Urban Residents to Finance Public Parks' Tree-planting Projects: An Investigation of Biodiversity Loss Consequence Perceptions and Park Visit Frequency

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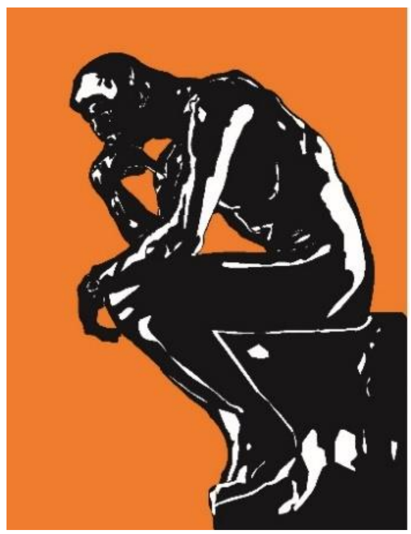

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"The sound of birds singing is common. The green mulberry foliage in that quiet alley is the dreamland of the birds."

—In "Dream"; *The Kingfisher Story Collection* (2022)

Abstract

Public parks play important roles in conserving biodiversity, promoting environmental sustainability, fostering community engagement, and enhancing the overall well-being of residents in urban areas. Nevertheless, finance is needed to maintain and expand the greenspaces in the parks. The current study aims to examine how perceptions of biodiversity loss consequences and park visitation frequency influence the residents' willingness to contribute financially to tree-planting projects in public parks. Employing the Bayesian Mindsponge Framework analytics on a dataset of 535 Vietnamese urban residents, we discovered that perceived health loss and knowledge erosion as consequences of biodiversity loss and park visitation frequency are directly positively associated with financial donation willingness. Meanwhile, the perceived economic growth loss was found to be indirectly positively associated with donation willingness through park visitation frequency, whereas the perceived loss of nature-based recreation opportunities exhibits the opposite indirect association. Based on these results, communication strategies focusing on the multifaceted benefits of biodiversity preservation and investments in public parks are recommended to improve urban residents' financial support to park panting initiatives, accessibility to greenspaces, and connections with nature. These are crucial for promoting an eco-surplus culture that enhances biodiversity conservation and human well-being.

Keywords: urban development; developing country; biodiversity conservation; financial contribution; biodiversity loss perceptions; urban park; tree planting

1. Introduction

Biodiversity loss is an urgent worldwide issue with far-reaching consequences for ecosystems and human well-being (Schmeller et al., 2020). It refers to the rapid decline in the variety and abundance of plant and animal species across the planet, a phenomenon primarily driven by human activities such as habitat destruction, climate change, pollution, overexploitation of resources, and the introduction of invasive species (Humbal et al., 2023). The consequences of biodiversity loss extend beyond ecological systems, profoundly impacting the resilience and sustainability of ecosystems and subsequently influencing human well-being (Adebayo, 2019; Roe, 2019).

The rapid pace of urbanization exacerbates these challenges, posing significant threats to biodiversity conservation (Kondratyeva et al., 2020). Urbanization has led to a disconnection between humans and nature, increasing climate change and biodiversity loss (Nguyen et al., 2023b). Moreover, urbanization has consistently been associated with declining species diversity, reflecting the disruption of species communities due to anthropogenic land cover changes (Kondratyeva et al., 2020). These alterations lead to less diverse ecosystems, heightened risks of extinction, and a disturbance of the essential services that thriving ecosystems offer (Simkin et al., 2022). For example, transforming natural landscapes into residential areas, road networks, and commercial zones eradicates critical resources for numerous species (Liu et al., 2016).

Additionally, the conversion of natural areas into urban landscapes results in the loss of crucial breeding and feeding grounds for many species. It influences their populations, making them more vulnerable to environmental changes (Simkin et al., 2022). Numerous studies have highlighted the direct correlation between urbanization and habitat destruction, a key driver of biodiversity loss (Abbass et al., 2022; Fenoglio et al., 2021).

In Vietnam, as in many other countries, urbanization poses significant challenges to biodiversity and natural habitats (Mai and Zhang, 2016; Ortmann and Ortmann, 2017). The expansion of urban areas often leads to the destruction or fragmentation of ecosystems, threatening the survival of many plant and animal species. In response to these challenges, conservation interventions are crucial to mitigate the impacts of urbanization on biodiversity (Nilon et al., 2017).

In the context of the broader challenge of global biodiversity loss and the specific threats posed by urbanization, public parks emerge as integral components in the urban landscape, providing multifaceted benefits to residents and the environment (Mexia et al., 2018). These public parks contribute significantly to biodiversity conservation by creating patches of greenery within urban settings, fostering a diverse range of plant and animal species (Jabbar et al., 2021). Thanks to this, public parks can serve as educational and recreational hubs that offer opportunities for learning about local ecosystems, wildlife, and sustainable practices, fostering environmental awareness and connecting urban dwellers with the natural world (Krasny et al., 2013). With these functions, urban green spaces can be crucial in mitigating the adverse effects of urbanization, providing habitats for various species, and promoting ecological balance within the city (Edeigba et al., 2024).

However, the current condition of urban parks in many countries, including Vietnam, presents several challenges, including inadequate maintenance, limited accessibility, and insufficient amenities (Linh et al., 2012). Many parks lack proper infrastructure and facilities, which diminishes their potential as community gathering spaces (Mai and Zhang, 2016). Moreover, rapid urbanization and population growth exert immense pressure on existing park spaces, resulting in encroachment and degradation of green areas (Fan et al., 2019; Hoang et al., 2019). Efforts are being made to improve park management, expand green spaces, and enhance the overall urban environment to promote the well-being of residents (Fund, 2019).

Supporting tree-planting projects in urban parks is important for promoting environmental sustainability, fostering community engagement, and enhancing the overall well-being of urban residents (Pataki et al., 2021; Turner-Skoff and Cavender, 2019). These initiatives are instrumental in improving urban green spaces, offering a multitude of benefits for both the environment and the community. Research indicates that urban trees effectively mitigate air pollution by absorbing carbon dioxide, sulfur dioxide, and nitrogen oxides, improving air quality and human health (Nowak et al., 2014). Furthermore, they act as natural noise barriers, reducing noise pollution in urban areas and contributing to a more peaceful environment. Additionally, urban trees provide essential shade, helping to lower temperatures in urban heat islands and decrease energy consumption for cooling buildings while also providing spaces for outdoor recreation and relaxation (Wang and Akbari, 2016). Moreover, the aesthetic enhancement of green spaces by trees has been linked to improved mental health and overall satisfaction with the urban environment, reducing stress, anxiety, and depression among residents (Jabbar et al., 2021). Overall, supporting tree planting initiatives is pivotal for expanding and maintaining green spaces, mitigating pollution, enhancing aesthetics, and promoting the health and well-being of urban communities, underscoring its significance as an investment in creating sustainable and livable cities.

Understanding the behavioral psychology of urban residents towards urban parks, including factors such as visitation frequency and willingness to donate toward planting trees, is crucial for effective park management and community well-being. Previous research has identified key factors influencing residents' park usage, such as access to well-maintained parks, age, proximity to parks, and past experiences with them (Nguyen et al., 2021; Van Vliet et al., 2021; Wang et al., 2015). These factors significantly impact park visitation patterns and residents' engagement with urban green spaces, which offer numerous benefits for physical, mental, and social health, including mood enhancement, stress reduction, promotion of physical activity, and facilitation of social interactions within communities (Kaczynski et al., 2014; Nguyen et al., 2021). Additionally, aspects like accessibility, safety, and socioeconomic status also play critical roles in shaping residents' interactions with urban parks (Fontán-Vela et al., 2021).

However, despite the extensive research on these factors, there has been limited investigation into the psychological behavior of urban residents regarding their visitation frequency to urban parks and their willingness to donate to park-related initiatives. To address these gaps, our study utilizes the mindsponge theory, which outlines how individuals perceive and process information, to examine urban residents' perceptions of biodiversity loss, public park visitation frequency, and willingness to support park-related initiatives in Vietnam. Employing the Mindsponge Bayesian Framework (BMF) analysis on a dataset consisting of 535 urban residents in Vietnam, the study aims to answer the following research questions:

1. How are perceptions of biodiversity loss consequences associated with urban people's frequency of visiting public parks?
2. How are perceptions of biodiversity loss consequences associated with urban peoples' willingness to contribute financially to public park planting projects?
3. How is urban people's frequency of visiting public parks associated with their willingness to donate to public parks?

These findings are expected to guide policymakers, urban planners, and conservationists in formulating efficient strategies to tackle financial shortage challenges and foster sustainable urban development, consequently enriching the overall enjoyment and advantages gained from urban park spaces.

2. Methodology

2.1. Theoretical Foundation

This study utilized the mindsponge theory (MT) for conceptualization, model construction, and discussion of the results. MT is grounded on the human mind's information processing mechanism, the mindsponge mechanism, which involves information absorption and ejection processes based on subjective benefit-cost judgments (Vuong, 2023; Vuong and Napier, 2015). The theory offers the capability to explain the way people perceive, think, believe, behave, and establish social constructs so that it can explain complex sociopsychological phenomena of human mental products and behavior, requiring a multidisciplinary approach (Davies and Gregersen, 2014). It has, therefore, been used in various studies on environmental and conservation psychology (Alzahrani et al., 2023; Asamoah et al., 2023; Huang et al., 2023; Khuc et al., 2023a; Khuc et al., 2023b; Nguyen et al., 2023a; Nguyen and Jones, 2022b).

The theory has two main spectrums: the mind and the environment. According to MT, the human mind is viewed as an information collection-cum-processor, while the environment is the infosphere, a broader information processing system (physically and socially) surrounding and providing inputs for the human mind. The human mind is constituted of the mindset, buffer zone, and multi-filtering system (Vuong et al., 2022). Mindset is a collection of highly trusted information; a buffer zone is a conceptual area in which information is temporarily stored before undergoing evaluation by the multi-filtering system; the multi-filtering system is the mind's subjective evaluation system of information. MT considers the human mind's filtering system of new information/value/idea/technology to be the key factor (Mantello et al., 2023).

In this study, the mental processes of Vietnamese residents involve inputs from the surrounding information or memory. At the same time, outputs are the mental products, such as thinking (i.e., perceptions of consequences of biodiversity loss and the willingness to donate to public park planting projects) and behavior (i.e., public park visitation frequency).

In the mind's information processing mechanism, two primary conditions must be satisfied for a piece of information to be absorbed and persist (Nguyen and Jones, 2022a; Vuong, 2023). First, the information must be available and accessible in the surrounding environment. Second, the information must be justified as beneficial by the mind to be absorbed and integrated into the mindset. The subjective cost-benefit evaluation of new information greatly depends on the existing highly-trusted information, core values, or beliefs in the mindset, as the mindset's content is used as the benchmark for new information assessment. In the current study, we mainly focus on the second condition, as we aim to examine the relationships between the perceptions of biodiversity loss consequences, public park visitation frequency, and tree-planting donation willingness.

Based on the information processing mechanism above, it can be deemed that for the ideations of visiting public parks (and then actual behavior) and donating to tree-planting projects to emerge in the urban residents' minds, visiting public parks and tree-planting donations need to be subjectively deemed beneficial by the minds.

Biodiversity loss is a real and recurring problem that adversely affects many aspects of human society globally (Zari, 2018). Health loss, knowledge loss, nature recreation loss, economic growth loss, and environmental degradation are consequences of biodiversity loss (Adebayo, 2019). When urban residents read, hear, or see information regarding biodiversity decline and its related consequences, such information is likely to be absorbed. The perceptions of biodiversity loss's consequences will likely emerge in the residents' minds (Bele and Chakradeo, 2021). If the information regarding biodiversity loss's consequences becomes highly trusted in the mind, it can subsequently influence the mind's information absorption and processing mechanism (Nguyen et al., 2023b).

As stated above, tree planting can expand and maintain green spaces, helping conserve and improve the biodiversity level in urban areas, which is beneficial for addressing the consequences caused by biodiversity loss (Martin et al., 2021; Woodward et al., 2023). Therefore, if urban residents acknowledge the consequences of biodiversity loss, they might be more likely to consider tree planting beneficial and absorb the tree planting information into their minds, forming the willingness to donate for tree planting projects. We hypothesized it as follows:

> **Hypothesis 1:** Residents who perceive more of the consequences of biodiversity loss are more willing to donate to tree planting projects.

Logically, people perceiving the consequences of biodiversity loss must also perceive the benefits of biodiversity. Thus, they will tend to think and behave to optimize such benefits. Public parks are seemingly areas that conserve the highest level of biodiversity in the urban areas. Urban residents might tend to visit more frequently to optimize the benefits of biodiversity. Thus, we hypothesized that:

> **Hypothesis 2:** Residents who perceive the consequences of biodiversity loss more frequently visit public parks.

Visiting public parks more frequently also means that the urban residents have more direct experiences with the surrounding natural environment, including biodiversity. This could help reinforce the perceived benefits of biodiversity and, thus, the perceived consequences of biodiversity loss. Therefore, we hypothesized that:

> **Hypothesis 3:** The frequency of public park visitation can mediate the relationship between the perceptions of biodiversity loss consequences and the willingness to donate to tree planting projects.

2.2. *Model construction*

2.2.1. Variable Selection and Rationale

This study used secondary data from a dataset of 535 urban residents from 35 cities across Vietnam. The dataset is about Vietnamese urban residents' multifaceted perceptions of the interactions between urban residents and biodiversity, which is constructed by six major categories, namely: 1) wildlife product consumption, 2) general biodiversity perceptions, 3) biodiversity at home and neighborhood, 4) public park visitation and motivations, 5) national park visitation and motivations, and 6) socio-demographic profiles (Nguyen, 2021).

Some comprehensive interview sessions were conducted on 38 urban residents in Hanoi and Ho Chi Minh City, the two largest cities in Vietnam, before instrument development was used in the cross-sectional survey. The qualitative data were collected between November 15 and December 26, 2020. The participants' age, gender, occupation, and personal experiences of interaction with biodiversity were considered during the sampling to diversify their viewpoints. The interview process was completed when data saturation was reached, and no new information or viewpoint was added to the data collected (Creswell and Poth, 2018).

After the instrument was finalized, the snowball sampling technique was employed to get the survey participants. The survey was conducted online via Google Forms. On the first page, participants were provided with an explanation of the survey's contents and objectives useful for obtaining their consent. Five hundred eighty-one respondents completed the online survey between June 18 and August 8, 2021. However, only 535 responses were eligible for further analysis after being assessed by a four-step quality check. Exclusion criteria were low-quality responses, non-urban inhabitants under 18, and repeated emails. Finally, the quantitative data were encoded and saved under a comma-separated value (CSV) format.

The dataset was peer-reviewed by two referees before it was published in Data Intelligence by address:

- https://direct.mit.edu/dint/article/3/4/578/107428/Multifaceted-Interactions-between-Urban-Humans-and

For the research objective of the current study, seven variables were employed for the statistical analysis (see Table 1). We employed the *PublicParkDonation* variable to estimate the urban residents' willingness to donate to tree-planting projects and *PublicParkFrequen* to demonstrate the frequency of residents visiting the public park. Variables of *EnvironmentalDegradation, EconomicGrowthLoss, NatureRecreationLoss, HealthLoss,* and *KnowledgeLoss* were employed to reflect the degree of perceived biodiversity loss consequences. Some variables are composite variables generated from 8 variables in the original dataset. Specifically, perceived pollution (variable *B3_1*) and climate change (*B3_2*) as a result of biodiversity loss were categorized under

EnvironmentalDegradation, showing a high Cronbach's alpha of 0.88. Perceived loss of green spaces (*B3_6*), natural aesthetics (*B3_7*), and nature-based recreational activities (*B3_8*) due to biodiversity loss were categorized under *NatureRecreationLoss*, with a Cronbach's alpha of 0.85. Lastly, perceptions of decreased physical health (B3_11), mental health (*B3_12*), and life expectancy (*B3_13*) were categorized under *HealthLoss*, achieving a Cronbach's alpha of 0.92. All these Cronbach alpha values exceed 0.8 and 0.9, indicating excellent internal consistency within these groups.

Table 1: Variable Description

Variable	**Variable in the original dataset**	**Description**	**Data type**	**Value**
EnvironmentalDegradation	B3_1, B3_2 (average value)	Whether the respondent perceives environmental degradation (pollution and climate change) as a consequence of biodiversity loss	Numerical	1 = strongly disagree 2 = disagree 3 = agree 4 = strongly agree
EconomicGrowthLoss	B3_5	Whether the respondent perceives the loss of economic growth as a consequence of biodiversity loss	Numerical	
NatureRecreationLoss	B3_6, B3_7, B3_8 (average value)	Whether the respondent perceives the loss of nature-based recreation (loss of greenspace, natural aesthetics, nature-based recreation) as a consequence of biodiversity loss	Numerical	

KnowledgeLoss	B3_9	Whether the respondent perceives the loss of knowledge as a consequence of biodiversity loss	Numerical	
HealthLoss	B3_11, B3_12, B3_13 (average value)	Whether the respondent perceives the loss of health (reduction of physical health, mental health, and life expectancy) as a consequence of biodiversity loss	Numerical	
PublicParkFrequen	D2	The visiting frequency of nearby public parks	Numerical	1 = never 2 = almost never 3 = sometimes 4 = almost everyday 5 = everyday
PublicParkDonation	D4	The willingness to donate to tree-planting projects in the neighborhood initiated by the local government	Numerical	1 = not at all 2 = not really 3 = willing 4 = fully/very willing

2.2.2. Statistical model

To test our hypotheses, we constructed four different analytical models. The first model was constructed to examine the first hypothesis, examining the associations between the perceptions of biodiversity loss consequences and willingness to donate to tree-planting projects in the parks. Model 1 is shown as follows:

$$PublicParkDonation \sim \mathrm{normal}(\mu, \sigma) \quad (1.1)$$

$$\mu_i = \beta_0 + \beta_1 * EnvironmentalDegradation_i + \beta_2 * EconomicGrowthLoss_i + \beta_3 * NatureRecreationLoss_i + \beta_4 * HealthLoss_i + \beta_5 * KnowledgeLoss_i \quad (1.2)$$

$$\beta \sim normal(M, S) \quad (1.3)$$

The probability around μ is determined by the form of the normal distribution, whose width is specified by the standard deviation σ. μ_i indicates the willingness level of urban resident i' to donate to tree planting projects; *EnvironmentalDegradation*$_i$ indicates the urban resident i' perceived biodiversity loss consequences on the environment; *EconomicGrowthLoss*$_i$ indicates the urban resident i' perceived biodiversity loss consequences on economic growth; *NatureRecreationLoss*$_i$ indicates the urban resident i' perceived biodiversity loss consequences on nature-based recreation; *KnowledgeLoss*$_i$ indicates the urban resident i' perceived biodiversity loss consequences on knowledge about nature; *HealthLoss*$_i$ indicates the urban resident i' perceived biodiversity loss consequences on physical health. The model has an intercept of β_0, coefficients of β_1-β_5, and the standard deviation of the "noise", σ. The coefficient values are normally distributed around the mean denoted M with the standard deviation denoted S.

The second model was constructed to test the second hypothesis or the relationship between the perceptions of biodiversity loss consequences and the frequency of public park visitation.

$$PublicParkFrequen \sim \mathrm{normal}(\mu, \sigma) \quad (2.1)$$

$$\mu_i = \beta_0 + \beta_1 * EnvironmentalDegradation_i + \beta_2 * EconomicGrowthLoss_i + \beta_3 * NatureRecreationLoss_i + \beta_4 * HealthLoss_i + \beta_5 * KnowledgeLoss_i \quad (2.2)$$

$$\beta \sim normal(M, S) \quad (2.3)$$

In the second model, μ_i indicates the public park visitation frequency of the resident i.

To examine the mediation effect of $PublicParkFrequen$ on the relationship between perceptions of biodiversity loss consequences and the donation willingness, Model 3 was constructed to examine the relationship between $PublicParkFrequen$ and $PublicParkDonation$

$$PublicParkDonation \sim \mathrm{normal}(\mu, \sigma) \quad (3.1)$$

$$\mu_i = \beta_0 + \beta_1 * PublicParkFrequen_{\ i} \quad (3.2)$$

$$\beta \sim normal(M, S) \quad (3.3)$$

We also constructed Model 4 using the perceptions of biodiversity loss consequences and public park visitation frequency as predictor variables to check whether the perceptions of biodiversity loss consequences affect the donation willingness directly, indirectly through park visitation frequency, or both.

$$PublicParkDonation \sim \mathrm{normal}(\mu, \sigma) \tag{4.1}$$

$$\mu_i = \beta_0 + \beta_1 * EnvironmentalDegradation_i + \beta_2 * EconomicGrowthLoss_i + \beta_3 * NatureRecreationLoss_i + \beta_4 * HealthLoss_i + \beta_5 * KnowledgeLoss_i + \beta_6 * PublicParkFrequen_i \tag{4.2}$$

$$\beta \sim normal(M, S) \tag{4.3}$$

2.2.3. Analysis and Validation

Bayesian Mindsponge Framework (BMF) analytics was employed in the current study for several reasons (Nguyen et al., 2022; Vuong et al., 2022). First, the method integrates the logical reasoning capabilities of Mindsponge Theory with the inferential advantages associated with Bayesian analysis, as these two approaches exhibit a high degree of compatibility (Nguyen et al., 2022). Second, Bayesian inference is a statistical approach that treats all the properties (including the known and unknown ones) probabilistically (Csilléry et al., 2010; Gill, 2014), enabling reliable prediction of parsimonious models. Third, Bayesian inference has various advantages over the frequentist approach. One notable advantage is the ability to utilize credible intervals for result interpretation instead of relying solely on the dichotomous decision based on *p*-values (Halsey et al., 2015; Wagenmakers et al., 2018). Moreover, Bayesian analysis with informative priors can alleviate the multicollinearity problems by addressing the weak data issue (Adepoju and Ojo, 2018; Jaya et al., 2019; Leamer, 1973).

In Bayesian analysis, selecting the appropriate prior is required during the model construction process (van de Schoot et al., 2021). Based on the Mindsponge Theory reasoning above, we defined the prior distributions that reflect our belief in the positive associations between the perceptions of biodiversity loss consequences, public park visitation frequency, and donation willingness (i.e., normal distribution with mean being 1 and standard deviation being 0.5). We also utilized the prior-tweaking technique to check the estimation robustness when the prior is modified. Specifically, we reran the analysis using priors reflecting our disbelief in the associations (i.e., normal distribution with the mean being 0 and standard deviation being 0.5). If the estimated results remain similar regardless of prior selection, the results can be deemed robust.

After the model was fitted, we employed the Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics to check the models' goodness-of-fit (Vehtari and Gabry, 2019; Vehtari et al., 2017). LOO is computed as follows:

$$LOO = -2LPPD_{loo} = -2\sum_{i=1}^{n} \log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

$p_{post(-i)}(\theta)$ is the posterior distribution based on the data minus data point i. The *k*-Pareto values are used in the PSIS method for computing leave-one-out cross-validation, which helps identify observations with a high degree of influence on the PSIS estimate. Observations with *k*-Pareto values greater than 0.7 are often considered influential and may be problematic for accurately estimating leave-one-out cross-validation. Commonly, a model is considered fit when the k values are below 0.5.

If the model had a good fit with the data, we would proceed with the convergence diagnoses and result interpretation. Commonly, the convergence of Markov chains can be validated using statistical values and visual illustrations. Statistically, the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) can be used to assess the convergence. The *n_eff* value represents the number of iterative samples that are not auto-correlated during stochastic simulation, while the *Rhat* value is referred to as the potential scale reduction factor or the Gelman–Rubin shrink factor (Brooks and Gelman, 1998). If *n_eff* is larger than 1000, it is generally considered that the Markov chains are convergent, and the effective samples are sufficient for reliable inference (McElreath, 2018). As for the *Rhat* value, if the value exceeds 1.1, the model does not converge. Typically, the model is considered convergent if *Rhat* = 1. Visually, the Markov chains' convergence was also validated using trace plots.

The Bayesian analysis was performed on R using the **bayesvl** open-access package, which provides good visualization capabilities (La and Vuong, 2019). Considering the issues of data transparency and the cost of reproduction, all data and code snippets of this study were deposited onto a preprint server for public examination and reuse (Vuong, 2018): https://zenodo.org/records/10589251

3. Results

Model fitting of all models was performed on R version 4.4.0 using four Markov chains, each consisting of 5000 iterations, with 2000 used for the warmup period.

3.1. Model 1: The associations between perceptions of biodiversity loss consequences and tree-planting donation willingness

Model 1 was estimated to investigate the associations between perceptions of biodiversity loss consequences and tree-planting donation willingness among urban residents. It incorporated five predictor variables corresponding to various perceived consequences of biodiversity loss: environmental degradation, economic growth loss, the loss of nature-based recreation opportunities, health loss, and knowledge loss.

Initially, the PSIS-LOO test was conducted to assess the goodness of fit between Model 1 and the collected data. The visualized PSIS-LOO plot shows that all *k* values are below 0.5, suggesting that Model 1 has a good fit with the dataset (see Figure 1).

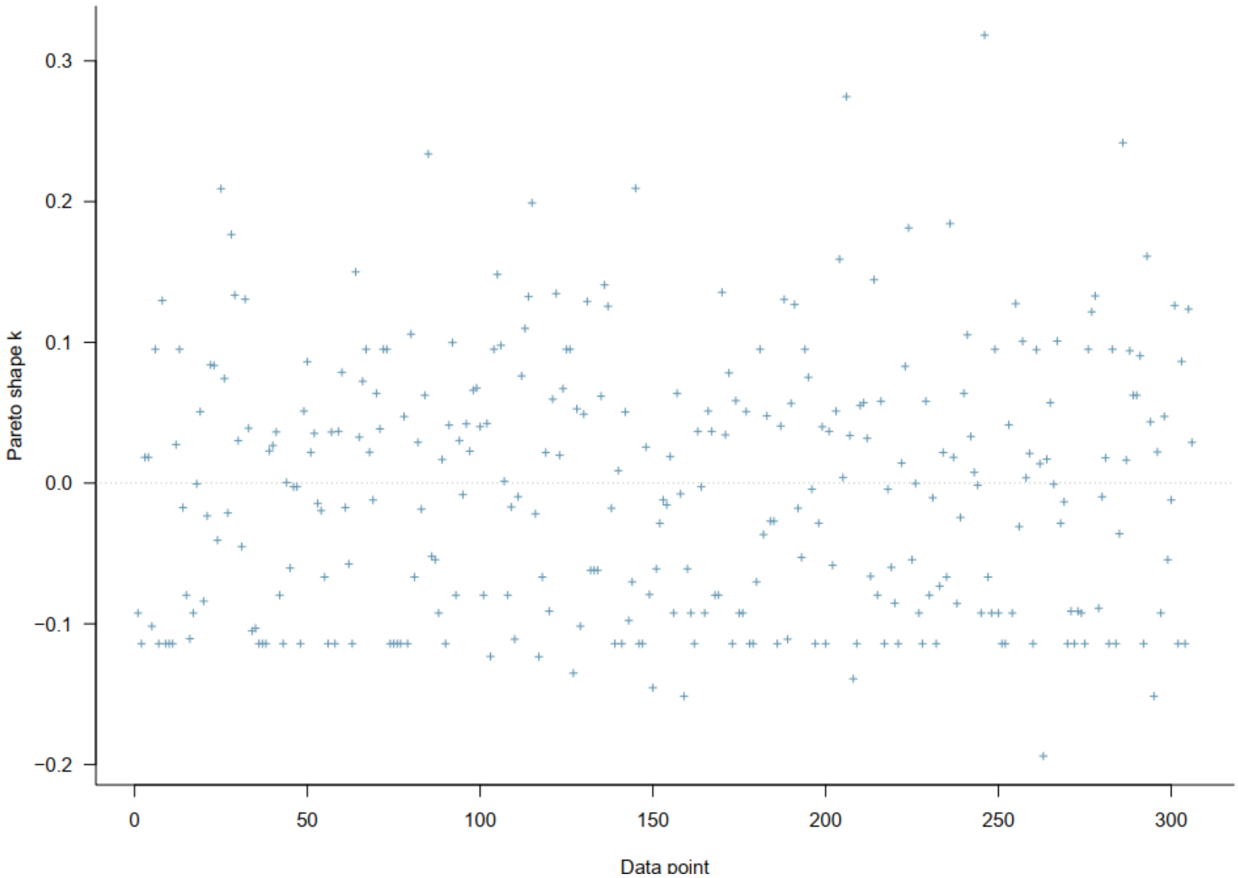

Figure 1: Model 1's PSIS-LOO diagnosis with priors as norm(1,0.5)

Next, it is necessary to diagnose Markov chain convergence using the *n_eff* and *Rhat*. All the coefficients' *n_eff* values are greater than 1000, and the *Rhat* values are equal to 1, so we can conclude that the Markov chains converge well. We also visualized trace plots to validate the Markov chain's convergence (or the Markov chain central limit theorem). The *y*-axis of the trace plots represents the posterior values of each parameter, while the *x*-axis represents the iteration order of the simulation. Figure 2 demonstrates the healthy mixing of all coefficients' Markov chains around an equilibrium, which is a good signal of convergence.

Table 2: Model 1's estimated posterior results

Parameters	Priors reflecting belief				Priors reflecting disbelief			
	M	S	n_eff	Rhat	M	S	n_eff	Rhat
Constant	2.47	0.23	10,483	1	2.47	0.23	10282	1
b_EnvironmentalDegradation_PublicParkDonation	-0.04	0.08	10,107	1	-0.04	0.08	9432	1

b_EconomicGrowthLoss_PublicParkDonation	0.07	0.06	11,060	1	0.07	0.06	10833	1
b_NatureRecreationLoss_PublicParkDonation	-0.04	0.11	9,137	1	-0.04	0.11	8564	1
b_HealthLoss_PublicParkDonation	0.09	0.08	10,387	1	0.09	0.08	9863	1
b_KnowledgeLoss_PublicParkDonation	0.13	0.07	9992	1	0.13	0.07	10806	1

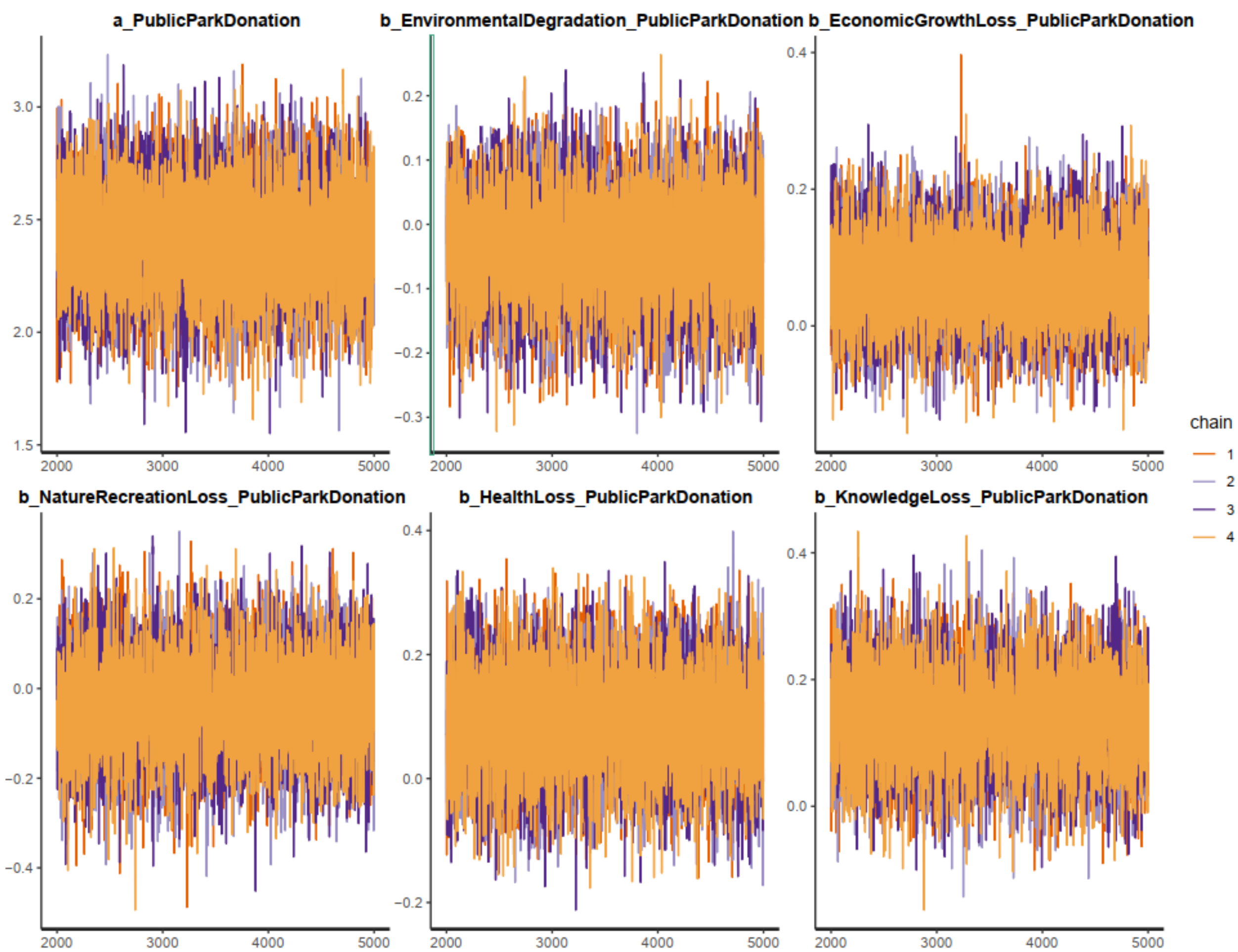

Figure 2: Model 1's trace plots with priors as norm (1,0.5)

The estimated posterior distributions using priors reflecting our belief in the associations indicate that *EconomicGrowthLoss*, *HealthLoss*, and *KnowledgeLoss* have positive associations with *PublicParkDonation* ($M_{b\_EconomicGrowthLoss\_PublicParkDonation}$ = 0.07 and $S_{b\_EconomicGrowthLoss\_PublicParkDonation}$ = 0.06; $M_{b\_HealthLoss\_PublicParkDonation}$ = 0.09 and $S_{b\_HealthLoss\_PublicParkDonation}$ = 0.08; $M_{b\_KnowledgeLoss\_PublicParkDonation}$ = 0.13 and $S_{b\_KnowledgeLoss\_PublicParkDonation}$ = 0.07).

The posterior distributions of *EconomicGrowthLoss*, *HealthLoss*, and *KnowledgeLoss* are in Figure 3. The thick blue lines in Figure 3 indicate the probability mass contained within the 89% highest posterior density intervals (HPDI), whereas the thin blue lines show the probability mass situated outside the highest credible region. As can be seen, the HDPI of *KnowledgeLoss* lies entirely on the positive side of the *x*-axis, suggesting that the positive association between *KnowledgeLoss* and *PublicParkDonation* is highly reliable (with at least 89% probability of being positive). Although the HDPIs of *EconomicGrowthLoss* and *HealthLoss* do not lie entirely on the positive side, most of them do, so their positive associations with *PublicParkDonation* can be deemed moderately reliable. For other coefficients (i.e., *EnvironmentalDegradation* and *NatureRecreationLoss*), their associations with *PublicParkDonation* exhibit ambiguous tendencies.

When "prior-tweaking" is performed using the priors representing our disbelief in the associations between biodiversity loss perceptions and donation willingness, the change is negligible. Thus, the Model 1's results are deemed robust. Thus, our first hypothesis is partly valid with perceived economic growth loss, health loss, and knowledge loss as consequences of biodiversity loss being positively associated with the willingness to donate.

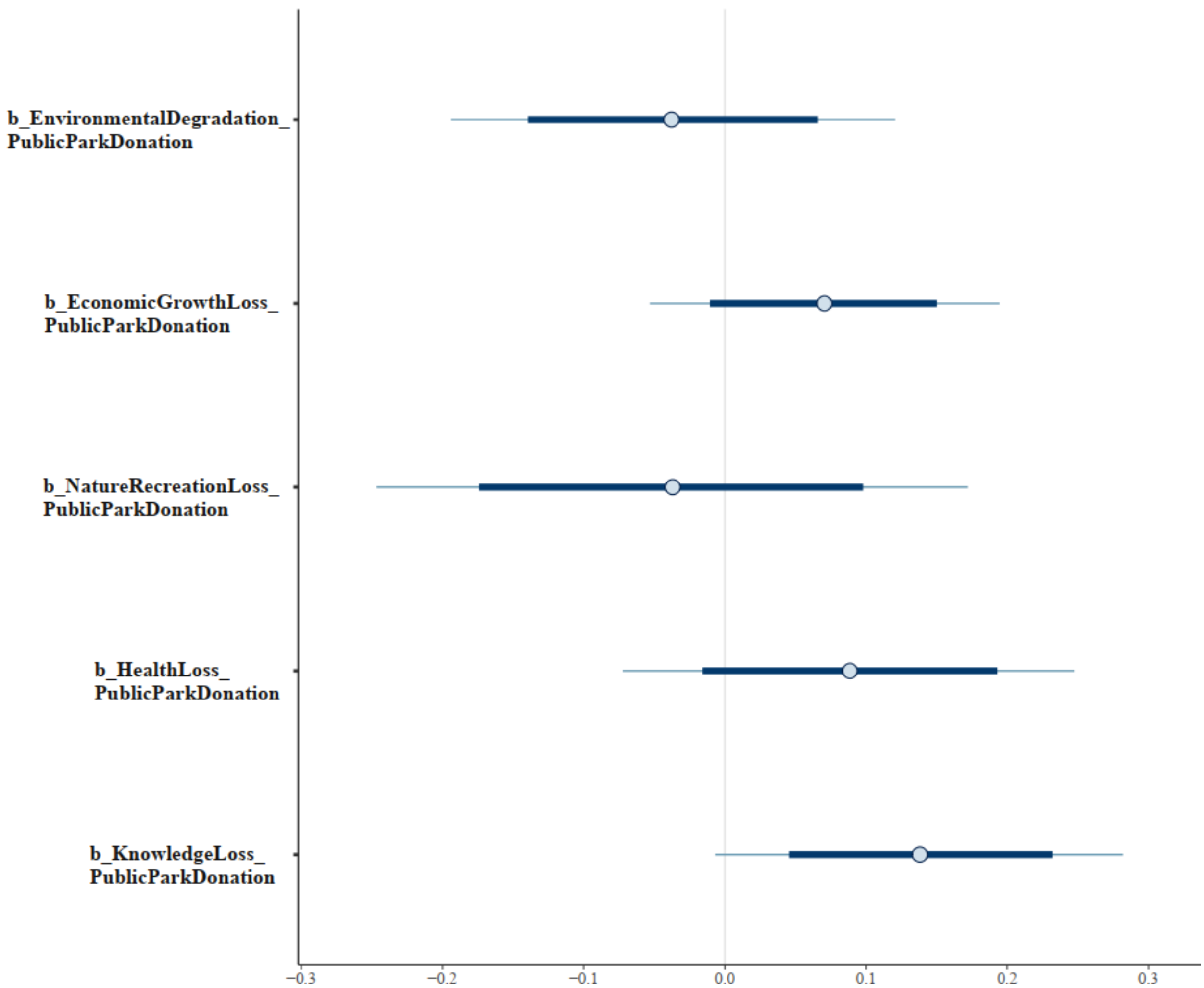

Figure 3: Model 1's interval plot with priors as norm (1,0.5)

3.2. Model 2: The associations between perceptions of biodiversity loss consequences and public park visitation frequency

Model 2 was examined to check the associations between perceptions of biodiversity loss consequences and public park visitation frequency. The PSIS-LOO test suggests that Model 2 also has an acceptable goodness of fit with the dataset, like Model 1.

Table 3: Model 2's estimated posterior results

Parameters	Priors reflecting belief				Priors reflecting disbelief			
	M	S	n_eff	Rhat	M	S	n_eff	Rhat
Constant	3.15	0.23	11852	1	3.32	0.26	12046	1
b_EnvironmentalDegradation_PublicParkFrequen	0.05	0.09	11684	1	0.04	0.09	11932	1
b_EconomicGrowthLoss_PublicParkFrequen	0.17	0.07	12862	1	0.16	0.07	12456	1
b_NatureRecreationLoss_PublicParkFrequen	-0.32	0.12	9462	1	-0.33	0.12	9436	1
b_HealthLoss_PublicParkFrequen	0.06	0.09	11853	1	0.06	0.09	11669	1
b_KnowledgeLoss_PublicParkFrequen	0.04	0.07	11512	1	0.04	0.08	11245	1

Convergence diagnostic values (*n_eff* and *Rhat*) of the model indicate that the models' Markov chains are convergent (see Table 3). The trace plots also confirm the convergence of Markov chains (see Figures A1 and A2).

The estimated results indicate that *EconomicGrowthLoss* has a positive association with *PublicParkFrequen* ($M_{b\_EconomicGrowthLoss\_PublicParkFrequen}$ = 0.17 and $S_{b\_EconomicGrowthLoss\_PublicParkFrequen}$ = 0.07), while *NatureRecreationLoss* has a negative association with *PublicParkFrequen* ($M_{b\_NatureRecreationLoss\_PublicParkFrequen}$ = -0.32 and $S_{b\_NatureRecreationLoss\_PublicParkFrequen}$ = 0.12), and other variables have ambiguous associations. Figure 4 also confirms the high reliability of *EconomicGrowthLoss*'s positive effect and *NatureRecreationLoss*'s negative effect.

Prior-tweaking using priors reflecting our disbelief leads to no different results estimated using priors reflecting our belief, so Model 2's findings can be deemed robust. Thus, the second hypothesis can be deemed valid only with the perception of economic growth loss as a consequence of biodiversity loss.

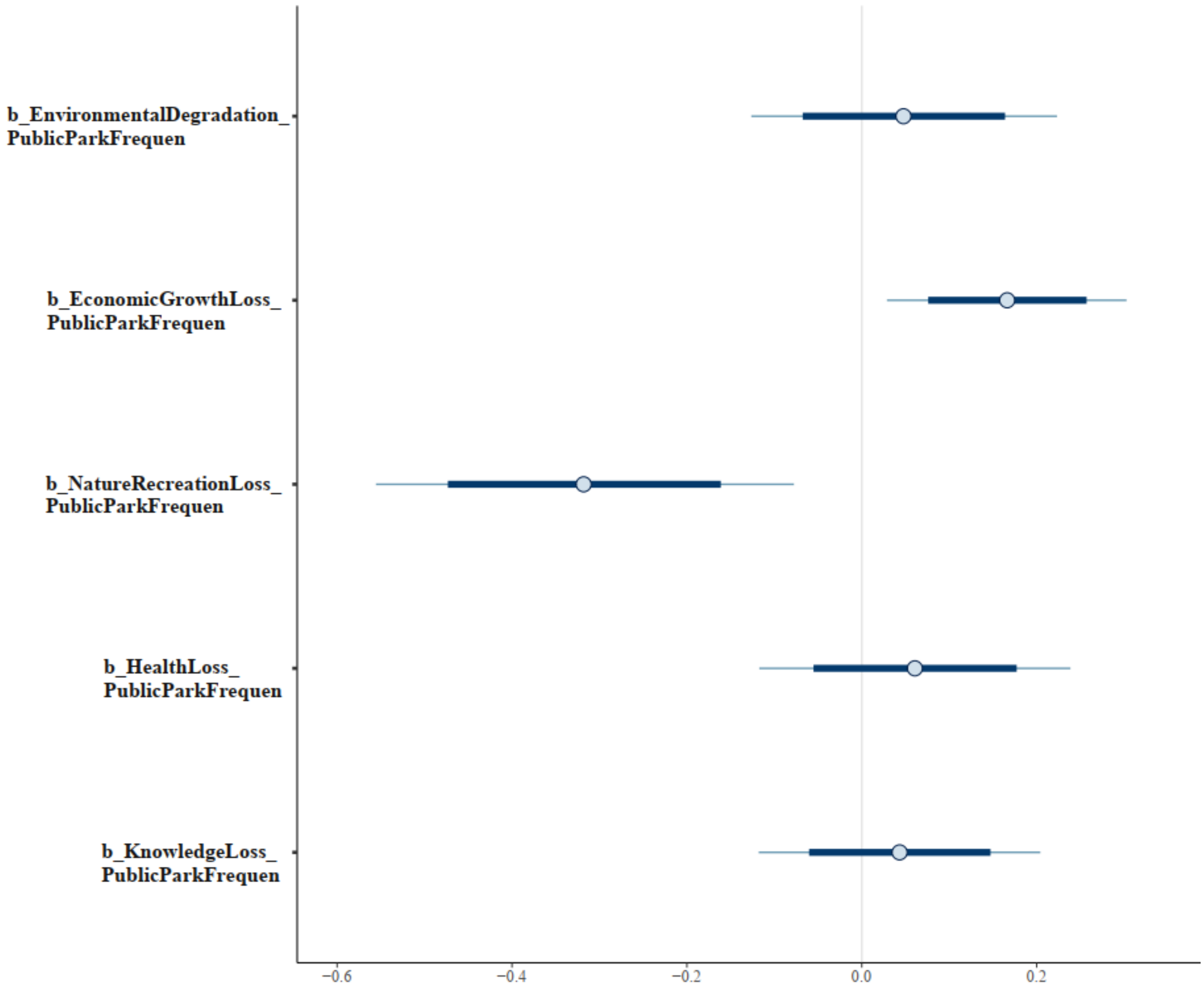

Figure 4: Model 2's interval plot with priors as norm (1,0.5)

3.3. *Model 3: The association between public park visitation frequency and tree-planting donation willingness*

Model 3 was examined to test the association between public park visitation frequency and tree-planting donation willingness to test the third hypothesis. The PSIS-LOO and convergence diagnoses suggest that the estimated results meet all the technical requirements for further interpretation (see Table 4, Figures A3 and A4).

The posterior distribution shown in Table 4 indicates that *PublicParkFrequen* has a positive association with *PublicParkDonation* ($M_{b\_PublicParkFrequen\_PublicParkDonation}$ = 0.21 and $S_{b\_PublicParkFrequen\_PublicParkDonation}$ = 0.05). The posterior distribution of *PublicParkFrequen,* visualized in Figure 5, is also located completely on the positive side of the *x*-axis, confirming the high reliability of the positive association. Prior-tweaking results also indicate the robustness of Model 3's results.

Therefore, our third hypothesis can be considered valid, as public park visitation frequency can act as a mediator between the perception of biodiversity loss consequence (i.e., perceived economic growth loss) and donation willingness.

Table 4: Model 3's estimated posterior results

Parameters	Priors reflecting belief				Priors reflecting disbelief			
	M	S	n_eff	Rhat	M	S	n_eff	Rhat
Constant	2.43	0.16	4052	1	2.45	0.16	3895	1
b_PublicParkFrequen_PublicParkDonation	0.21	0.05	4302	1	0.20	0.05	3874	1

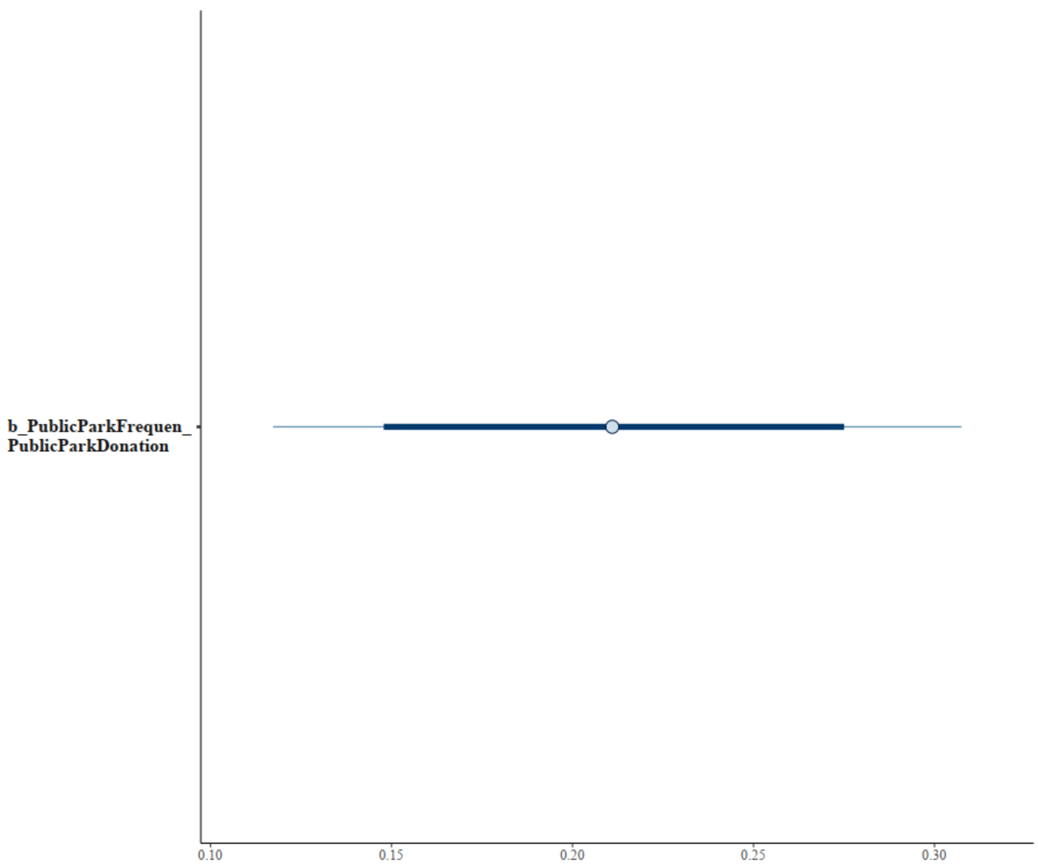

Figure 5: Model 3's interval plot with priors as norm (1,0.5)

3.4. *Model 4: The associations between perceptions of biodiversity loss consequences, public park visitation frequency, and tree-planting donation willingness*

Model 4 was examined to check whether the perceptions of biodiversity loss consequences affect the donation willingness directly, indirectly through park visitation frequency, or both. The PSIS-LOO and convergence diagnoses also suggest that the estimated results meet all the technical requirements for further interpretation (see Table 5, Figures A5 and A6).

Table 5: Model 4's estimated posterior results

Parameters	Priors reflecting belief				Priors reflecting disbelief			
	M	S	n_eff	Rhat	M	S	n_eff	Rhat
Constant	1.73	0.27	9202	1	1.83	0.27	8742	1
b_EnvironmentalDegradation_PublicParkDonation	-0.05	0.08	10516	1	-0.05	0.08	9500	1
b_EconomicGrowthLoss_PublicParkDonation	0.04	0.06	11563	1	0.03	0.06	10925	1
b_NatureRecreationLoss_PublicParkDonation	0.03	0.11	8542	1	0.02	0.11	7854	1
b_HealthLoss_PublicParkDonation	0.08	0.08	10216	1	0.08	0.08	9658	1
b_KnowledgeLoss_PublicParkDonation	0.13	0.07	12566	1	0.13	0.07	10687	1
b_PublicParkFrequen_PublicParkDonation	0.21	0.05	9754	1	0.20	0.05	8606	1

As can be seen from the posterior distributions of Model 4, the positive associations of *HealthLoss* and *KnowledgeLoss* remain consistent with Model 1's, but the effect of *EconomicGrowthLoss* becomes more ambiguous (see Figure 6). Meanwhile, the positive association between *PublicParkFrequen* and *PublicParkDonation* remains consistent with Model 3's. Prior tweaking does not change the results, so these patterns are deemed robust regardless of the prior beliefs.

Based on these findings, it can be conclusive that *EconomicGrowthLoss* has a positive indirect impact on *PublicParkDonation* through *PublicParkFrequen*, whereas *NatureRecreationLoss* has a negative indirect impact. *HealthLoss*, *KnowledgeLoss*, and *PublicParkFrequen* have positive direct impacts on *PublicParkDonation*.

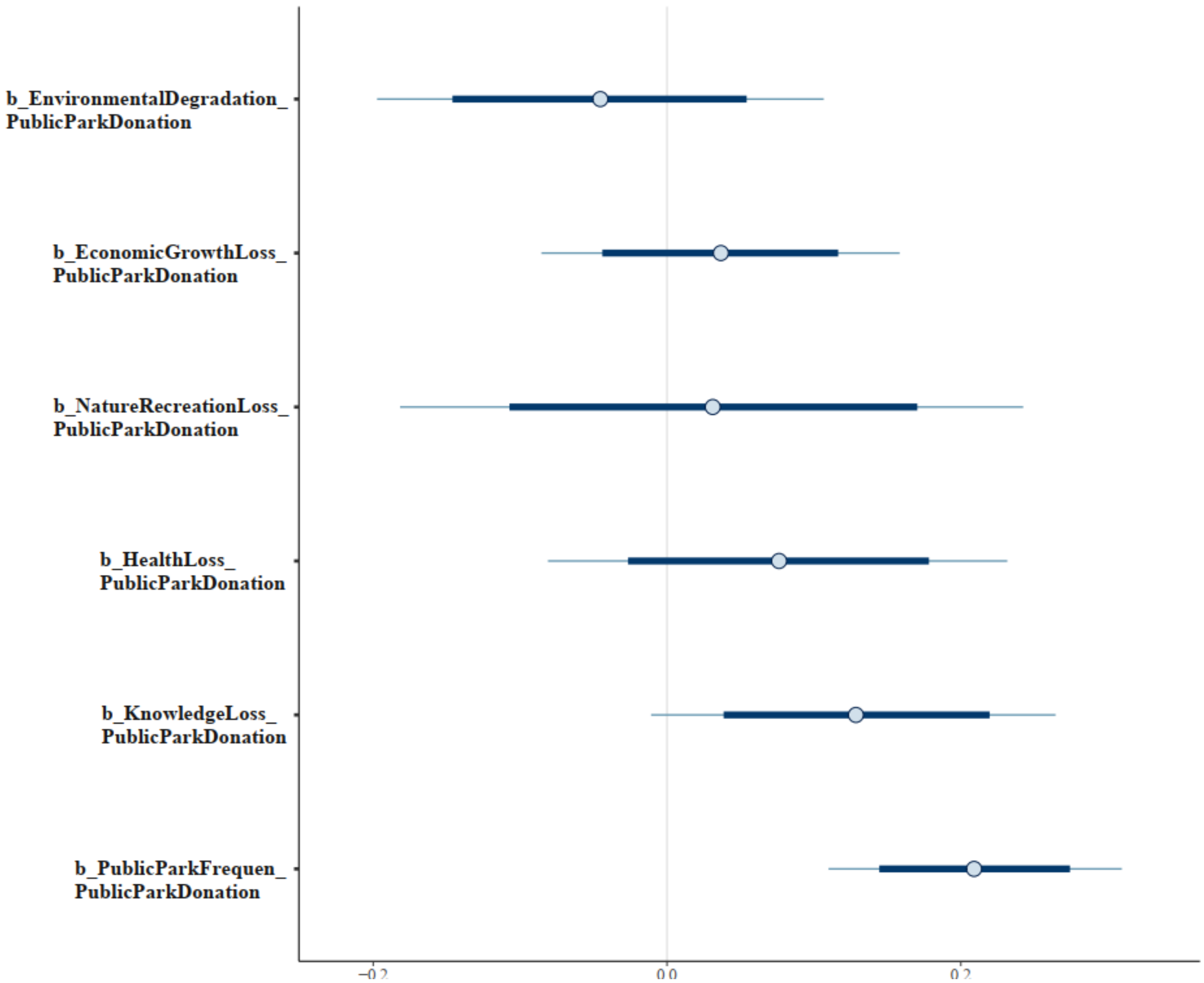

Figure 6: Model 4's interval plot with priors as norm (1,0.5)

4. Discussion

Understanding how perceptions of biodiversity loss influence individuals' willingness to contribute to public park planting projects is crucial for effective conservation efforts in Vietnam. The findings of this study highlight the relationships between perceptions of biodiversity loss consequences, public park visitation frequency, and donation willingness among urban residents.

We found that perceptions of health loss and knowledge loss as consequences of biodiversity loss exhibit positive direct associations with donation willingness for tree planting in public parks, which partly validates our first hypothesis, which proposes that residents perceiving more consequences of biodiversity loss are more willing to donate. The Mindsponge theory suggests that individuals tend to think and behave according to their existing highly trusted information or beliefs, making them prioritize information that can maximize their perceived benefits and minimize their perceived costs Vuong (2023). In the context of this study, concerns about personal well-being and knowledge erosion due to biodiversity loss can drive financial support for tree-planting projects in public parks, perhaps due to perceived connections between tree planting and health or knowledge generated by biodiversity (Marselle et al., 2021).

Although other perceptions related to environmental degradation, economic growth loss, and nature-based recreation loss are not directly linked to donation willingness, some are indirectly linked through the mediation of public park visitation frequency. For instance, economic growth loss indirectly enhances donation willingness through its positive correlation with park visitation frequency. When individuals perceive that biodiversity loss is negatively affecting economic growth, they tend to visit public parks more frequently, which partly supports our second and third hypotheses. This inclination is particularly evident during economic downturns, as visiting parks provides a cost-effective means of engaging in recreational activities, thereby making them an appealing option for urban residents (Poudyal et al., 2013). It should be noted that the data were collected between June 18 and August 8, 2021 (Nguyen, 2021), when the COVID-19 pandemic in Vietnam was getting more severe with a rapidly rising number of cases and causing tremendous negative consequences on the economy due to economic lockdowns (Dang et al., 2023; Worldometers, 2024). Meanwhile, zoonotic SARS-CoV-2 is intricately linked to biodiversity loss and ecosystem health (Lawler et al., 2021).

Conversely, the perceived loss of nature-based recreation opportunities has an opposite indirect effect on the donation willingness through public park visitation opportunities, which contradicts our second hypothesis that perceptions of biodiversity loss consequences are positively associated with park visitation frequency. This contradiction might be explained by the contextual factor during data collection. As noted above, the collection period was during the COVID-19 pandemic, so rigorous quarantines, social distancing, and stay-at-home orders were implemented for public health purposes. As a result, access to public green spaces was restricted, leading to the perceived loss of nature-based recreation opportunities and, subsequently, the reduced frequency of public park visitation. Through this reasoning, the negative association between perception related to nature-based recreation and park visitation frequency might be explained.

However, it remains ambiguous why the perceptions of economic growth loss and nature-based recreation loss as consequences of biodiversity loss have reliable associations with public park visitation frequency, but perceptions of health loss, environmental degradation, and knowledge do not. Future studies are, therefore, suggested to examine the different effects of these perceptions on public visitation frequency.

In addition, the research emphasizes the important role of public park visitation frequency in influencing donation willingness. Regular public park visits foster a deeper connection to nature and an increased sense of environmental stewardship among individuals (Basu and Nagendra, 2021; DeVille et al., 2021). As public parks become primary accessible options for connecting with nature and enjoying its benefits (Konijnendijk et al., 2013; Paudel and

States, 2023), increased visitation can foster a stronger connection to nature and enhance individuals' awareness of environmental issues, including the importance of biodiversity conservation. This enhanced connection to nature can influence individuals' inclination to financially support conservation efforts (DeVille et al., 2021). As individuals gain a deeper understanding of the importance of biodiversity conservation and the associated risks, they are motivated to contribute financially to projects to establish public parks (Ibrahim et al., 2023).

These insights are significant for understanding the relationships between perceptions of biodiversity loss consequences, park visitation behavior, and tree-planting donation willingness in Vietnam, offering guidance for policymakers and park managers. Policymakers and park managers can design their public communication messages to emphasize the multifaceted benefits of biodiversity preservation, including both personal well-being and broader societal advantages. By emphasizing these aspects, communication strategies have the potential to increase donation intentions and inspire more effective action, ranging from personal lifestyle changes to supporting park planting initiatives (Perry and Cox, 2024).

Additionally, policymakers should prioritize investments in green infrastructure and biodiversity conservation as essential elements of urban development agendas (Bush, 2020). This includes allocating resources toward establishing, maintaining, and improving public parks to ensure they remain preserved and accessible to urban residents. By integrating green infrastructure into urban development plans, policymakers can effectively minimize the negative effects of urbanization on ecosystems while simultaneously improving residents' quality of life (Pamukcu-Albers et al., 2021) and connections to nature (Maurer et al., 2021; Nguyen et al., 2023b; Shanahan et al., 2015). Integrating conservation principles into urban planning can lead to the development of more sustainable and livable cities, benefiting current and future generations (Kruize et al., 2019). Ultimately, it can help foster an eco-surplus culture, essential for protecting biodiversity and enhancing the quality of urban life in Vietnam and beyond (Vuong, 2021; Vuong and Nguyen, 2023, 2024; Vuong et al., 2024).

While our study offers insights into the relationship between biodiversity awareness, park visitation behavior, and urban conservation support among urban residents in Vietnam, it is crucial to acknowledge its limitations (Vuong, 2020). One such limitation is the reliance on a cross-sectional design, which precludes the establishment of causal relationships between variables. Additionally, focusing solely on urban residents in Vietnam may restrict the generalizability of the findings to other populations or geographical contexts due to potential variations in cultural, social, and economic factors. To address these limitations, future research could employ longitudinal or experimental designs to explore causal relationships more effectively. Moreover, ensuring a larger and more diverse sample would enhance the robustness and generalizability of the findings, providing a more comprehensive understanding of conservation behaviors in urban settings. Incorporating qualitative methodologies could also provide insights into underlying motivations, contributing to a deeper understanding of the human dimensions of conservation.

Appendix

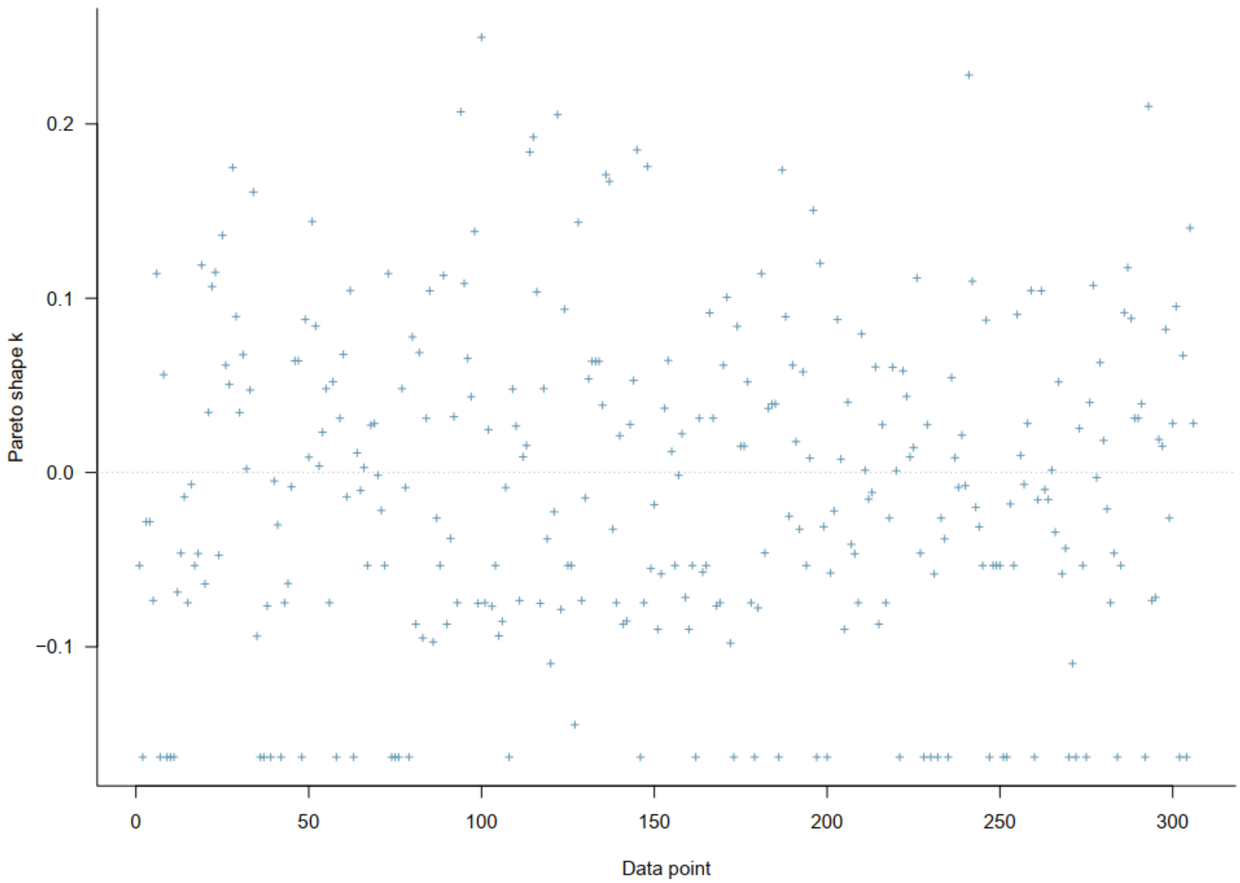

Figure A1: Model 2's PSIS-LOO diagnosis with priors as norm (1,0.5)

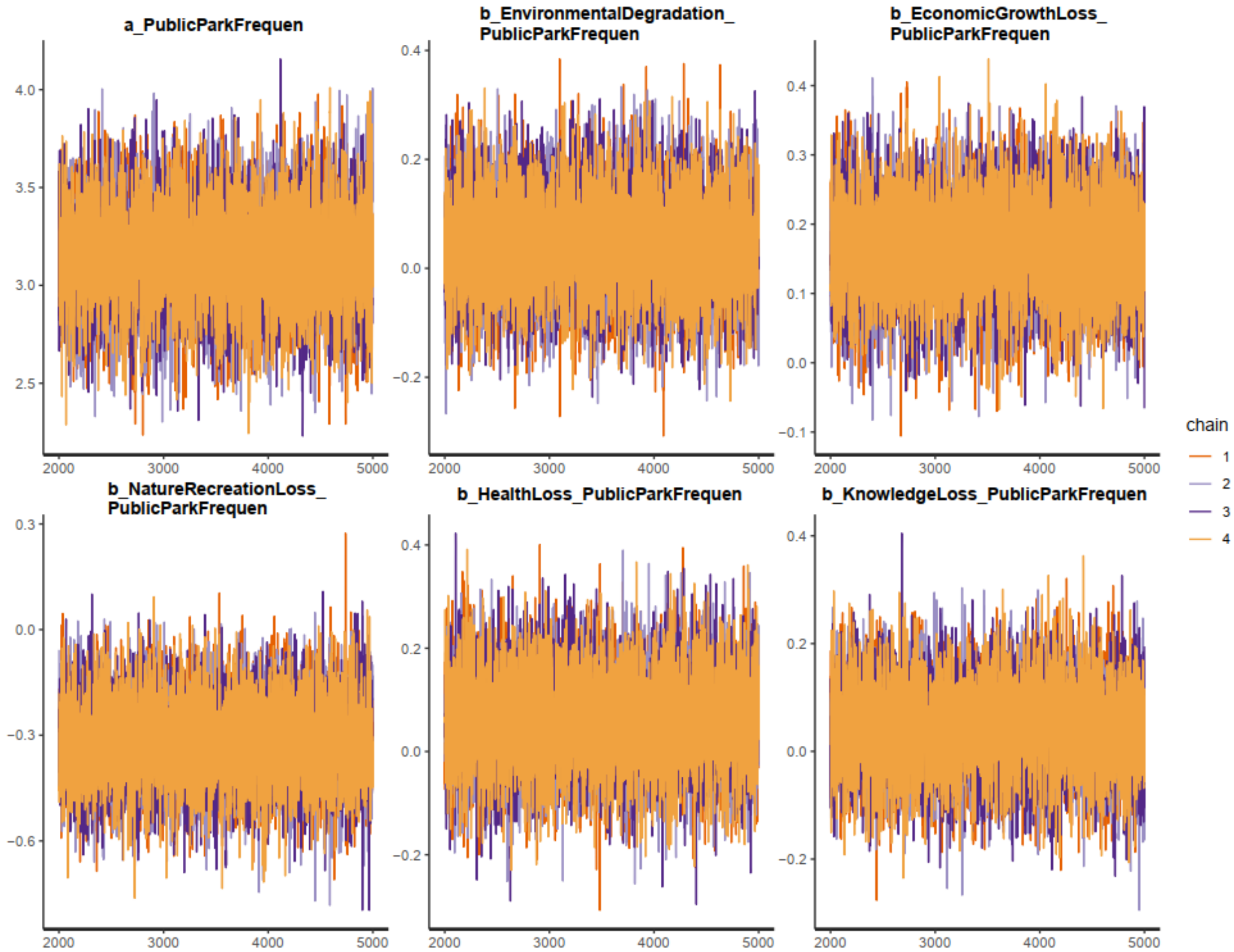

Figure A2: Model 2's trace plots with priors as norm(1,0.5)

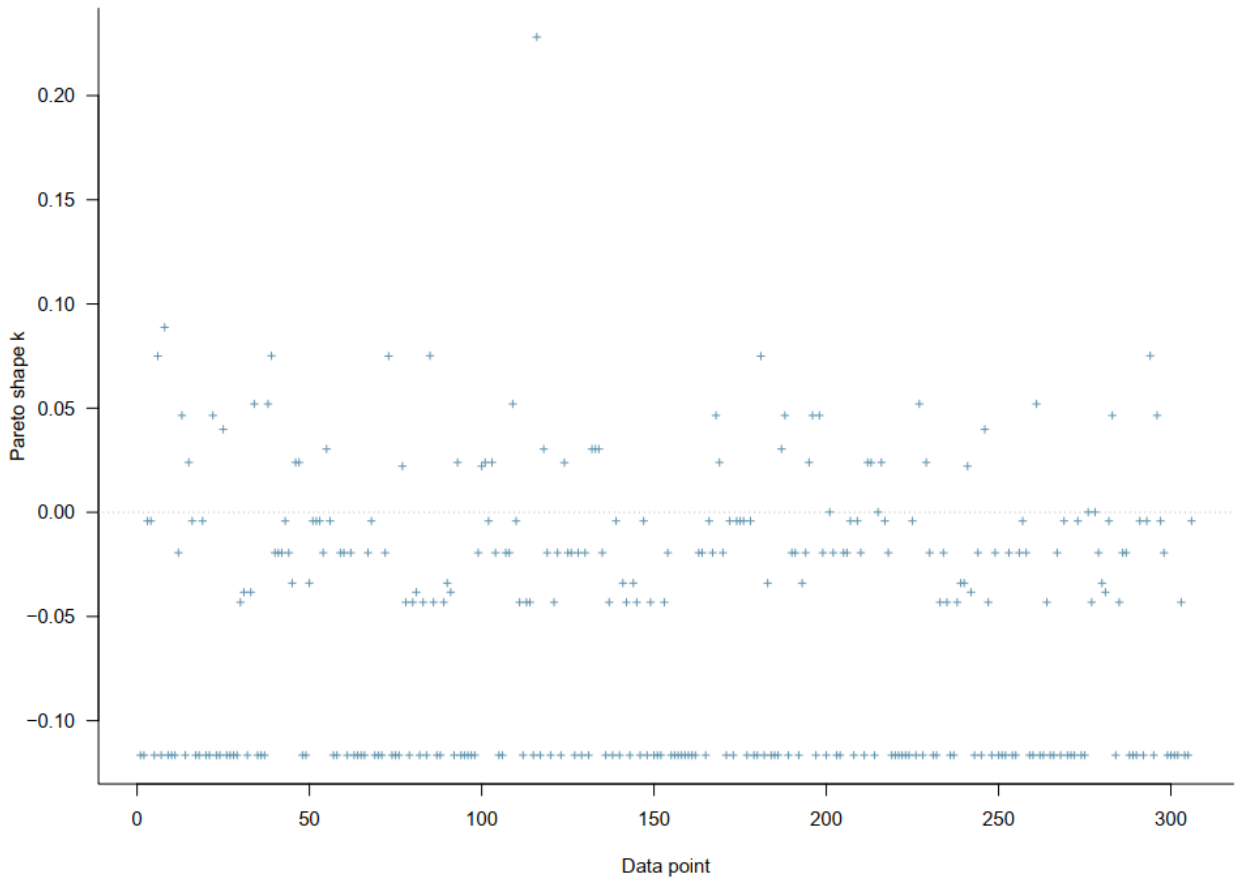

Figure A3: Model 3's PSIS-LOO diagnosis with priors as norm (1,0.5)

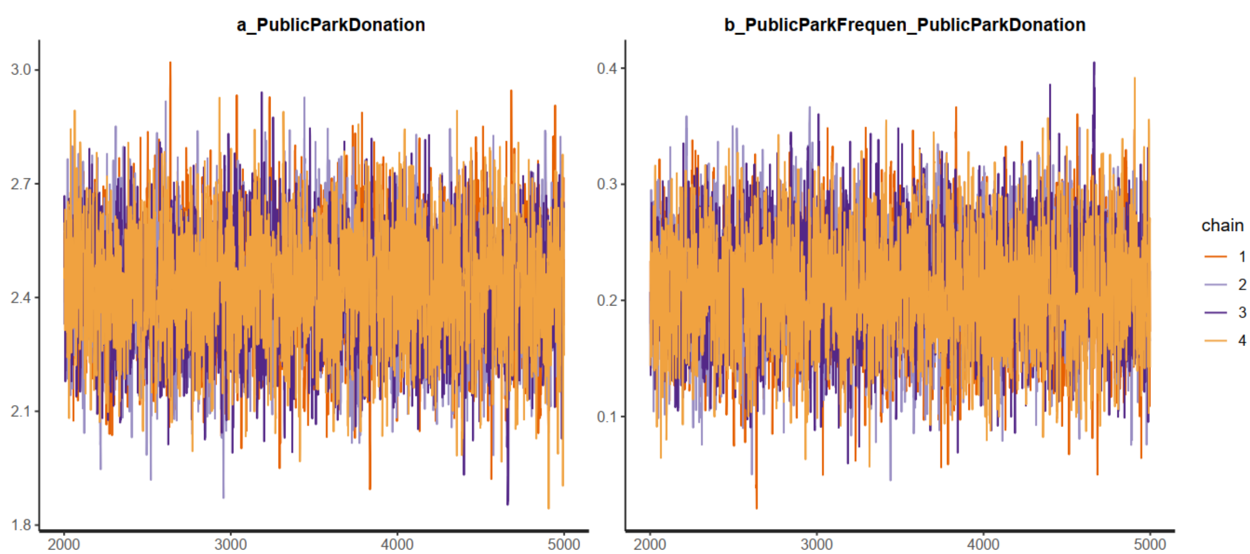

Figure A4: Model 3's trace plots with priors as norm(1,0.5)

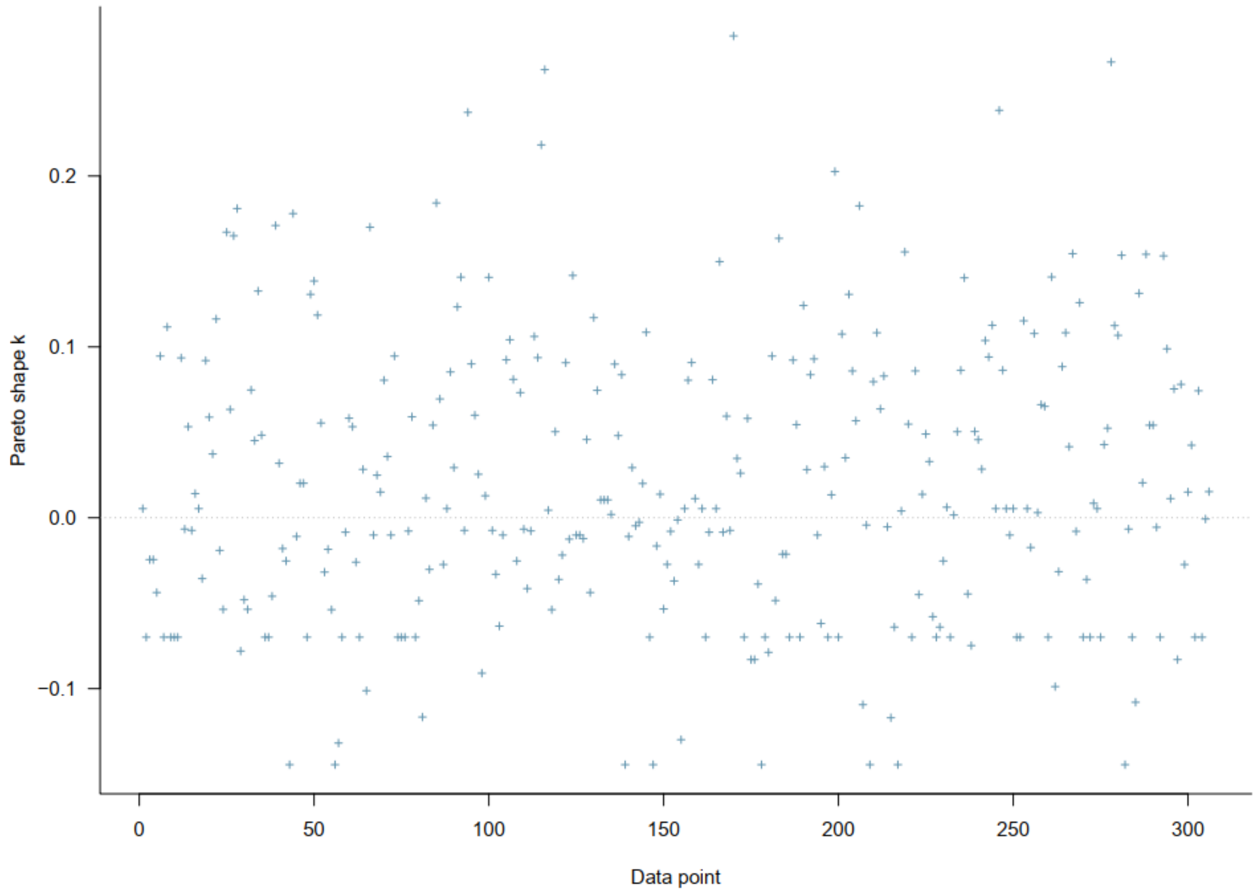

Figure A5: Model 4’s PSIS-LOO diagnosis with priors as norm (1,0.5)

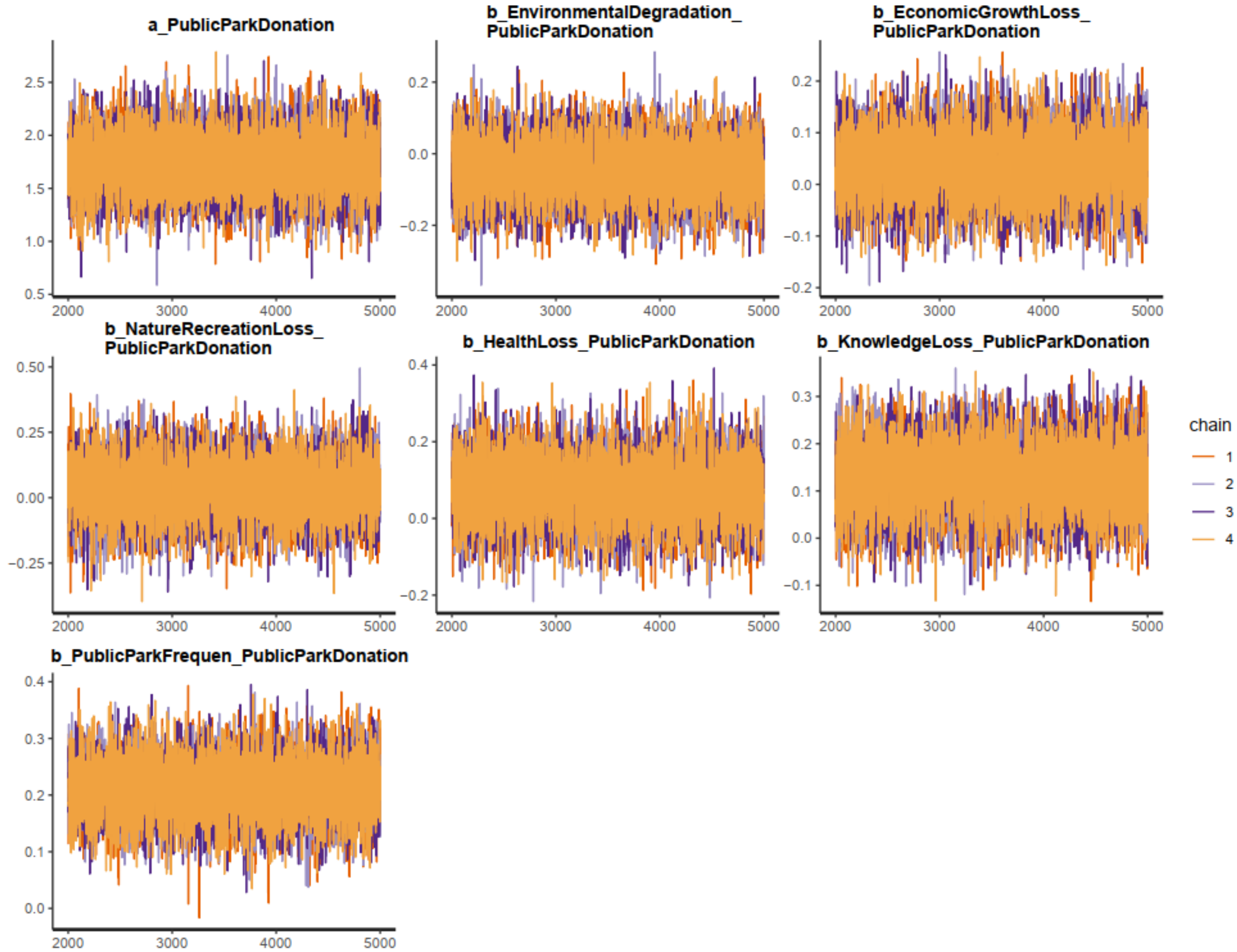

Figure A6: Model 4's trace plots with priors as norm(1,0.5)

References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., and Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research* **29**, 42539-42559.

Adebayo, O. (2019). Loss of biodiversity: the burgeoning threat to human health. *Annals of Ibadan postgraduate medicine* **17**, 5-7.

Adepoju, A. A., and Ojo, O. O. (2018). Bayesian method for solving the problem of multicollinearity in regression. *Afrika Statistika* **13**, 1823-1834.

Alzahrani, K., Ali, M., Azeem, M. I., and Alotaibi, B. A. (2023). Efficacy of Public Extension and Advisory Services for Sustainable Rice Production. *Agriculture* **13**, 1062.

Asamoah, O., Danquah, J. A., Bamwesigye, D., Verter, N., Acheampong, E., Macgregor, C. J., Boateng, C. M., Kuittinen, S., Appiah, M., and Pappinen, A. (2023). The perception of the locals on the impact of climate variability on non-timber forest products in Ghana. *Acta Ecologica Sinica*.

Basu, S., and Nagendra, H. (2021). Perceptions of park visitors on access to urban parks and benefits of green spaces. *Urban Forestry & Urban Greening* **57**, 126959.

Bele, A., and Chakradeo, U. (2021). Public perception of biodiversity: a literature review of its role in urban green spaces. *Journal of Landscape Ecology* **14**, 1-28.

Brooks, S. P., and Gelman, A. (1998). General methods for monitoring convergence of iterative simulations. *Journal of computational and graphical statistics* 7, 434-455.
Bush, J. (2020). The role of local government greening policies in the transition towards nature-based cities. *Environmental Innovation and Societal Transitions* 35, 35-44.
Creswell, J. W., and Poth, C. N. (2018). "Qualitative inquiry and research design : choosing among five approaches," SAGE, Los Angeles.
Csilléry, K., Blum, M. G., Gaggiotti, O. E., and François, O. (2010). Approximate Bayesian computation (ABC) in practice. *Trends in Ecology and Evolution* 25, 410-418.
Dang, H.-A. H., Nguyen, C. V., and Carletto, C. (2023). Did a successful fight against COVID-19 come at a cost? Impacts of the pandemic on employment outcomes in Vietnam. *World Development* 161, 106129.
Davies, P., and Gregersen, N. H. (2014). "Information and the nature of reality: From physics to metaphysics," Cambridge University Press, Cambridge.
DeVille, N. V., Tomasso, L. P., Stoddard, O. P., Wilt, G. E., Horton, T. H., Wolf, K. L., Brymer, E., Kahn Jr, P. H., and James, P. (2021). Time spent in nature is associated with increased pro-environmental attitudes and behaviors. *International journal of environmental research and public health* 18, 7498.
Edeigba, B. A., Ashinze, U. K., Umoh, A. A., Biu, P. W., and Daraojimba, A. I. (2024). Urban green spaces and their impact on environmental health: A Global Review. *World Journal of Advanced Research and Reviews* 21, 917-927.
Fan, P., Ouyang, Z., Nguyen, D. D., Nguyen, T. T. H., Park, H., and Chen, J. (2019). Urbanization, economic development, environmental and social changes in transitional economies: Vietnam after Doimoi. *Landscape and Urban Planning* 187, 145-155.
Fenoglio, M. S., Calviño, A., González, E., Salvo, A., and Videla, M. (2021). Urbanisation drivers and underlying mechanisms of terrestrial insect diversity loss in cities. *Ecological Entomology* 46, 757-771.
Fontán-Vela, M., Rivera-Navarro, J., Gullón, P., Díez, J., Anguelovski, I., and Franco, M. (2021). Active use and perceptions of parks as urban assets for physical activity: A mixed-methods study. *Health & place* 71, 102660.
Fund, U. C. C. R. T. (2019). "Nature-Based Solutions for Cities in Viet Nam: Water Sensitive Urban Design."
Gill, J. (2014). "Bayesian methods: A social and behavioral sciences approach," CRC press.
Halsey, L. G., Curran-Everett, D., Vowler, S. L., and Drummond, G. B. (2015). The fickle P value generates irreproducible results. *Nature methods* 12, 179-185.
Hoang, A. T., Apparicio, P., and Pham, T.-T.-H. (2019). The provision and accessibility to parks in Ho Chi Minh city: disparities along the urban core—periphery Axis. *Urban Science* 3, 37.
Huang, Y., Hou, Y., Ren, J., Yang, J., and Wen, Y. (2023). How to Promote Sustainable Bamboo Forest Management: An Empirical Study from Small-Scale Farmers in China. *Forests* 15, 12.
Humbal, A., Chaudhary, N., and Pathak, B. (2023). Urbanization trends, climate change, and environmental sustainability. *In* "Climate Change and Urban Environment Sustainability", pp. 151-166. Springer.
Ibrahim, M. S. N., Assim, M. I. S. A., Johari, S., Mohammad, S. K. W., Afandi, S. H. M., and Hassan, S. (2023). Public awareness on biodiversity conservation and well-being: case of Gunung Mulu National Park, Sarawak. *GeoJournal* 88, 3471-3496.

Jabbar, M., Yusoff, M. M., and Shafie, A. (2021). Assessing the role of urban green spaces for human well-being: A systematic review. *GeoJournal*, 1-19.

Jaya, I., Tantular, B., and Andriyana, Y. (2019). A Bayesian approach on multicollinearity problem with an Informative Prior. *In* "Journal of Physics: Conference Series", Vol. 1265, pp. 012021. IOP Publishing.

Kaczynski, A. T., Besenyi, G. M., Stanis, S. A. W., Koohsari, M. J., Oestman, K. B., Bergstrom, R., Potwarka, L. R., and Reis, R. S. (2014). Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. *International Journal of Behavioral Nutrition and Physical Activity* 11, 1-14.

Khuc, Q. V., Dang, T., Tran, M., Nguyen, D. T., Nguyen, T., Pham, P., and Tran, T. (2023a). Household-level strategies to tackle plastic waste pollution in a transitional country. *Urban Science* 7, 20.

Khuc, Q. V., Tran, M., Nguyen, T., Thinh, N. A., Dang, T., Tuyen, D. T., Pham, P., and Dat, L. Q. (2023b). Improving energy literacy to facilitate energy transition and nurture environmental culture in Vietnam. *Urban Science* 7, 13.

Kondratyeva, A., Knapp, S., Durka, W., Kühn, I., Vallet, J., Machon, N., Martin, G., Motard, E., Grandcolas, P., and Pavoine, S. (2020). Urbanization effects on biodiversity revealed by a two-scale analysis of species functional uniqueness vs. redundancy. *Frontiers in Ecology and Evolution* 8, 73.

Konijnendijk, C. C., Annerstedt, M., Nielsen, A. B., and Maruthaveeran, S. (2013). Benefits of urban parks. *A systematic review. A Report for IFPRA, Copenhagen & Alnarp* 70.

Krasny, M. E., Lundholm, C., Shava, S., Lee, E., Kobori, H., Shava, S., Kobori, H., Lee, E., and Krasny, M. E. (2013). Urban landscapes as learning arenas for biodiversity and ecosystem services management. *In* "Urbanization, biodiversity and ecosystem services: Challenges and opportunities: A global assessment", pp. 629-664. Springer Netherlands Dordrecht.

Kruize, H., van Der Vliet, N., Staatsen, B., Bell, R., Chiabai, A., Muiños, G., Higgins, S., Quiroga, S., Martinez-Juarez, P., and Aberg Yngwe, M. (2019). Urban green space: creating a triple win for environmental sustainability, health, and health equity through behavior change. *International journal of environmental research and public health* 16, 4403.

La, V.-P., and Vuong, Q.-H. (2019). bayesvl: Visually learning the graphical structure of Bayesian networks and performing MCMC with'Stan'. *The Comprehensive R Archive Network (CRAN)*.

Lawler, O. K., Allan, H. L., Baxter, P. W., Castagnino, R., Tor, M. C., Dann, L. E., Hungerford, J., Karmacharya, D., Lloyd, T. J., and López-Jara, M. J. (2021). The COVID-19 pandemic is intricately linked to biodiversity loss and ecosystem health. *The Lancet Planetary Health* 5, e840-e850.

Leamer, E. E. (1973). Multicollinearity: a Bayesian interpretation. *The Review of Economics and Statistics* 55, 371-380.

Linh, N., Erasmi, S., and Kappas, M. (2012). Quantifying land use/cover change and landscape fragmentation in Danang City, Vietnam: 1979–2009. *Aster* 2, 4.

Liu, Z., He, C., and Wu, J. (2016). The relationship between habitat loss and fragmentation during urbanization: an empirical evaluation from 16 world cities. *PloS one* 11, e0154613.

Mai, T. T., and Zhang, S. (2016). Urbanization, urban green space and urban biodiversity in Vietnam. *International Agricultural Engineering Journal* **25**, 303-312.

Mantello, P., Ho, M.-T., Nguyen, M.-H., and Vuong, Q.-H. (2023). Machines that feel: behavioral determinants of attitude towards affect recognition technology—upgrading technology acceptance theory with the mindsponge model. *Humanities and Social Sciences Communications* **10**, 430.

Marselle, M. R., Lindley, S. J., Cook, P. A., and Bonn, A. (2021). Biodiversity and health in the urban environment. *Current environmental health reports* **8**, 146-156.

Martin, M. P., Woodbury, D. J., Doroski, D. A., Nagele, E., Storace, M., Cook-Patton, S. C., Pasternack, R., and Ashton, M. S. (2021). People plant trees for utility more often than for biodiversity or carbon. *Biological Conservation* **261**, 109224.

Maurer, M., Zaval, L., Orlove, B., Moraga, V., and Culligan, P. (2021). More than nature: Linkages between well-being and greenspace influenced by a combination of elements of nature and non-nature in a New York City urban park. *Urban Forestry and Urban Greening* **61**, 127081.

McElreath, R. (2018). "Statistical rethinking: A Bayesian course with examples in R and Stan," Chapman and Hall/CRC Press, Boca Raton, London, New York.

Mexia, T., Vieira, J., Príncipe, A., Anjos, A., Silva, P., Lopes, N., Freitas, C., Santos-Reis, M., Correia, O., and Branquinho, C. (2018). Ecosystem services: Urban parks under a magnifying glass. *Environmental research* **160**, 469-478.

Nguyen, M.-H. (2021). Multifaceted interactions between urban humans and biodiversity-related concepts: A developing-country dataset. *Data Intelligence* **3**, 578–605.

Nguyen, M.-H., Duong, M.-P. T., Nguyen, M.-C., Mutai, N., Jin, R., Nguyen, P.-T., Le, T.-T., and Vuong, Q.-H. (2023a). Promoting stakeholders' support for marine protection policies: Insights from a 42-country dataset. *Sustainability* **15**, 12226.

Nguyen, M.-H., and Jones, T. E. (2022a). Building eco-surplus culture among urban residents as a novel strategy to improve finance for conservation in protected areas. *Humanities & Social Sciences Communications* **9**, 426.

Nguyen, M.-H., and Jones, T. E. (2022b). Predictors of support for biodiversity loss countermeasures and bushmeat consumption among Vietnamese urban residents. *Conservation Science and Practice* **4**, e12822.

Nguyen, M.-H., La, V.-P., Le, T.-T., and Vuong, Q.-H. (2022). Introduction to Bayesian Mindsponge Framework analytics: an innovative method for social and psychological research. *MethodsX* **9**, 101808.

Nguyen, M.-H., Nguyen, M.-H. T., Jin, R., Nguyen, Q.-L., La, V.-P., Le, T.-T., and Vuong, Q.-H. (2023b). Preventing the separation of urban humans from nature: The impact of pet and plant diversity on biodiversity loss belief. *Urban Science* **7**, 46.

Nguyen, P.-Y., Astell-Burt, T., Rahimi-Ardabili, H., and Feng, X. (2021). Green space quality and health: a systematic review. *International journal of environmental research and public health* **18**, 11028.

Nilon, C. H., Aronson, M. F., Cilliers, S. S., Dobbs, C., Frazee, L. J., Goddard, M. A., O'Neill, K. M., Roberts, D., Stander, E. K., and Werner, P. (2017). Planning for the future of urban biodiversity: a global review of city-scale initiatives. *BioScience* **67**, 332-342.

Nowak, D. J., Hirabayashi, S., Bodine, A., and Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. *Environmental pollution* **193**, 119-129.

Ortmann, S., and Ortmann, S. (2017). Introduction: The Environmental Challenges in Vietnam. *Environmental Governance in Vietnam: Institutional Reforms and Failures*, 1-34.
Pamukcu-Albers, P., Ugolini, F., La Rosa, D., Grădinaru, S. R., Azevedo, J. C., and Wu, J. (2021). Building green infrastructure to enhance urban resilience to climate change and pandemics. *Landscape ecology* **36**, 665-673.
Pataki, D. E., Alberti, M., Cadenasso, M. L., Felson, A. J., McDonnell, M. J., Pincetl, S., Pouyat, R. V., Setälä, H., and Whitlow, T. H. (2021). The benefits and limits of urban tree planting for environmental and human health. *Frontiers in Ecology and Evolution* **9**, 603757.
Paudel, S., and States, S. L. (2023). Urban green spaces and sustainability: Exploring the ecosystem services and disservices of grassy lawns versus floral meadows. *Urban Forestry & Urban Greening* **84**, 127932.
Perry, G., and Cox, R. D. (2024). Opportunities for Biodiversity Conservation via Urban Ecosystem Regeneration. *Diversity* **16**, 131.
Poudyal, N. C., Paudel, B., and Tarrant, M. A. (2013). A time series analysis of the impact of recession on national park visitation in the United States. *Tourism Management* **35**, 181-189.
Roe, D. (2019). Biodiversity loss—more than an environmental emergency. *The Lancet Planetary Health* **3**, e287-e289.
Schmeller, D. S., Courchamp, F., and Killeen, G. (2020). Biodiversity loss, emerging pathogens and human health risks. Vol. 29, pp. 3095-3102. Springer.
Shanahan, D. F., Lin, B., Gaston, K., Bush, R., and Fuller, R. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology* **30**, 153-165.
Simkin, R. D., Seto, K. C., McDonald, R. I., and Jetz, W. (2022). Biodiversity impacts and conservation implications of urban land expansion projected to 2050. *Proceedings of the National Academy of Sciences* **119**, e2117297119.
Turner-Skoff, J. B., and Cavender, N. (2019). The benefits of trees for livable and sustainable communities. *Plants, People, Planet* **1**, 323-335.
van de Schoot, R., Depaoli, S., King, R., Kramer, B., Märtens, K., Tadesse, M. G., Vannucci, M., Gelman, A., Veen, D., and Willemsen, J. (2021). Bayesian statistics and modelling. *Nature Reviews Methods Primers* **1**, 1.
Van Vliet, E., Dane, G., Weijs-Perrée, M., Van Leeuwen, E., Van Dinter, M., Van Den Berg, P., Borgers, A., and Chamilothori, K. (2021). The influence of urban park attributes on user preferences: Evaluation of virtual parks in an online stated-choice experiment. *International journal of environmental research and public health* **18**, 212.
Vehtari, A., and Gabry, J. (2019). Bayesian Stacking and Pseudo-BMA weights using the loo package.
Vehtari, A., Gelman, A., and Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing* **27**, 1413-1432.
Vuong, Q.-H. (2018). The (ir)rational consideration of the cost of science in transition economies. *Nature Human Behaviour* **2**, 5.
Vuong, Q.-H. (2020). Reform retractions to make them more transparent. *Nature* **582**, 149.
Vuong, Q.-H. (2021). The semiconducting principle of monetary and environmental values exchange. *Economics and Business Letters* **10**, 284-290.
Vuong, Q.-H. (2022). "The kingfisher story collection."

Vuong, Q.-H. (2023). "Mindsponge Theory," Walter de Gruyter GmbH.
Vuong, Q.-H., and Napier, N. K. (2015). Acculturation and global mindsponge: An emerging market perspective. *International Journal of Intercultural Relations* **49**, 354-367.
Vuong, Q.-H., and Nguyen, M.-H. (2023). Kingfisher: Contemplating the connection between nature and humans through science, art, literature, and lived experiences. *Pacific Conservation Biology*.
Vuong, Q.-H., and Nguyen, M.-H. (2024). Call Vietnam mouse-deer “cheo cheo” and let the empathy save them from extinction: a conservation review and call for name change. *Pacific Conservation Biology* **30**, PC23058.
Vuong, Q.-H., Nguyen, M.-H., and La, V.-P. (2022). "The mindsponge and BMF analytics for innovative thinking in social sciences and humanities," Walter de Gruyter GmbH.
Vuong, Q.-H., Nguyen, M.-H., and La, V.-P. (2024). The overlooked contributors to climate and biodiversity crises: Military operations and wars. *Environmental Management*.
Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., Šmíra, M., and Epskamp, S. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin Review* **25**, 35-57.
Wang, D., Brown, G., Zhong, G., Liu, Y., and Mateo-Babiano, I. (2015). Factors influencing perceived access to urban parks: A comparative study of Brisbane (Australia) and Zhongshan (China). *Habitat international* **50**, 335-346.
Wang, Y., and Akbari, H. (2016). The effects of street tree planting on Urban Heat Island mitigation in Montreal. *Sustainable cities and society* **27**, 122-128.
Woodward, A., Hinwood, A., Bennett, D., Grear, B., Vardoulakis, S., Lalchandani, N., Lyne, K., and Williams, C. (2023). Trees, Climate Change, and Health: An Urban Planning, Greening and Implementation Perspective. *International journal of environmental research and public health* **20**, 6798.
Worldometers (2024). Vietnm Coronavirus cases. Vol. 2024.
Zari, M. P. (2018). The importance of urban biodiversity–an ecosystem services approach. *Biodiversity International Journal* **2**, 357-360.