Relationships Between Vegetation Density and Preference of Bioretention Landscapes: The Roles of Perceived Naturalness and Safety in the United States

ความสัมพันธ์ระหว่างความหนาแน่นของพืชพรรณและความชอบต่อพื้นที่ดูดซับน้ำฝน: บทบาทของความรับรู้เชิงธรรมชาติและความปลอดภัยในสหรัฐอเมริกา

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บทคัดย่อ: ในปัจจุบัน กลยุทธ์ในการจัดการสภาพแวดล้อมคือการแนะนำให้ใช้พืชและกระบวนการทางธรรมชาติในการจัดการน้ำท่วมขังและน้ำฝนที่ไหลบ่ามากยิ่งขึ้น หนึ่งในกลยุทธ์นั้นคือ การใช้พื้นที่ซับน้ำฝนทางชีวภาพ (bioretention) ซึ่งเริ่มมีการนำมาใช้ประโยชน์ในหลายประเทศแล้ว ในประเทศไทย เรื่องนี้เป็นเรื่องใหม่ ความเข้าใจในเรื่องของการรับรู้และการใช้ประโยชน์ของพื้นที่ซับน้ำฝนทางชีวภาพ ของผู้ออกแบบภูมิทัศน์ นักวางผัง และวิศวกร ยังมีอยู่น้อย ส่งผลต่อการยอมรับและการทำให้เกิดความยั่งยืนของการใช้พื้นที่ในลักษณะนี้ ได้มีรายงานถึงพื้นที่ภูมิทัศน์ที่มีจำนวนพืชพรรณในปริมาณที่มาก เป็นที่ยอมรับและชื่นชอบในทางบวก ในขณะที่กลไกที่จะอธิบายว่าทำไมมนุษย์ชอบพื้นที่ที่มีความหนาแน่นของพืชพรรณมากกว่าพื้นที่ที่มีความหนาแน่นของพืชพรรณน้อยกว่า ยังไม่ชัดเจน ผู้วิจัยจึงได้ออกแบบสอบถามความคิดเห็นกับบุคคลทั่วไป โดยใช้ภาพจำนวน 54 ภาพ หาความสัมพันธ์เปลี่ยนถ่าย (mediation) ระหว่างความหนาแน่นของพืชพรรณ การรับรู้ในความเป็นธรรมชาติและความปลอดภัย และความชอบในรูปแบบของพื้นที่ซับน้ำฝนทางชีวภาพ ผลการศึกษาพบว่า การรับรู้ในความเป็นธรรมชาติเป็นตัวแปรเปลี่ยนถ่ายที่มีอิทธิพลสูงระหว่างความหนาแน่นของพืชพรรณและความชอบ ในขณะที่การรับรู้ในความปลอดภัยเป็นตัวแปรเปลี่ยนถ่ายที่มีอิทธิพลต่ำ ผู้ออกแบบภูมิทัศน์ นักวางผัง และวิศวกร ควรใช้ความรู้นี้เป็นเครื่องมือในการประเมินการออกแบบพื้นที่ซับน้ำฝนชีวภาพ ผลที่ได้จากการศึกษาในครั้งนี้เป็นเรื่องใหม่ ที่ช่วยทำให้เข้าใจถึงการรับรู้ของมนุษย์ต่อการออกแบบภูมิทัศน์และสิ่งแวดล้อมในเชิงลึกมากยิ่งขึ้น ในอนาคต ควรวิจัยความสัมพันธ์ของความ-หลากหลายของพื้นที่ซับน้ำฝนชีวภาพ ความแตกต่างของวัฒนธรรมและเอกลักษณ์ของพื้นที่แต่ละแห่งต่อไป

คำสำคัญ: การจัดการสภาพแวดล้อม การออกแบบภูมิทัศน์ การรับรู้ภูมิทัศน์ น้ำฝน การออกแบบที่ตอบสนองต่อน้ำ

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Abstract: Recently, environmental management strategies suggest the implementation of plants and natural processes for flood and stormwater management. Among those strategies, bioretention is growing in popularity across nations. However, the understanding of perceptions and preferences of bioretention landscapes are lacking among landscape designers, planners, and engineers. This lack of knowledge risks the acceptance and sustainability of such projects. While research suggest landscapes with higher vegetation density increase positive landscape perceptions and preference, the mechanism of why denser landscapes are preferred is still missing. Thus, this research aims to understand how some landscape perceptions mediate the relationships between vegetation density and preference of bioretention landscapes. The researchers deployed 54 item photo-questionnaires and analyzed the relationships between vegetation density, landscape perceptions, and landscape preference. We found that perceived naturalness strongly mediated the relationships between vegetation and preference of bioretention landscapes while perceived safety had a weak mediative effect. Designers, planners, and engineers can use this information as a tool to assess how they can implement bioretention designs towards landscapes. This research is new because it helps us understand humans' perception of landscapes and environments more deeply. Future research may explore more diverse variety of bioretention landscapes and differences among cultural and place identities.

Keywords: Environmental management, landscape design, landscape perception, stormwater, water sensitive design

Introduction

Growing evidence suggests strong positive relationships between natural elements and human well-being (Suppakittpaisarn *et al*., 2017; Suppakittpaisarn *et al*., 2020a). That is, natural elements, such as trees, parks, open spaces, and forests, played important roles in reducing risks of cardiovascular based mortality, stress-related morbidity, and mental health disorders. They also supported positive social interaction and increase cognitive performances (Sullivan *et al*., 2014). These relationships can be explained by the biophilia hypothesis, which posits that humans prefer certain elements of nature that are important to our survivals (Kellert and Wilson, 1993); stress reduction theory, which posits that exposure to natural elements helps lower acute stress thus prevent negative effects from chronic stress (Ulrich, 1999); and attention restoration theory, which posits that humans cognitive functioning can be improved by spending time, undistracted, experiencing natural elements with certain characteristics (Kaplan, 1995).

One of the remaining questions in the relationship of nature and well-being is 'how much nature' or what the environmental psychologists call 'dose.' Dose refers to the amount of nature a person can experience, including intensity, duration, and frequency of exposure to nature (Jiang, 2013; Yaipimol *et al*., 2022). We have limited information about the dose-responses relationships between nature elements and human well-being, including stress, attention, and preference (Jiang *et al*., 2014a; Jiang *et al*., 2014b; Sullivan *et al*., 2014). This limits our understanding towards how to design natural elements into every day landscapes.

In term of dose of nature and preference, a study examined the relationship between vegetation density and preference, and found that it was in a power relationship (Suppakittpaisarn *et al*., 2019b). That is, when there are little natural elements and some more is added, the preference increased rapidly; however, if the natural elements amount past a certain point, the increase in these elements is not increasing preference as much as before. However, questions about what constitute landscape preference remain, especially for bioretention landscapes.

Bioretention landscapes are the landscapes that are designed for stormwater management. These landscapes, such as rain gardens and bioswales, are gardens or patches of trees and herbaceous plants that slow and absorb stormwater before it hits conventional sewer system (USEPA, 2008). In the past decades, they have become a popular strategy in stormwater management, but due to the characteristics of the plants, which are likely to be high-stemmed grasses and native plants than the traditional flowering landscapes, their preference, perception, and acceptance still need further understanding (Suppakittpaisarn *et al*., 2020b; Suppakittpaisarn *et al*., 2019b).

In a study attempting to understand people's preference and acceptance of bioretention landscapes, three dimensions of perceptions were identified as related preference: perceived naturalness, safety, and messiness (Suppakittpaisarn, 2017). These characteristics may be keys to understanding how landscape and perceptions are linked towards bioretention landscapes, especially for perceived naturalness and safety, which predicted landscape preference (Suppakittpaisarn *et al*., 2020b).

The researchers suspect that there are mediative relationships between vegetation density, landscape perceptions, and landscape preferences. Specifically, landscape perceptions may act as mediating variables in such relationships. Mediating variable is a variable that is explained by the independent variable and explain the dependent variable of a relationship (Baron and Kenny, 1986; Dassopoulos and Monnat, 2011).

Thus, these gaps of knowledge established the research question: do landscape perception (safety and naturalness) mediate the relationship between vegetation density and preference?

Materials and Methods

Photo-questionnaires preparation

In this study, the researchers took 6 eye-level photographs of an urban environment based on Midwestern United States. Photographs selections were made and confirmed by landscape architectural researchers to reflect typical streetscapes with wide sidewalks, enough to add plants and street trees, and buildings or other structures on the side. Each image then was added 3 levels of trees (none, few, many) and 3 levels of bioretention planting based on the amount (none, little, a lot), providing 9 conditions of each case and 54 images in total. The images were tested in previous studies. These images were then made into 4 separate questionnaires, asking the following questions for each image.

- How much do you like this landscape ?
- In your opinion, how natural is this landscape ?
- In your opinion, how safe is this landscape ?
- In your opinion, how messy is this landscape ?

The participants rated the images in 5 Likert scale from not at all (0), a little (1), somewhat (2), a lot (3) to very much (4). The examples of images could be found in Figure 1.

The questionnaires were deployed via Amazon Turk crowdsourcing system in July 2017, limiting the participants to those living in the United States between the age of 18-65-year-old. The age group was chosen because they were adults and were the majority of those who spend time outdoors. The relevant ethical screening was sought and approved before the deployment of the questionnaires. The survey was also deployed and tested successfully in a previous study (Suppakittpaisarn *et al*., 2020b).

Vegetation Density

Eye-level vegetation density was calculated by Brown Dog Green Index Extractor, a machine-based tool that used color detection to identify the percentage This tool has been used in previous studies tested to provide similar results with human perception of vegetation in each image (Padhy *et al*., 2015). (Suppakittpaisarn *et al*., 2020a; Suppakittpaisarn *et al*., 2019b). The vegetation density numbers were provided in continuous variables based on the calculation.

Statistical analyses

The researchers used Baron & Kenny Mediation Analysis in this study, similar to a previous landscape and well-being study (Kuo and Sullivan, 2001). The analysis first analyzed the correlations between the independent variable (the predictor) and the dependent variables that were hypothesized as outcome variable (the outcome) and mediating variable (the mediator). Typically, the test's assumption was that independent variables should predict significant correlations between both the outcome and the mediator (Baron and Kenny, 1986).

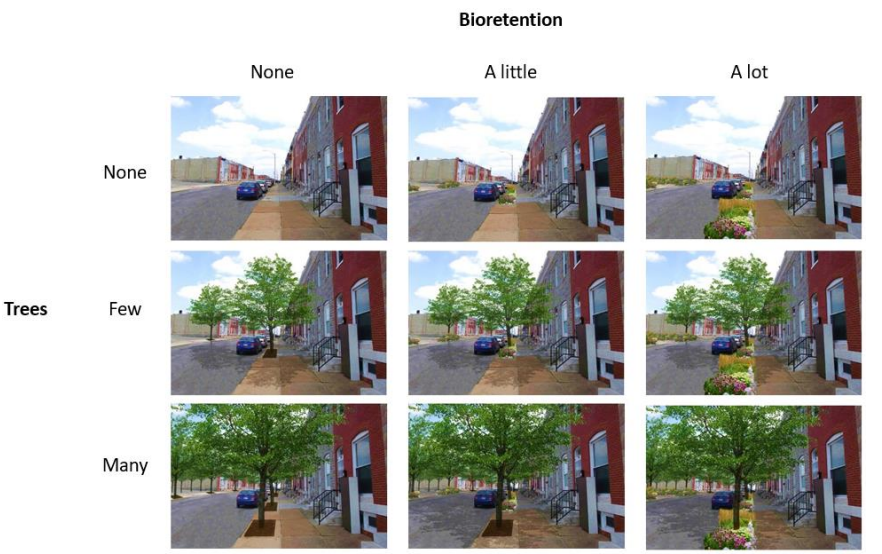


Figure 1. Example images used in the questionnaire with varying levels of trees and bioretentions

For the mediator to be proven as mediating variable, when running the multi-variable correlation test, the beta coefficient of the predictor would drop greatly or the predictor would lose the significance altogether (Baron and Kenny, 1986).

Results

Descriptive Statistics

A total of 427 participants answered the questionnaires. Of these, 249 were male (58 %) 175 were female (41 %), and 3 did not identify their gender (1 %). There were 390 people (92 %) from US and Canada, 5 people (1 %) from Western Europe, 1 person from Australia and New Zealand (0 %) and 31 people (7 %) who did not specify their locations in the past five years. Gender and geographical locations did not significantly predict differences in landscape preference and perceptions in these studies.

Vegetation density among the images (n = 54) had the mean of 22.6 %, S.D. of 0.2, with maximum of 46.4 % and minimum of 0.0 %. Landscape preference had the mean of 1.7 and S.D. of 0.6, meaning that most people find the landscapes 'a little bit' preferrable moving towards 'somewhat' preferrable. Perceived naturalness had the mean of 1.5 and S.D. of 0.4, meaning that people find the landscapes 'a little bit' natural. Perceived safety had the mean of 2.3 and S.D. of 0.4, meaning that overall, people find the landscapes 'somewhat' safe.

Vegetation Density from trees and bioretention, Perceived Naturalness, and Preference

In this test, vegetation density from trees and bioretention acted as the predictor, perceived naturalness as the mediator, and preference as the outcome. The Pearson's correlation test between vegetation density and perceived naturalness resulted as $r(1,52) = 0.96$, $p = 0.00$, beta coefficient = 1.0. The Pearson's correlation test between vegetation density and preference resulted as $r(1,52) = 0.89$, $p = 0.00$, beta coefficient = 0.9.

The Pearson's correlation test between vegetation density, perceived naturalness, and preference resulted as $r(2,51) = 0.96$, $p = 0.00$, beta coefficient for vegetation density = -0.1, p for vegetation density = 0.37, beta coefficient for perceived naturalness = 1.1, $p = 0.00$. (Table 1)

This suggested that perceived naturalness acted as a strong mediator for the relationships between vegetation density and preference.

Table 1. Vegetation density from trees and bioretention, perceived naturalness, and preference

Model	Variable	df	r	p	Beta coefficient
1: vegetation density and perceived naturalness	Model	(1,52)	0.96	0.000	
	Vegetation density			**0.000**	**1.0**
2: vegetation density and preference	Model	(1,52)	0.89	0.000	
	Vegetation density			**0.000**	**0.9**
3:vegetation density, perceived naturalness, and preference	Model	(2,51)	0.96	0.000	
	Vegetation density			0.370	-0.1
	Perceived naturalness			**0.000**	**1.1**

Vegetation Density from trees and bioretention, Perceived Safety, and Preference

In this test, vegetation density from trees and bioretention acted as the predictor, perceived safety as the mediator, and preference as the outcome. The Pearson's correlation test between vegetation density and perceived safety resulted as r(1,52) = 0.95, p = 0.00, beta coefficient = 1.0. The Pearson's correlation test between vegetation density and preference resulted as r(1,52) = 0.89, p = 0.00, beta coefficient = 0.9.

The Pearson's correlation test between vegetation density, perceived safety, and preference resulted as r(2,51) = 0.97, p = 0.00, beta coefficient for vegetation density= 0.4, p = 0.00, and beta coefficient for perceived safety = 0.7, p = 0.00. (Table 2)

This suggested that perceived safety acted as a weaker mediator for the relationships between vegetation density and preference

Discussion

Key findings

In this study, the researchers aimed to answer the mediating roles of perceived landscape naturalness and safety towards the relationship between vegetation density and preference of bioretention landscapes. We found that perceived naturalness strongly mediated the relationship, while perceived safety did in a smaller degree.

Contributions

The results of this study were congruent with previous studies in that vegetation density predicted perceived naturalness and safety of bioretention landscapes, and these landscape perceptions predicted preference of such landscapes (Jiang *et al*., 2015; Jiang *et al*., 2017; Suppakittpaisarn *et al*., 2020b; Suppakittpaisarn, *et al*., 2019b). While denser bioretention plants might, in previous discussions, provide discomfort due to the possibility of its unkempt appearance and habitation of unwanted wildlife species based on the biophilia hypothesis, the current studies suggested a different direction (Kellert and Wilson, 1993). This might be because the existing vegetation density levels did not exceed the comfort zone, and because other unkempt factors, such as cracked sidewalks or broken windows, were not included in the study (O'Brien *et al*., 2019).

Table 2. Vegetation density from trees and bioretention, perceived safety, and preference

Model	Variable	df	r	p	Beta coefficient
1: vegetation density and perceived safety	Model	(1,52)	0.95	0.000	
	Vegetation density			**0.000**	**1.0**
2: vegetation density and preference	Model	(1,52)	0.89	0.000	
	Vegetation density			**0.000**	**0.9**
3: vegetation density, perceived safety, and preference	Model	(2,51)	0.97	0.000	
	Vegetation density			0.000	0.4
	Perceived safety			**0.000**	**0.7**

The incongruent could be discussed in term of 'messy ecosystem, orderly frames' concept provided by Nassauer (Nassauer, 1995). This study is novel as the first few studies that explored the mediating relationships between vegetation density, landscape perceptions, and landscape preferences in urban bioretention landscapes.

Implications

The results of the study may bridge the gaps about dimensions of landscape perceptions which can help predict landscape preference. Researchers and designers may use these perceived naturalness and safety to engage laypeople as more specific design parameters for further understanding for public streetscape designs, including bioretention design, thus bridging the gaps between laypeople and designers (Suppakittpaisarn *et al*., 2019a). This would also refine the understanding of what constitute landscape preference, which could inform future design guidelines and instructions. However, the results of the study would need to consider the contexts of the design locations and understand how well-known the elements such as bioretention are, local vegetation, and the stakeholders' perception towards native plants and rainwater.

Limitations and Future Studies

While novel and exploratory, the study is not without limitations. First, this study engaged with perceptions and preference of landscape. While these measures across populations are widely used to determine landscape preference, researchers must admit to their subjective nature. Decision makers should only use this information within context and along with other factors. Secondly, this study focused on wide range of participants. There might be demographic factors, such as genders, cultures, and socio-economic statuses, that influenced the differences in their perceptions and preferences. Thirdly, this is a study about landscape perception, thus, it did not consider the performance of the bioretention landscapes. Future studies should include wider range of landscapes, not just streetscapes. They should include potential performances, different population groups, and seasonal variations. Other factors that predict perceived naturalness and safety, such as vegetation health and numbers of people in the images, should be included in the future study designs. These research gaps were mentioned in previous studies. (Saengngern *et al*., 2012; Suppakittpaisarn *et al*., 2019a; Thompson and Travlou, 2007).

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