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Local environment perceived in daily life and urban green and blue space visits: Uncovering key factors for different age groups to access ecosystem services

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A R T I C L E I N F O

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A B S T R A C T

Inequality in access to green and blue spaces is a major issue in the field of environmental justice. Various factors significantly influence visitations to these spaces, including residential, commuting, and shopping areas. However, studies have mainly focused on residential environments. Analyzing the coupling of environmental and socioeconomic factors, including age, income, and childhood experience, and examining the direct and indirect effects of these factors for different age groups are needed to better understand the detailed context of inequalities in access to ecosystem services. We conducted a questionnaire survey and analysis to address these needs in an urban setting. The results demonstrate that several land use categories (i.e., agricultural lands in residential areas, grasslands near shopping areas, and deciduous forests near commuting destinations) positively correlated with visitation frequency, suggesting the lack thereof may be the cause of access inequalities. In particular, the perimeter per unit area of some land cover types, which shows the complexity of the form of each land cover category, was found to be a significant factor. We identified inequality in nature experience to be the key factor correlated with inequality in nature visits among the young age group. For the middle-aged and old age groups, nature-relatedness was positively correlated with visitation frequency. Proper design of the local environment, such as through land use planning, can be an effective measure for all age groups. For instance, long-bordered green areas in the Monsoon Asian region are an attractive traditional landscape, with high accessibility and a comfortable thermal environment. The key factors for each age group should be considered in spatial design and inclusive information-sharing to reduce inequality in access to ecosystem services.

1. Introduction

1.1. Background

Green and blue spaces provide people with various ecosystem services. These spaces include parks with lush vegetation, garden ponds, grasslands, agricultural lands, forestlands, streams, lakes, and coasts. Equitable access to the services provided by these spaces is a pressing issue in various regions worldwide (Loos et al., 2023; Langemeyer and Connolly, 2020; Nyelele and Kroll, 2020). This is also an emerging issue in environmental justice (Pineda-Pinto et al., 2021; Fang et al., 2023).

Environmental justice is the principle that “all people and communities are entitled to equal protection of environmental and public health laws and regulations” (Bullard, 1996). According to Bullard, the physical environment cannot be separated from the cultural environment (Schweizer, 1999). As part of relevant international policy trends on environmental justice, the General Assembly of the United Nations adopted a resolution, “The human right to a clean, healthy and sustainable environment” (A/RES/76/300), on July 28, 2022. In the context of ongoing global environmental change, “just sustainability” in policy-making, which combines social justice and sustainability, must be assessed from the perspective of environmental justice (Mohai et al.,

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2009).

In urban areas, there is a great demand for ecosystem services but the problem of equity and inclusive access is relatively severe because of the limited green and blue spaces (Law et al., 2022). For example, as an effect of access to ecosystem services, exposure to nature by visiting green and blue spaces for at least two hours a week is associated with human well-being (White et al., 2019). Hence, equitable access to and spending some time in nature is important for urban residents.

One way to access ecosystem services is to visit green and blue spaces; the visits affect access to ecosystem services relating to improved health and well-being, such as psychological and physical healing and recreation (Remme et al., 2021; Jansen et al., 2017; White et al., 2021; Labib et al., 2020). Walking to and within green and blue spaces is also a healthy physical activity (Tan et al., 2021), and status of accessing such spaces can be influenced by the socioeconomic characteristics of neighborhoods and individuals (Dai, 2011; Koohsari et al., 2017). During the recent pandemic, there has been a marked increase in the need for such spaces (Bristowe and Heckert, 2023). However, some people face hindrances or difficulties visiting such spaces, which creates environmental access disparities. Environmental disparities have become more serious during the pandemic (Gao et al., 2023; Uchiyama and Kohsaka, 2022). For example, the disparity in people's physical activity (Kyan and Takakura, 2022) is a relevant point. Understanding the contexts and circumstances of these disparities is crucial for implementing appropriate measures to address the root causes of access inequality.

Studies on visits to green and blue spaces in urban areas have been conducted before the pandemic and have been accumulated to a certain extent (Wolch et al., 2014; Kabisch and Van Den Bosch, 2017; Paloniemi et al., 2018; Rigolon et al., 2018). People who visit such spaces often have high socioeconomic status (Astell-Burt et al., 2014; Pineda-Pinto et al., 2021; Yasumoto et al., 2021). The specific characteristics of such people include those with high income, who are married, and living in a high-quality local environment with green and blue spaces near their residences (Uchiyama and Kohsaka, 2022). Socioeconomic and environmental factors that influence and limit green and blue space visitation include age, gender, income, and the local environment experienced daily (hereinafter referred to as the daily environment) (Shanahan et al., 2015). This study defines the daily environment as the local environment that people perceive and experience in their daily lives; residential areas, commuting, and shopping destinations were included. Green and blue spaces represent elements of the daily environment. Other personal factors influencing visitation frequency include participation in social activities, sports, nature visits, and farming clubs, and availability of time/resources to visit green and blue spaces (Lin et al., 2017; Szewczenko et al., 2023; Pan et al., 2021). Nature experience and nature-relatedness (NR) are memory-related and influential psychological factors for visitation frequency (Shanahan et al., 2016; Nisbet and Zelenski, 2013). The importance of childhood nature experience has been discussed in existing studies (Soga and Gaston, 2016). NR is the subjective psychological relatedness between people and nature (Nisbet and Zelenski, 2013).

Studies have noted limited integrative methodologies that comprehensively consider various socioeconomic and environmental factors (Pyky et al., 2019; Heo and Bell, 2023). Analyzing multiple ecosystem types is one of the main challenges in analyzing characteristics of the daily environment, which includes multiple ecosystems such as agricultural lands and various types of forests. In addition, it is necessary to analyze not only residential areas but also environments that people frequently have direct and indirect interactions with in daily life, such as spaces surrounding workplaces, schools, and shopping destinations. However, existing research on visits to green and blue spaces in urban areas has not analyzed the effects of such diverse environments addressed in this study.

1.2. Existing research on green and blue space visitation and environmental justice

Research examining green and blue space visitation as access to ecosystem services has been conducted in diverse fields, including urban planning, tourism management, geography, sociology, environmental management, and public health (De Bell et al., 2017; Jakstis et al., 2023; Korpilo et al., 2022; Kronenberg et al., 2020; Zhang et al., 2020). Interdisciplinary research primarily addresses issues related to environmental justice and disparities within the realm of environmental management. Research conducted in this field identifies groups with access difficulties, such as minorities and low-income groups in each city, to plan for and ensure equitable green and blue spaces and suggest measures to solve these issues (Rigolon and Gibson, 2021; Pineda-Pinto et al., 2021; Uchiyama and Kohsaka, 2022). The literature on environmental justice in access to urban ecosystem services has been rapidly growing in recent years; however, there is a lack of relevant literature on cities except in the United States, Germany, and China (Haque and Sharifi, 2024).

Environmental justice-related issues involve distributional, procedural, and recognition justice (Kronenberg et al., 2020; Rigolon and Gibson, 2021; Dobbs et al., 2023). Numerous studies on distributional justice have analyzed the distribution of green and blue spaces. However, the environmental elements covered by these studies are the size of the green spaces around residential areas (White et al., 2021; Tani et al., 2021; Maas et al., 2008). Analysis of environmental elements in places for daily activities, such as working and shopping, is insufficient. Despite research suggesting that it is important to consider both the size of green spaces and the spatial form of such spaces to improve the health of residents in the neighborhood (Chang et al., 2020), such an analysis is limited. In this study, the analysis considers not only residential areas but also commuting and shopping destinations. In addition, we analyzed not only the quantity of green and blue spaces but also the form of these spaces as qualitative features.

Relatively few studies analyzing environmental justice in relation to visits to green and blue spaces have focused on procedural and recognitional justice, and further research is needed. Ecosystem services have the characteristics of social constructs (Ernstson, 2013). Therefore, to acknowledge the benefits of such ecosystem services, it is necessary to understand and recognize ecosystem services and their effects (Kabisch, 2015). Furthermore, the decision-making processes in environmental management for the sustainable supply of such services must be an inclusive process (van Oudenhoven et al., 2018). In our analysis of visits to green and blue spaces, we included not only the relationship between the distribution of these spaces and accessibility but also factors related to recognition, such as childhood nature experience and NR.

The frequency and quality of natural experiences, especially childhood experiences, differ significantly between generations (Uchiyama et al., 2022). For example, the current generation (65 years old and above) in Japan has a relatively rich childhood nature experience because rich natural lands remained until around 1960 and 1970, even in Tokyo-Yokohama and Osaka-Kobe, major metropolitan areas in the country. Most of these natural lands have been urbanized and are presently built-up areas, in which younger generations have difficulty with natural experiences. Childhood nature experiences influence nature-relatedness and behaviors toward nature, such as conservation actions and visiting nature (Soga and Gaston, 2016). Natural experiences also influence the relationship between psychological health and visits to nature (Van den Berg et al., 2016). Given the importance of nature experiences and the differences between generations, an analysis that considers different age groups is required.

Factors that influence visitation to green and blue spaces are diverse, and visitation is also influenced by factors related to time, such as weekdays/weekends and the availability of time to visit there (Stearns et al., 2023; Neuvonen et al., 2007). It is assumed that each factor correlates with visitations either directly or indirectly through other factors. However, insufficient research has been conducted to analyze the direct and indirect effects of these factors. An example of the direct and indirect influences of these factors is that the experience of nature and the daily environment at a young age influences NR (Colléony et al., 2020; Perrins et al., 2021; Fleury-Bahi et al., 2023), which consequently influences their visitation attitude, behavior, and practices (Pyky et al., 2019). The daily environment also affects psychological and physical aspects (Geneshka et al., 2021; Astell-Burt et al., 2023). Certain daily environments may directly or indirectly influence attitudes toward green and blue space visitation practices.

Urgent measures are needed, especially in large cities, where green and blue space per capita tend to be small, and evidence for policy-making is needed; however, there is a lack of research, especially for large cities and megacities with populations of 10 million or more. This reflects a regional imbalance in environmental justice research on urban ecosystem services (Haque and Sharifi, 2024). Notably, Asia, where megacities are concentrated (Uchiyama and Okabe, 2012), requires further efforts to increase research in such fields (Haque and Sharifi, 2024). The reasons for the urgency of this issue are as follows: First, large cities tend to be occupied by the built environment, and because of the limited green and blue spaces, environmental inequality in visiting those spaces tends to be worse compared with cases in medium- or small-sized cities. Second, various resources tend to be concentrated in large cities, inducing rapid urban development and land-use changes to generate built-up areas.

Literature review suggests the need to address the following challenges: (1) Comprehensive analysis of the daily environment, considering its form as a qualitative characteristic, (2) integrated analysis of various factors and consideration of time and timing, such as the length of available time, weekdays, and weekends, and (3) analysis of the direct and indirect effects of each factor. Considering the remaining tasks of existing research on urban green and blue space visitation and inequality in access to these spaces, we conducted a large-scale questionnaire survey, statistical analysis (including structural equation modeling), and GIS analysis to obtain suggestions for environmental management to ensure equitable access to green and blue spaces.

2. Materials and methods

We conducted an online questionnaire survey on residents of the Tokyo-Yokohama and Osaka-Kobe metropolitan areas. These are the first and second largest metropolitan areas in Japan, respectively. Tokyo-Yokohama metropolitan area comprises 23 wards in Tokyo and Yokohama City. The Osaka-Kobe metropolitan area is composed of Osaka City, Kobe City, and eight surrounding municipalities. The study sample collection was conducted considering the proportions of the population in each age group in individual cities. The survey period was March 24th–28th, 2023. The survey was administered to registered panel members of MyVoice Communications, Inc. The survey company had 1,062,973 registered members (as of August 2023), recruited

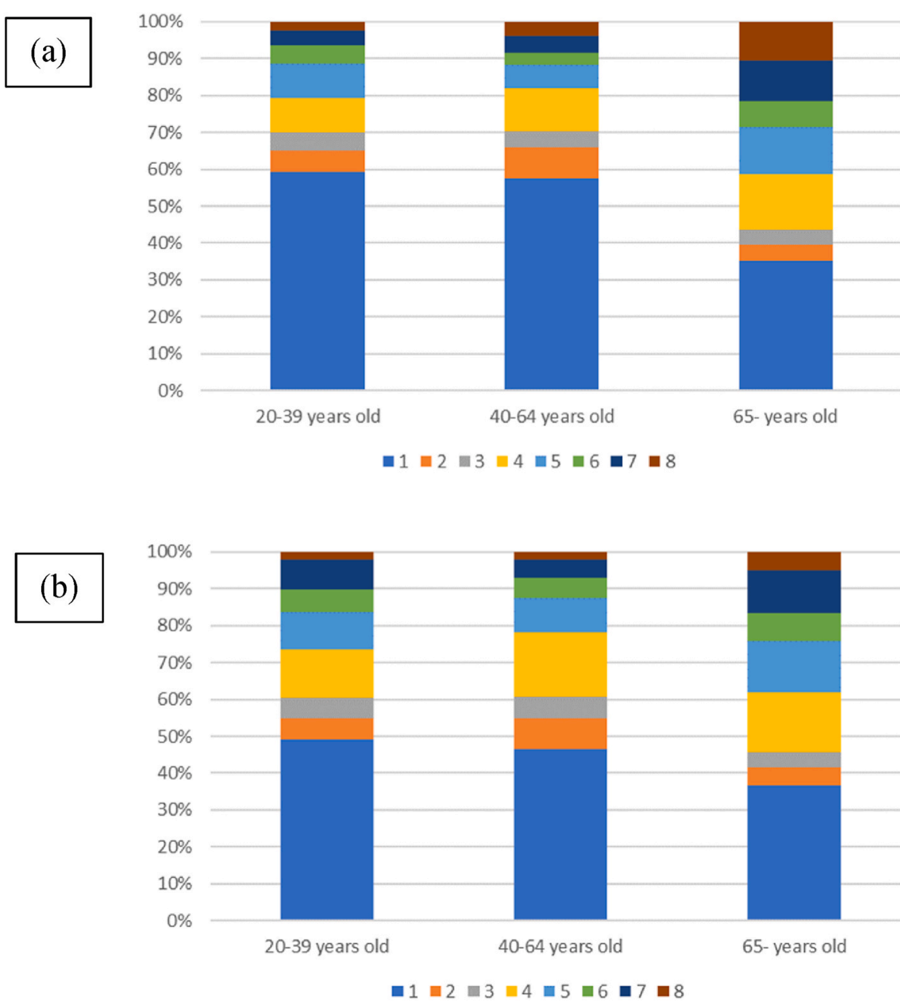

Fig. 1. Frequency of visitation to green and blue spaces of three age groups. 1. Do not visit, 2. Once in several years, 3. Once every one to two years, 4. several times per year; 5. Once in a month, 6. Once in two weeks, 7. Once to three times per week, 8. Almost every day (more than three times per week). (a) weekdays, (b) weekends. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

through advertisements on the Internet and could participate in online surveys once registered. Respondents who took too short a time to answer or those who continuously made the same choices for the multiple-choice questions were excluded from the collected samples. The total number of valid responses was 3,500. Before conducting the survey, the questionnaire was reviewed and approved by the Research Ethics Review Committee of the Kobe University Graduate School of Human Development and Environment.

Basic attributes such as age, gender, and household income were collected, in addition to various variables including the frequency of green and blue space visitation, nature experience, NR, civic participation, and length of free time for each respondent. A detailed list of variables is provided in the appendix. As explored in the Introduction, age is an important variable, as confirmed by the differences in the frequency of green and blue space visitation and childhood nature experiences between age groups (Figs. 1 and 2).

The daily environments of the respondents included (1) residential districts, (2) workplaces, and (3) shopping areas. The locations of the residential districts were detected using the zip codes provided by the respondents. Workplaces and shopping areas were detected using 1 km square grids with ID codes because it might be difficult for respondents to remember the area zip codes. The online grid maps for the target areas were prepared by the authors. The respondents then used the maps in the answer to the online questionnaire to confirm grids that included their workplaces and shopping areas.

High-resolution land-cover data provided by the Japan Aerospace Exploration Agency were used to compute the ratios of each land-cover category in the residential districts and grids of workplaces and shopping areas of each respondent. To aggregate the land-cover data into each district and grid, the zonal statistics function of a GIS application, ArcGIS Pro (version 2.6.2), was used. The perimeters of the individual land-cover categories in these three areas were also computed based on the land-cover data. The perimeter was used as an indicator of the shapes of green and blue spaces. Long perimeters indicate complex shapes and short perimeters indicate simple shapes. The resolution of the data is a 10-m square grid, which can detect small green and blue spaces in urban areas. The distribution of the land cover categories is shown in the map (Fig. 3).

The responses to the questionnaire and land cover indicators to show the landscape of the daily environment were analyzed using the following statistical methods: Binary and ordinal logistic regressions were used to analyze the relationships between the frequency of green and blue space visits and other variables, including the daily environment, respondents' individual attributes, and questionnaire responses. Furthermore, structural equation modeling (SEM) was performed to analyze the direct and indirect effects of socio-ecological variables on the frequency of green and blue space visitation. We used the maximum likelihood estimation method in the SEM. The flow of analyses is indicated in Fig. 4.

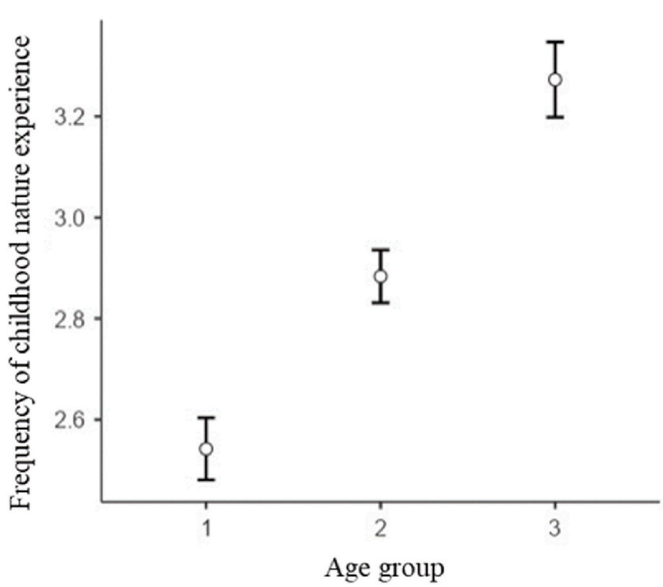

Fig. 2. Childhood nature experience of three age groups. 1. 20–39 years old, 2. 40–64 years, 3. over 65 years. Average values and upper and lower 95% CI are presented in the figure.

We developed binary and ordinal logistic regression models for the frequency of green and blue space visitation on weekdays and weekends separately because visitation frequency and the influence of land cover can differ between weekdays and weekends. Weekday and weekend models were developed for three age groups because age is a significant factor: (1) 20–39 years, (2) 40–64 years, and (3) 65 years and above.

For the analysis of the daily environment, the dependent variable was the frequency of visitation, and the independent variables were the perimeters or area ratios of nine land cover categories (a: water body; b: agricultural land; c: grassland; d: deciduous broadleaf forest [ex. *Zelkova serrata* and Cerasusu spp.]; e: deciduous needleleaf forest [ex. *Metasequoia glyptostroboides*]; f: evergreen broadleaf forest [ex. *Cinnamomum camphora* and *Quercus myrsinifolia*]; g: evergreen needleleaf forest [ex. *Cryptomeria japonica* and *Pinus densiflora*]; h: bare land; i: bamboo forest). The perimeter per unit area indicates the shape characteristics of the land-cover categories. The area ratio represents the size or spatial extent of the land cover categories. We developed models for shopping areas, commuting destinations, and residential areas based on land cover information for each location. In the ordinal logistic regression models, the ordinal dependent variable had eight frequencies (1. Do not visit, 2. Once in several years, 3. Once every one to two years, a 4. several times per year; 5. Once in a month, 6. Once in two weeks, 7. One to three times per week, 8. Almost every day, meaning more than three times per week.) The dependent variables of the binary logistic regression models had two values: 0 and 1. Frequencies "less than once per month" are given the number 0, and frequencies "equal to or more than once per month" are given the number 1. Based on the results of the binary logistic regressions, we identified land cover categories that are correlated with constant visits to green and blue spaces. The results of ordinal logistic regressions indicate land-cover categories that can enhance visitation frequency.

To analyze socioeconomic and environmental factors, we used various variables to develop binary and ordinal logistic regression models. The dependent variable was the frequency of visits to green and blue spaces. The dependent variables of the ordinal logistic regression models were the eight levels of visitation frequency, and those of the binary logistic regression models had values of 0 (frequencies less than once a month) and 1 (frequencies equal to or more than once a month). The independent variables included eight indicators: age, gender, household income, length of available (free) time, civic participation, nature experience, NR, and land cover indicators (area ratio or perimeter of a land cover category). The following are the basic attributes and socio-ecological characteristics of the respondents: Civic participation refers to the number of clubs or social activities the respondents participate in. Nature experiences indicate the frequency of nature-related activities that respondents participated in when they were junior high school students or younger. The frequency of nature experiences was measured using a four-point Likert scale (1. None, 2. Very little experience, 3. Some experience, 4. Much experience). The NR is an established indicator proposed by Nisbet and Zelenski (2013) to assess the degree of nature-relatedness among people. The value of the indicator is one (weakest relatedness) to five (strongest relatedness). The land-cover indicator was selected based on the significance shown in the analysis results for the daily environment. If there was more than one significant land cover indicator for a model for an age group, we chose the indicator that had the strongest positive correlation with visitation frequency among the indicators for the model of the age group. If there

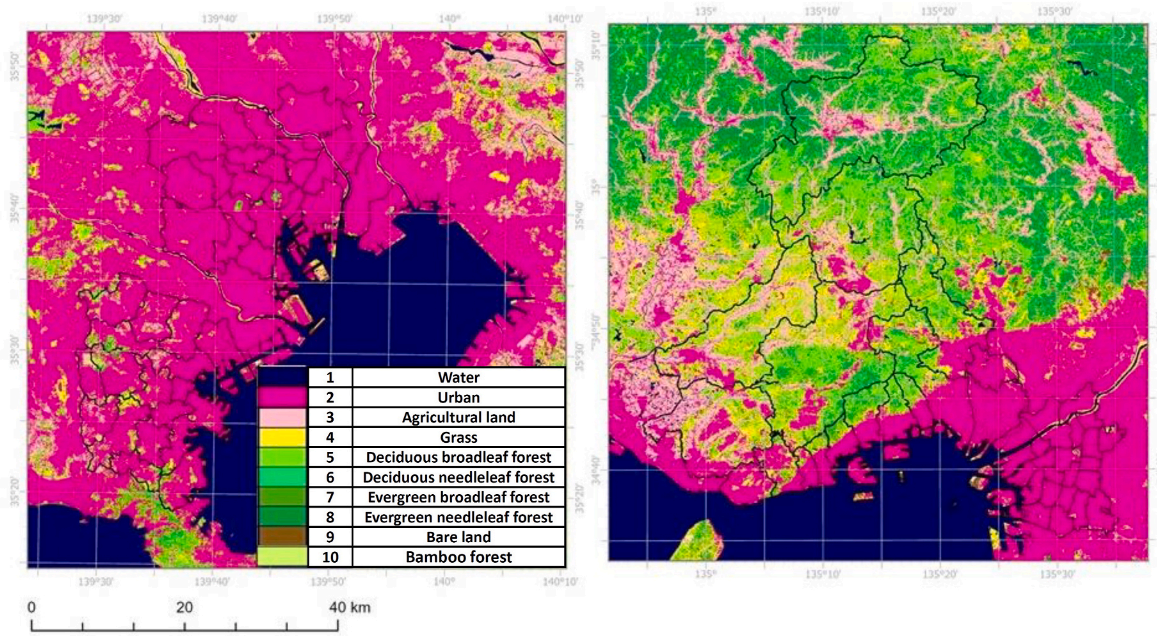

Fig. 3. Distribution of land cover categories of (1) Tokyo and Yokohama (left) and (2) Osaka, Kobe, and surrounding eight municipalities (right).

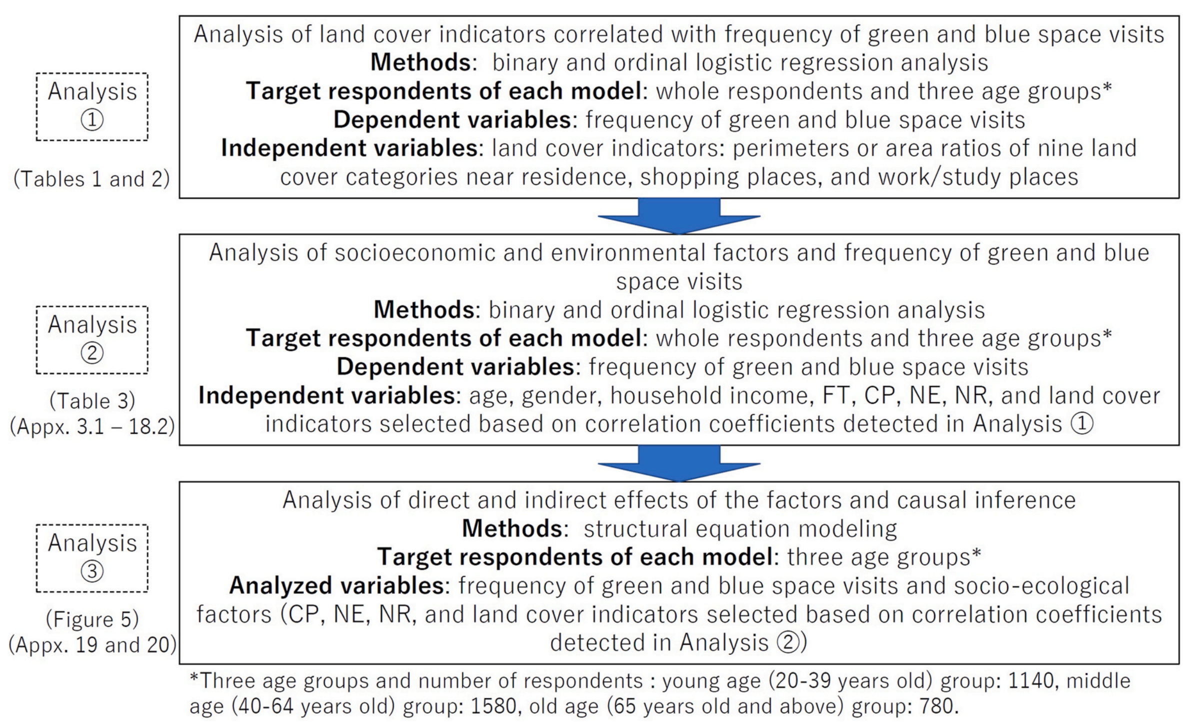

Fig. 4. Process of analyses: methods, target respondents, and variables.

were no significant land cover indicators, they were not included in the models.

We focused on the causal relationships between socio-ecological factors and used a SEM for the causal inference. The variables used to analyze the direct and indirect effects on the frequency of green and blue space visits were civic participation, nature experience, NR, land cover indicators, and frequency of green and blue space visits. Based on the correlation coefficient with the frequency of visitation, land-cover indicators with the highest positive correlations were chosen from the land-cover indicators used in the analysis models of socioeconomic and environmental factors. These land cover indicators were chosen for the weekday and weekend models respectively. The relationships among the factors in the SEMs can be explained as the following hypotheses: Natural experiences correlate with civic participation, NR, and visitation frequency. Land-cover indicators correlate with NR and visitation frequency. Civic participation and NR correlate with the visitation frequency.

3. Results

3.1. Analysis of daily environments

The following tables present the results of the model analyses of the frequency of green and blue space visitation, the area ratios (Table 1), and the perimeters of land cover categories (Table 2) in residential areas and shopping and commuting destinations. The analysis of all respondents indicated that the perimeters and area ratios of agricultural land were the most statistically significant factors for visitation frequency. The binary logistic regression models for weekdays showed that deciduous broadleaf forests were also a significant factor in the perimeter model. The binary and ordinal logistic regression models for weekends indicated that the perimeters of agricultural land near shopping areas were also significant factors. The perimeter of grassland near shopping areas in the ordinal model for weekdays was another factor positively correlated with visitation frequency.

The perimeter of agricultural lands in residential areas was also a significant factor in the binary and ordinal models for the 20–39-year-old age group (hereafter, the young age group). For the young age group, the area ratios of deciduous broadleaf forests and grasslands in residential areas were positive factors in the weekend binary models and weekday ordinal models, respectively. The perimeter of deciduous needleleaf forests near shopping areas in the weekend ordinal model was another factor positively correlated with visitation frequency. In contrast, the perimeter of the water body in the weekend binary model and the evergreen broadleaf forests in the weekday ordinal model were negatively correlated with visitation frequency.

The area ratio and perimeter of grasslands in residential areas are significant positive factors in both weekday and weekend binary models for the 40–64-year-old age group (hereafter referred to as the middle-aged group). The perimeter of grasslands near shopping areas was also a positive factor in weekday binary and ordinal models. The evergreen broadleaf forest perimeter was negatively correlated with visitation frequency, as shown in the weekend binary model. The results of the analysis of the middle-aged group indicate the relatively strong positive correlations between the existence of grassland and visitation frequency.

The area ratio of agricultural land positively correlated with the frequency of visitation of the 65 or older age group (hereafter referred to as the old age group), as shown in all models of area ratios of land cover categories. As for the perimeter of land cover categories, the perimeter of agricultural land was a positive factor in the weekday and weekend binary models, and that of deciduous broadleaf forests near commuting destinations positively correlated with the frequency of visitation in the old age group. The results of the analysis of the old age group show that the existence of agricultural land positively correlated with visitation frequency.

These results suggest that land-cover categories that correlated with visitation frequency differ depending on the age group, timing (weekday or weekend), and place (shopping area, commuting destination, or residential area). The variety of significant land cover categories of the middle and old age groups was not as diverse as that of the young age group. Agricultural land was a common important factor between the young and old age groups; however, not its area ratio but its perimeter was significant for the young age group. In addition to agricultural lands and grasslands, deciduous broad-leaf forests were positively correlated with the visitation frequency in some models. In contrast, evergreen broadleaf forests and water bodies were negatively correlated with the frequency of visitation in young age and middle-aged groups.

3.2. Analysis of socio-economic and environmental factors

The results of the binary and ordinal logistic regression analyses for all respondents showed a similar trend, in which gender was not a significant variable in weekday models and age was not a significant variable in weekend models (Table 3). The other variables were statistically

Table 1
Frequency of the visitation and area ratios of land cover categories.

	Weekdays Name of statistically significant land cover category (Odds ratio, 95% CI. Lower, Upper)	Weekends Name of statistically significant land cover category (Odds ratio, 95% CI. Lower, Upper)
Binary logistic regression (All respondents)	Shopping area: N/A Commuting destination: Deciduous broadleaf forest** (1.00, 1.000, 1.000) Residential area: **Agricultural land*** (1.02, 1.009, 1.030)** Grassland* (1.02, 0.996, 1.052)	Shopping area: N/A Commuting destination: N/A Residential area: **Agricultural land*** (1.02, 1.005, 1.026)** Grassland* (1.02, 0.996, 1.051)
Binary logistic regression (Age 20–39)	Shopping area: Bare land** (1.00, 1.000, 1.001) Commuting destination: Waterbody** (1.00, 1.000, 1.000) Deciduous needleleaf forest* (1.03, 0.997, 1.063) Residential area: N/A	Shopping area: Bare land** (1.00, 1.000, 1.001) Commuting destination: Deciduous needleleaf forest* (1.03, 0.995, 1.060) Residential area: **Deciduous broadleaf forest** (1.03, 1.003, 1.059)**
Binary logistic regression (Age 40–64)	Shopping area: Grassland** (1.00, 1.000, 1.000) Commuting destination: N/A Residential area: **Grassland** (1.05, 1.010, 1.085)**	Shopping area: N/A Commuting destination: N/A Residential area: **Grassland** (1.04, 1.001, 1.073)**
Binary logistic regression (Age 65-)	Shopping area: Bamboo forest* (1.00, 1.000, 1.000) Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.009, 1.051)**	Shopping area: N/A Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.013, 1.056)**
Ordinal logistic regression (All respondents)	Shopping area: N/A Commuting destination: N/A Residential area: **Agricultural land*** (1.01, 1.010, 1.020)**	Shopping area: N/A Commuting destination: N/A Residential area: **Agricultural land*** (1.01, 1.010, 1.020)**
Ordinal logistic regression (Age 20–39)	Shopping area: N/A Commuting destination: Deciduous needleleaf forest* (1.02, 0.997, 1.05) Residential area: Waterbody* (0.97, 0.933, 1.000) **Grassland** (1.04, 1.001, 1.088)**	Shopping area: N/A Commuting destination: N/A Residential area: N/A
Ordinal logistic regression (Age 40–64)	Shopping area: Grassland* (1.00, 1.00, 1.00) Commuting destination: Bare land* (1.00, 0.999, 1.000) Residential area: N/A	Shopping area: N/A Commuting destination: Evergreen broadleaf forest* (1.00, 1.000, 1.000) Residential area: N/A
Ordinal logistic regression (65-)	Shopping area: Bare land* (1.00, 0.999, 1.000) Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.010, 1.040)**	Shopping area: N/A Commuting destination: Deciduous broadleaf forest* (1.00, 1.000, 1.000) Residential area: **Agricultural land*** (1.03, 1.010, 1.050)**

Binary logistic regression (0: less than once per month; 1: equal to or more than once per month).
Ordinal logistic regression (8 levels of the frequency of the visitation).

*p < 0.1, **p < 0.05, ***p < 0.01. N/A: No statistically significant independent variable.
Statistically significant land cover categories with 95 CI. that do not include 1.000 are indicated in bold.

significant in all the models. Gender did not correlate with the frequency of visits to green and blue spaces on weekdays. The other variables had positive coefficients, suggesting that older respondents who live in districts with longer perimeters per area of agricultural land and have higher income, longer free time (FT), frequent civic participation (CP), more natural experience (NE), and stronger NR tended to visit green and blue spaces on weekdays.

In contrast, age was not a significant factor in the frequency of green and blue space visits on weekends. The results of the weekend models indicate that male respondents who live in districts with longer perimeters per area of agricultural land and have a higher income, longer free time, frequent CP, more NE, and stronger NR tend to visit green and blue spaces on weekends (Table 3). Most of the generations can visit these spaces on weekends. This may explain why age was not a significant variable in the weekend models. Although age itself was not statistically significant in the models, NE, which largely differed between age groups, was significant, suggesting that the analysis of different age groups implemented in this research was still useful for understanding the characteristics of respondents' green and blue space visitations.

A few variables were significant in the models of the young age group. In the weekday binary model, only income, NE, and NR were statistically significant (Table 3). CP was a significant indicator in the weekday ordinal model. Basic individual attributes, such as age and gender, were not significant for green and blue space visitations on weekdays for the young age group. Several indicators, including age, free time, and a land cover indicator (perimeter of agricultural land) were also significant in their weekend binary model, in addition to income, NE, and NR. In their ordinal weekend model, CP was a significant indicator. The inequality of green and blue space visits in the young age group on weekdays can be addressed by dealing with issues related to relatively limited variables (such as income, NE, and NR). However, more variables were correlated with visitation frequency on weekends. Gender was not significant in any of the models for the young age group.

Basic individual attributes, including age, gender, and income, were not significant in the weekday models for the middle-aged group (Table 3). On the other hand, income was a significant variable in their weekend models, although age and gender were not significant in their weekend binary model, and gender was not significant in their weekend ordinal model. Free time was significant in the ordinal weekday model but not in the other models. The CP, NE, and NR positively correlated with the frequency of visitation in all models for the middle-aged group. CP was an important variable for the frequency of visitation in the middle-aged group but was less important in the young age group because it was not statistically significant in the binary models of the latter group. In contrast, free time may be less important for the middle-aged group because it was significant in only one model.

In the old age group, age was not significant in any of the models. Gender was significant in the weekend models, showing that older male respondents tended to visit green and blue spaces on weekends compared with female respondents (Table 3). Income was significant in all models, except for the original weekday model. Free time was significant in all models; however, it was less important in the weekend binary model in terms of the odds ratio (Appendix Table 14.2). CP, NE, NR, and land cover indicators had statistically significant positive correlations in all models for the old age group.

In addition to land cover indicators which show the landscape of the respondents' daily environment, socioeconomic and personal factors, such as income, CP, and NE, can influence the frequency of green and blue space visitation, and they should be considered when developing measures to reduce inequality in visitation frequency to these spaces. Regarding the statistical significance of each factor, it should be noted

Table 2
Frequency of the visitation and perimeters of land cover categories per area.

	Weekday	Weekends
Binary logistic regression (All respondents)	Shopping area: N/A Commuting destination: **Deciduous broadleaf forest** (1.02, 1.002, 1.047)** Residential area: **Agricultural land*** (1.04, 1.021, 1.049)**	Shopping area: **Agricultural land*** (1.02, 1.009, 1.032)** Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.021, 1.048)**
Binary logistic regression (Age 20–39)	Shopping area: N/A Commuting destination: Waterbody* (1.081, 0.988, 1.182) Residential area: N/A	Shopping area: N/A Commuting destination: N/A Residential area: **Waterbody** (0.86, 0.745, 0.981)** **Agricultural land*** (1.04, 1.014, 1.063)**
Binary logistic regression (Age 40–64)	Shopping area: **Grassland*** (1.07, 1.018, 1.116)** Commuting destination: N/A Residential area: **Grassland** (1.07, 1.017, 1.134)**	Shopping area: N/A Commuting destination: N/A Residential area: **Grassland** (1.08, 1.017, 1.138)** **Evergreen broadleaf forest** (0.84, 0.709, 0.983)**
Binary logistic regression (Age 65-)	Shopping area: N/A Commuting destination: N/A Residential area: **Agricultural land** (1.03, 1.008, 1.057)**	Shopping area: N/A Commuting destination: Deciduous broadleaf forest* (1.08, 1.000, 1.165) Residential area: **Agricultural land*** (1.05, 1.021, 1.072)**
Ordinal logistic regression (All respondents)	Shopping area: **Grassland*** (1.04, 1.010, 1.070)** Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.010, 1.040)**	Shopping area: Waterbody* (0.96, 0.917, 1.010) Deciduous needleleaf forest* (1.332, 0.930, 1.88) **Agricultural land** (1.01, 1.002, 1.020)** Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.010, 1.040)**
Ordinal logistic regression (Age 20–39)	Shopping area: N/A Commuting destination: **Evergreen broadleaf forest* (0.91, 0.813, 0.994)** Residential area: N/A	Shopping area: **Deciduous needleleaf forest** (1.63, 1.130, 3.910)** Commuting destination: N/A Residential area: **Agricultural land*** (1.03, 1.010, 1.050)**
Ordinal logistic regression (Age 40–64)	Shopping area: **Grassland** (1.05, 1.010, 1.090)** Commuting destination: N/A Residential area: N/A	Shopping area: Deciduous broadleaf forest* (0.98, 0.955, 1.000) Commuting destination: N/A Residential area: N/A
Ordinal logistic regression (Age 65-)	Shopping area: N/A Commuting destination: N/A Residential area: N/A	Shopping area: N/A Commuting destination: **Deciduous broadleaf forest*** (1.18, 1.060, 1.330)** Evergreen broadleaf forest* (0.69, 0.436, 1.050) Residential area: N/A

Binary logistic regression (0: less than once per month; 1: equal to or more than once per month).
Ordinal logistic regression (8 levels of the frequency of the visitation).
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$. N/A: No statistically significant independent variable.
Statistically significant land cover categories with 95 CI. that do not include 1.000 are indicated in bold.

that the significance of each factor depended on the timing (weekdays/weekends) and age group. Overall, relatively many factors correlated with the frequency of green and blue space visits by the older age groups; NE and NR were common significant factors among all age groups. Land cover indicators were also relatively significant factors.

The results provided in this subsection are important for understanding significant factors in the context of environmental inequalities. We analyzed the correlations of individual factors with the frequency of green and blue space visits. In the next subsection, the results of the causal inference and the analysis of direct and indirect effects between variables such as the land cover indicators to show the landscape elements perceived in daily life, NR, and visitation frequency are provided.

3.3. *Analysis of direct and indirect effects of the factors*

The results are presented in Fig. 5 and Appendix Tables 19 and 20. As indicated in the table, the model fit was good, including SRMR (<0.05), RMSEA (<0.08), and CFI (>0.9) values. As an overall trend of the direct effects of the factors, the correlations between NE and green and blue space visitations were stronger in weekend models. The correlations between NR and visitation frequency were also stronger in the weekend models of the middle-aged and old age groups, and the correlation between the two variables was similar in the weekend and weekday models of the young age group. NE and NR are the memory-related and psychological attributes of the respondents, respectively, which can be interpreted as "internal factors," and the influence of such factors tends to be relatively strong on weekends. CP had statistically significant positive correlations with visitation frequency in all models. The land cover indicator of the weekend models, the perimeter of agricultural land in residential areas, had statistically significant positive correlations with the frequency of visitation in the models of the young and old age groups. The land cover indicator of weekday models, the perimeter of grassland near shopping areas, had a statistically significant positive correlation with the frequency of visitation in the middle-aged group model.

The statistical significance of the indirect effects of these factors on visitation frequency was relatively weak in the young age group models. For example, the indirect effects of land cover indicators were not statistically significant in both the weekend and weekday models. Furthermore, the indirect effects of NE through CP in their weekend model and that of NE through NR in their weekday model were also not significant. Other analyzed indirect effects in the models of each age group were statistically significant, except for the indirect effect of the land cover indicator through NR in the weekend model of the middle-aged group.

Compared with other age groups, individual correlations between the factors were relatively weak in the young age group models. For example, the influence of land cover indicators on NR and the influence of NE on CP were not statistically significant in the weekend and weekday models. Furthermore, more than half of the analyzed indirect effects were not statistically significant in the young age group models, whereas most of the indirect effects were significant in the models of other age groups. However, the influence of NE on visitation frequency in the young age group models was exceptionally strong, although the influence of other factors was weak.

In the models for the middle-aged group, the influence of the land cover indicator (perimeter of agricultural land) on weekends was weak and not statistically significant for NR and visitation frequency. The indirect effect of the land cover indicator on visitation frequency through NR was also not significant. In the models of the old age group, most of the correlations, except the correlation between the land cover indicator and visitation frequency and the correlation between NE and visitation frequency in the weekday model, were statistically significant. In addition, all indirect effects of the models were significant.

4. Discussion and conclusion

4.1. *Findings and possible measures to achieve environmental justice*

4.1.1. *Implications from the analysis of daily environments*

The results of the analysis of daily environments using logistic regression models show that agricultural land in residential places was a relatively significant factor among the land-use categories, especially for the young and old age groups. Both the area ratio of agricultural land and the perimeter per area of agricultural land strongly correlated with the frequency of green and blue space visitation. It should be noted that significant land cover categories differ depending on age group, timing,

Table 3
Logistic regression models (weekday/weekend) for all respondents and each age group: statistically significant variables.

Target respondents	All respondents		Age 20–39 (Young age group)		Age 40–64 (Middle-aged group)		Age 65 or older (Old age group)	
Weekday/Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
Binary logistic regression model	Age** Income† FT** CP** NE** NR** PA**	Gender(M)* Income** FT** CP** NE** NR** PA**	Income† NE** NR**	Age** Income** FT* NE** NR** PA**	CP** NE** NR** PG_S*	Income** CP** NE** NR** AG*	Income† FT** CP** NE† NR** AA*	Gender(M)* Income* FT† CP** NE** NR** PA**
Ordinal logistic regression model	Age** Income** FT** CP** NE** NR** PA**	Gender(M)* Income** FT** CP** NE** NR** PA**	Income** CP† NE** NR**	Age† Income** FT* CP† NE** NR** PA*	FT** CP** NE** NR** PG_S*	Age† Income** CP** NE** NR**	FT** CP** NE* NR** AA**	Gender(M)† Income* FT** CP** NE** NR** AA**

Note: $p < 0.01$: **, $p < 0.05$: *, $p < 0.1$:.
All statistically significant independent variables listed in the table, except Gender, have a positive correlation with the dependent variable (frequency of green and blue space visits). Gender (M) means that male respondents tended to visit green and blue spaces more frequently than female respondents.
PA: Perimeter of agricultural land, PG_S: Perimeter of grassland near shopping areas, AG: Area ratio of grassland in residential areas, AA: Area ratios of agricultural land in residential areas.
The detailed result of each regression analysis is provided in the appendix.

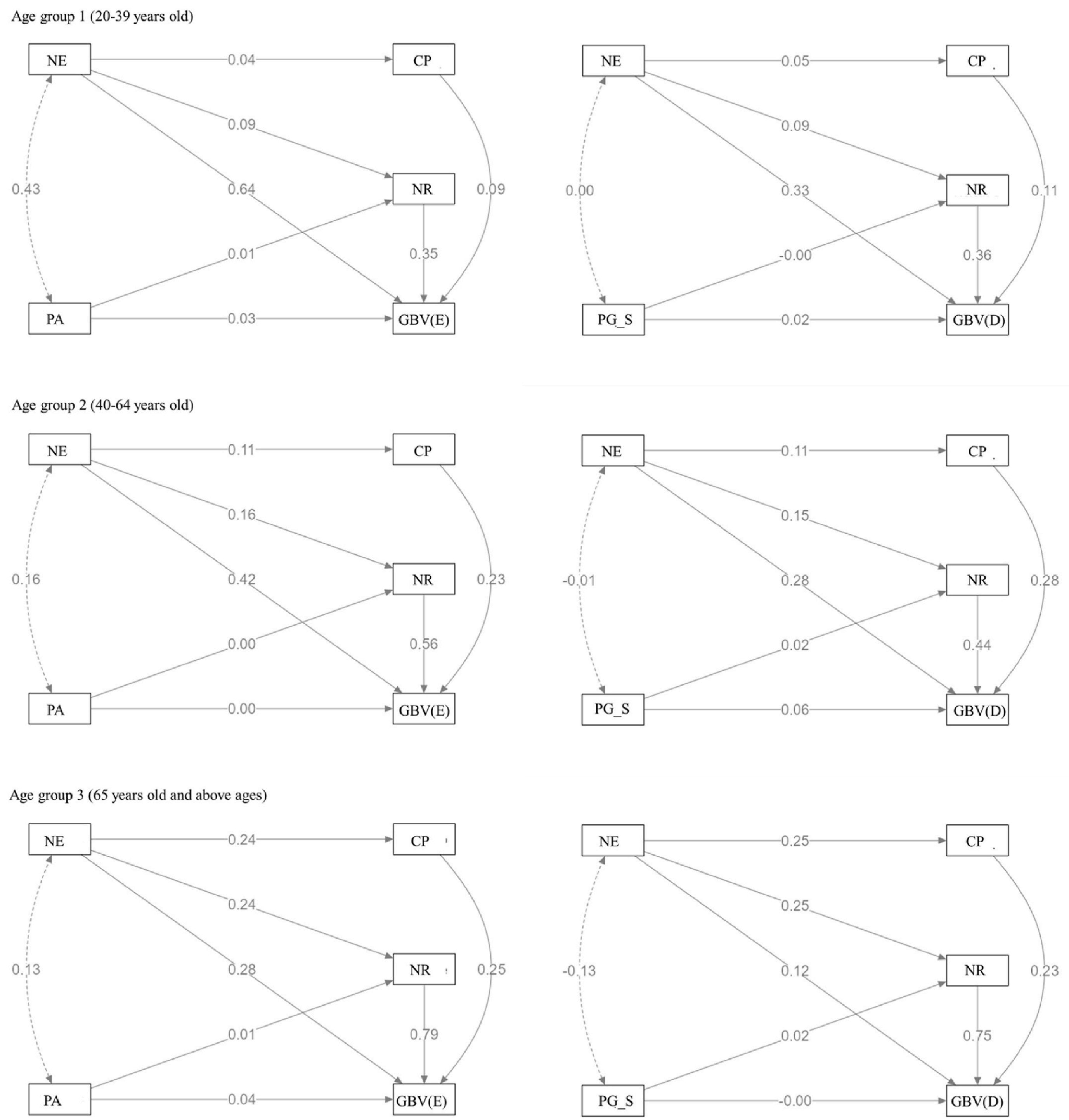

Fig. 5. Correlation coefficients between the factors. Note: NE, Nature experience; NR, Nature-relatedness; CP, Civic participation. PA: Perimeter per area of agricultural land in residential areas, PG_S: Perimeter per area of grassland near shopping areas, GBV(E): Green and blue space visitation on weekends, GBV(D): Green and blue space visitation on weekdays.

and place. The other main finding was that deciduous broadleaf forests near commuting destinations and deciduous needleleaf forests and grasslands near shopping areas were relatively significant positive factors for visitation frequency in some models.

These land-cover categories of the daily environment can be strategically distributed and designed, and information on the locations of attractive land-cover types for each age group should be disseminated to facilitate visitation to green and blue spaces and reduce inequalities in access to these spaces. Such management of the daily environment can be effective for all age groups, and it might be more effective for the young and old age groups because the various land cover types correlated with green and blue space visits by them. As Harada et al. (2022) suggested, local environmental factors that the old age group faces in their daily lives can have a certain impact on their motivation to go out and visit green and blue spaces. Younger age groups can be influenced by relatively diverse land-cover types. This might be because they have less childhood nature experience than other age groups and are open to the influence of various ecosystem types. In contrast, the middle-aged group might not be strongly influenced by land cover, and only grasslands had a positive correlation with their visitation to green and blue spaces. The characteristics of the middle-aged group could be generated because they might frequently go to certain places, such as parks with grasslands with their children and/or parents.

The deciduous forest landscape changes seasonally and provides cultural and aesthetic value for visitors (Aiba et al., 2023), which can attract people to visit such forests and other natural lands. Agricultural landscapes also undergo seasonal changes and likely provide a space and an opportunity for interactions between people, plants, soil, insects, and so on, which can be attractive to people. Among the land-use categories, waterbody did not positively correlate with visitation frequency. In future research, detailed categories of water bodies such as rivers, ponds, lakes, and seas can be used to understand the effect of the existence of waterbody on blue and green space visitation. Larger districts or grids can be utilized for the analysis of relatively large blue spaces, such as the sea or coastal areas, to properly analyze their influences (Jo et al., 2022). An existing study observed synergistic positive health effects of green and blue spaces on visitors (Yin et al., 2023). Such effects also need to be analyzed in future research.

4.1.2. Implications from the analysis of socioeconomic and environmental factors and their direct and indirect effects

The analysis revealed that socioeconomic and personal factors such as NE, NR, CP, and the length of free time might influence the frequency of green and blue space visitation in addition to the daily environment. These factors should be considered when developing effective measures to reduce the inequality in access to these spaces. By analyzing these various factors and their direct and indirect effects, we found that NE can be a key factor for young age groups. In this generation, having NE was strongly correlated with visiting green and blue spaces. Opportunities to experience nature are important for them. As an effective measure to facilitate visitation and reduce access inequality to these spaces, creating and distributing such opportunities can be effective, especially for the young age groups.

NR is another important factor for all age groups. In particular, the association between NR and green and blue space access by the old age and middle-aged groups was relatively strong. Although these age groups generally have more NE compared with the young age group, and NE and NR have a certain positive correlation, NR as a psychological factor needs to be improved to reduce access inequality between the middle and old age groups. Obtaining knowledge on ecosystems and joining the activities of CP held in green and blue spaces can be effective in improving NR of these age groups.

CP was a significant factor for the frequency of visitation in the middle-aged and old age groups, unlike in the young age group. Connecting CP with green and blue space visitation in social activities and promoting such CP can be another effective measure for all age groups to facilitate nature visits.

The length of free time was less important as a factor in facilitating green and blue space visitation of the middle-aged group. This result suggests that people in the age group do not visit these spaces even if they have time because they might be busy with other things due to their high responsibilities in households and workplaces. The study recommends that when they are working or spending private time, it should be inside or near green and blue spaces so that they can have more chances to visit these places.

4.2. Association between the characteristics of daily environment and green and blue space visits

One of the unique findings of this study was the statistically significant correlation between the perimeter per area of agricultural land and the frequency of green and blue space visitation. In most related studies, the size of green areas, including forestland and agricultural land, was considered; however, their spatial form, which can be analyzed using indicators such as perimeter, was overlooked. In the field of urban environmental management, the perimeter of green areas has been analyzed mainly in research on the thermal environment (Du et al., 2017; Huang et al., 2018; Zhang et al., 2022). In the analysis of the thermal environment, it was pointed out that the perimeter of green areas is important, in addition to size, to generate a comfortable environment. A case study of the effects of the perimeter of green areas on human health conditions has been conducted in the field of public health (Chang et al., 2020); however, such research is still limited.

There are three possible reasons for the statistically significant positive correlation of the perimeter per area of agricultural land with visitation frequency. One is that a complex form of agricultural land, which is indicated by a long perimeter, can be an element of attractive traditional landscapes such as multifunctional Satoyama landscapes (Takeuchi et al., 2016). Satoyama landscapes are composed of complex mosaic land use patterns. Modernized agricultural land tends to have simple rectangular shapes. In contrast, traditional methods tend to have complex shapes based on topographical and historical features. Another possible reason is that complex forms of agricultural land, which is one of the main types of urban green areas, can provide a comfortable thermal environment. The other reason is that the long perimeter of individual land cover categories means the lands have many entrances for visitors. In particular, such long perimeters can be more important for lands with low vegetation, including agricultural lands and grasslands. This is because people can easily enter lands with many entrances. On the other hand, if lands with tall vegetation such as forestlands have high tree density and do not have proper management, it is difficult to enter the lands even if they have long perimeters and many entrances.

The correlation coefficients of the perimeter per area of agricultural land with other variables were relatively small. However, as Guo et al. (2023) suggest, based on an analysis of the built environment, there may be more complexity (ex. nonlinear), and strong correlations between the perimeter, visitation frequency, and NR, as shown in Fig. 6. This figure shows the average values of the frequency of visitation and NR in each perimeter range. It appears that there were positive correlations, although the relationships were not simply linear. Further analysis is needed to identify more detailed relationships among perimeter, visitation, and related factors, such as NR. The SEM results indicated the significant direct and indirect effects of the land cover indicators. Existing studies also suggest that such an environment can influence people's behavior and ways of thinking (Kyoi et al., 2023). The reasons and contexts for choosing the daily environment, including residential places, workplaces, and shopping destinations, and the effect of the perceived local environment on the reasons also need to be identified in future research.

5. Contextualized approach and future directions

The characteristics of Satoyama landscapes include biodiversity and historical human-nature interactions. Methods of urban environmental management based on citizens' awareness of biodiversity have been discussed in existing studies (Jo et al., 2022), and strategies to develop attractive green and blue spaces for citizens compatible with biodiversity conservation have been explored. There are two future research directions to develop design methods for attractive green and blue spaces with biodiversity: (1) identifying more detailed relationships between the daily environment and green and blue space visitation, and (2) detecting the relationships between biodiversity and spatial forms of daily environmental factors that can be analyzed by indicators such as the perimeter of certain land use categories. Developing and managing attractive and accessible green and blue spaces can contribute to equitable access to ecosystem services and sustainable urban environmental management.

In the context of urban environmental management, both the rights to the city and to nature are important; however, only one of the rights is focused on (McGrath et al., 2023). In Monsoon Asian urban areas, nature

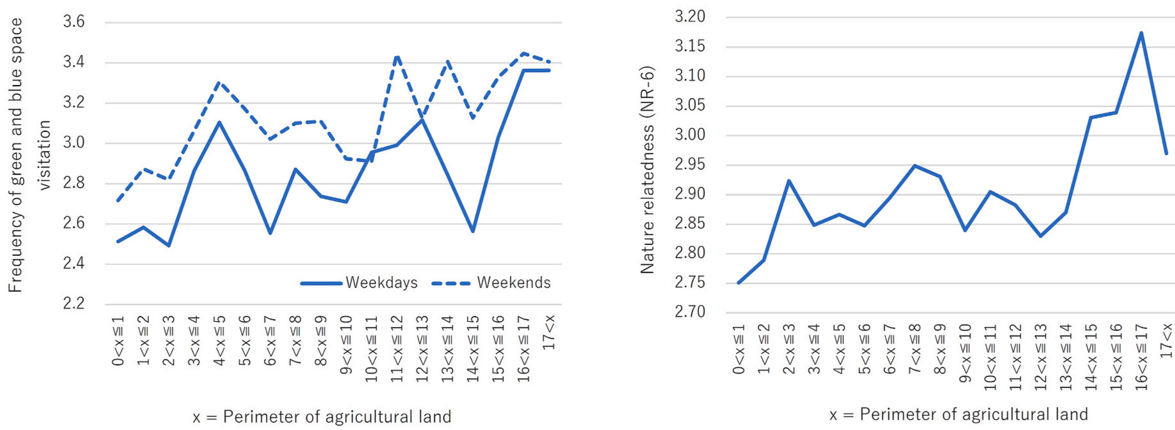

Fig. 6. Ranges of perimeter per area of agricultural land and average values of the frequency of the visitation and nature-relatedness in each range of the perimeter.

as the subject in the right to nature is not nature without human activities but "nature" with human activities, which are embedded in or attached to urban areas. They are called Satoyama or socio-ecological production landscapes. Such nature has the potential to become an urban commons or place for the collective actions of citizens (Shimpo, 2022; Sato et al., 2023). This potential is an important characteristic of nature-based solutions, which are measures to achieve biodiversity conservation and environmental justice (Frantzeskaki, 2019). Understanding the effects of nature in Asian urban areas on human health and the effective size and spatial form of nature can contribute to the social implementation of contextualized green and blue space management.

In the measures to achieve environmental justice through the reduction of inequalities in visitation to green and blue spaces, more efforts are needed to develop concrete measures for daily environmental conditions than for socio-economic conditions. Relevant environmental policies and spatial planning to address environmental inequalities are yet to be established. Welfare and educational policies were developed and highlighted. For example, further cross-scale research is needed to identify the specific types of attractive ecological and built environments and the ideal size and spatial patterns of such environments to facilitate nature visits. Furthermore, minorities, such as people with disabilities, must be included in research and action. A drawback of the survey method is that older generations may not be familiar with online surveys. In future research, other survey methods using interviews and papers could be utilized to improve accuracy, especially for the older generations. A long-term time series analysis is also necessary to verify the changes in the relationships between the frequency of green and blue space visits and socioeconomic and environmental factors. The findings and methodology of this study can contribute to the development of a basis for future research on green and blue space visitation and access inequality.

CRediT authorship contribution statement

Yuta Uchiyama: Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Akira Kyan:** Writing – review & editing, Methodology, Conceptualization. **Masayuki Sato:** Writing – review & editing, Resources, Project administration, Investigation, Conceptualization. **Atushi Ushimaru:** Writing – review & editing, Resources, Methodology, Investigation, Conceptualization. **Toshifumi Minamoto:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Mieko Kiyono:** Methodology, Investigation, Conceptualization. **Kazuhiro Harada:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Minoru Takakura:** Writing – review & editing, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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