these aims and purposes, a literature review was carried out to scrutinize previous research on bio-retentions, while a survey of the landscape aesthetic values and user perceptions was employed at three bio-retention facilities in the Seoul metropolitan area.

The results indicated that the degree of bio-retention awareness was 34%, which shows that the majority of the general public is not aware of the existence of bio-retentions. Moreover, this study revealed that low public awareness of bio-retentions and storm water management need to be the priority for the effective implementation of related policies. In summary, in order to increase support for a bio-retention policy, public awareness ought to take priority over an understanding of the specific policy. Likewise, this study discovered that those who were aware of bio-retentions generally scored the main survey questions positively. Consequently, the current bio-retention schemes are expected to be more proactive in supplying information to the general public about the benefits and environmental functions.

Where visitors' expectations of bio-retentions were concerned, the research results suggest that besides the general expectation that bio-retentions serve as urban green open spaces, visitors also have higher expectations of their functional facets, especially in relation to pollution and frequent natural disasters including flash floods and droughts. Therefore, such functional features need to be a high priority in the design of bio-retentions. In addition, a failure to prevent natural disaster or to improve water quality might lead to counterproductive outcomes in terms of environmental policy implementation.

The outcomes regarding the aesthetic scoring of bio-retention landscapes revealed that the distinctive planting species from those of conventional landscaping contributes to visitors' aesthetic satisfaction. Bio-retention landscape presently receives positive evaluations where aesthetics are concerned; however, as the regression analysis illustrated, general public support for bio-retention installation is strongly expected to increase where planted species are differentiated from those of conventional urban gardens and where, at the same time, such gardens have an attractive appearance. The most common motives for visitors to prefer conventional gardens to bio-retentions were related to physical appearance, such as aesthetics or maintenance conditions, suggesting that diversification of bio-retention planting species, accompanied by the addition of further aesthetic aspects, would assist in increasing public support for bio-retentions.

Finally, this study has significance on two levels: first, the study validates visitors' perception of bio-retentions and illustrates the expectations of the general public concerning the gardens' function; second, the study identifies main development challenges facing bio-retention implementations, with regards to landscape aesthetics. The findings of this paper propose that further research is required, focusing on the diversity of planting species. By performing a correlation analysis of bio-retentions' aesthetics and functionality, additional analysis of user insights has the potential to offer valuable quantitative gauges of landscape aesthetics in addition to identify specific policies for improvement.

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