Association between objective and subjective relatedness to nature and human well-being: Key factors for residents and possible measures for inequality in Japan's megacities

Uchiyama, Yuta ; Kyan, Akira ; Sato, Masayuki ; Ushimaru, Atushi ; Minamoto, Toshifumi ; Harada, Kazuhiro ; Takakura, Minoru ; Kohsaka,…

(Citation)
Landscape and Urban Planning,261:105377

(Issue Date)
2025-09

(Resource Type)
journal article

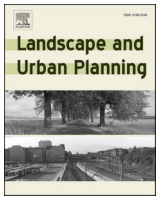
(Version)
Version of Record

Landscape and Urban Planning 261 (2025) 105377

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan



Association between objective and subjective relatedness to nature and human well-being: Key factors for residents and possible measures for inequality in Japan's megacities

Yuta Uchiyama [a,*], Akira Kyan [b,c], Masayuki Sato [a], Atushi Ushimaru [a], Toshifumi Minamoto [a], Kazuhiro Harada [a], Minoru Takakura [d,b], Ryo Kohsaka [e], Mieko Kiyono [a], Tetsuya Tsurumi [f], Atsuhiko Uchida [a], Tatsuya Saga [a], Kenta Yamamoto [a]

[a] Graduate School of Human Development and Environment, Kobe University, Tsurukabuto 3-11, Nada-ku, Kobe 657-8501 Japan
[b] Faculty of Medicine, University of the Ryukyus, Kiyuna 1076, Ginowan City, Okinawa 901-2720, Japan
[c] Graduate School of Medicine, Kyoto University, Yoshida-Konoe-cho, Sakyo-ku, Kyoto 606-8501 Japan
[d] Graduate School of Sports and Health Sciences, Meio University, Biimata 1220-1, Nago City, Okinawa 905-8585, Japan
[e] Graduate School of Agricultural and Life Sciences, The University of Tokyo, Yayoi 1-1-1, Bunkyo ku, Tokyo 113-0032, Japan
[f] Graduate School of Social Sciences, Nanzan University, Yamazatocho 18, Showa Ward, Nagoya, Aichi 466-0824 Japan

HIGHLIGHTS

- Human well-being was correlated with the objective and subjective nature relatedness.
- Respondents were categorized based on area deprivation index (ADI) and urbanicity.
- Nature visits of subgroups with high ADI values had positive correlations with their self-rated health.
- Childhood nature experience significantly predicted adult well-being including self-rated health.
- Nature relatedness is a key factor positively correlated with residents' health in deprived areas.

ARTICLE INFO

Keywords:
Nature relatedness
Childhood nature experience
Self-rated health
Psychological health
Purpose of life
Life satisfaction
Area deprivation index

ABSTRACT

Enhancing human well-being based on relatedness to nature requires a clear understanding of the associations between nature relatedness and well-being, particularly in urban contexts. The socioeconomic and environmental characteristics of neighborhoods are associated with residents' perceptions of and access to nature. However, research addressing the interplay between area-level deprivation, objective and subjective nature relatedness, and well-being remains limited. To address this, we surveyed 3500 residents in Japan's Tokyo-Yokohama and Osaka-Kobe metropolitan areas, categorizing respondents by the Area Deprivation Index (ADI) and urbanicity. Frequent nature visits in highly urbanized areas were positively associated with various well-being indicators. In high-ADI areas, nature visits correlated with better self-rated health, and the proportion of non-built-up areas was linked to improved well-being measures. Childhood experiences with nature significantly predicted adult well-being and that were associated with improved self-rated health and low psychological distress, as measured by the Kessler Psychological Distress Scale (K6). Objective factors such as access to natural spaces, and subjective factors such as perceived relatedness to nature, were deemed critical for well-being. The results suggest that equitable access to nature and early-life exposure to nature are essential for public health, particularly in deprived areas. Addressing disparities in nature access can contribute to reducing inequalities in well-being, underscoring the need for policies promoting nature relatedness to support well-being in urban communities.

* Corresponding author at: Graduate School of Human Development and Environment, Kobe University, Tsurukabuto 3-11, Nada-ku, Kobe 657-8501, Japan.
E-mail address: yuta.uchiyama@landscape.kobe-u.ac.jp (Y. Uchiyama).

https://doi.org/10.1016/j.landurbplan.2025.105377
Received 26 June 2024; Received in revised form 4 February 2025; Accepted 14 April 2025
Available online 3 May 2025

1. Introduction

Frequent access to nature can decrease the risk of various health problems (Shanahan et al., 2016; Martin et al., 2020), with significant positive correlations observed between nature access and well-being (Remme et al., 2021; Astell-Burt et al., 2023). For example, the existence of nature can provide relaxation effects (Raanaas et al., 2012; Korpela et al., 2017) and reduce harmful elements from the local environment (Law et al., 2022; Elliott et al., 2023). However, inequality in nature access is a serious urban issue that reflects socioeconomic inequality (Shanahan et al., 2014; Loos et al., 2023). Proper nature relatedness, meaning subjectively perceived human–nature relationships and objectively observed relationships, including nature visits and nature exposure, should be ensured across socioeconomic and environmental backgrounds to improve human well-being.

Both subjectively perceived and objectively observed nature relatedness were particularly important during the COVID-19 pandemic period (Lopez et al., 2021; Sia et al., 2022; Uchiyama & Kohsaka, 2022). People underwent social distancing and were under substantial stress owing to the restricted social and economic activities. In the post-pandemic era also, adequate access to nature remains important. For example, the General Assembly of the United Nations adopted a relevant resolution, "The human right to a clean, healthy and sustainable environment" (A/RES/76/300), on July 28, 2022. To realize this human right, governments need to ensure physical accessibility to public green spaces and other basic environmental services (Preston, 2024). This resolution is linked with the Sustainable Development Goals (A/RES/70/1) adopted on October 21, 2015, especially with Goal 11.7 to provide universal access to safe, inclusive, and accessible green and public spaces.

Area-level deprivation and individual or household socioeconomic status are significant factors impacting the equality of access to nature (Boyd et al., 2018; Mohan & Barlow, 2023; Nakaya et al., 2014). Area-level deprivation is a socioeconomic status at the district level that can be assessed by indicators such as unemployment rate, proportion of households with single older individuals, and proportion of blue-collar workers (Nakaya et al., 2014). Individual socioeconomic status, quality or characteristics of neighborhood communities, and landscape of residential districts might be associated with the local perception of nature or accessibility of nature for each resident (Jones et al., 2009; Mouratidis, 2020). Therefore, depending on the status of area-level deprivation, objective and subjective nature relatedness and relationships between well-being and the two types of nature relatedness may differ. However, analysis of area deprivation levels in the research on nature relatedness and well-being remains limited (Boyd et al., 2018). By understanding the relationships, priority policies and actions to improve well-being based on nature relatedness can be identified for each residential district with a different deprivation status. Possible priority policies include introducing or redesigning natural areas to improve objective nature relatedness and implementing environmental educational programs to enhance subjective nature relatedness. In this context, understanding the status of nature relatedness and well-being in different area deprivation levels is necessary for urban planning and environmental management.

The correlations between objective and subjective relatedness to nature and human well-being have been analyzed. Objective relatedness to nature can be analyzed by focusing on the frequency of visiting nature, which is typically positively correlated with well-being in different regional contexts (White et al., 2019; Hong et al., 2019; Garrett et al., 2023). Nature access and contact are particularly correlated with human health in urban settings (Browning et al., 2022). Subjective relatedness to nature is another important domain of research (Nisbet et al., 2011; Dean et al., 2018). This is subjectively perceived in human–nature relationships and can be interpreted as psychological connectedness to nature and a part of people's identity related to nature (Nisbet et al., 2011). Subjective relatedness can be generated through experiencing activities in nature or learning about nature. The nature relatedness index (NR) proposed by Nisbet & Zelenski (2013) has been widely used in studies on well-being (Zelenski & Nisbet, 2014; Keaulana et al., 2021; Krols et al., 2022; Shentova et al., 2022). Regarding overall trends, NR positively correlated with well-being, including self-rated health aspects (Kövi et al., 2023). However, negative correlations between certain aspects of nature relatedness with well-being have also been detected (Dean et al., 2018). The detailed associations between subjective nature relatedness and well-being should be analyzed by comparing them with the associations between objective relatedness to nature, such as nature access and exposure and well-being. To understand the relative importance of individual types of nature relatedness, researchers should identify partial correlation coefficients between well-being and each type of nature relatedness in an analysis model. This can elucidate the implications of methods to improve well-being based on the enhancement of various types of nature relatedness.

The association between nature relatedness and well-being can differ depending on environmental conditions such as urbanicity. For example, correlations between accessibility to nature and well-being can be stronger in areas with higher urbanicity (Sarkar et al., 2018; Browning et al., 2022), which are urbanized areas with high percentages of built-up areas (Xu et al., 2023). Browning et al. (2022) reviewed existing papers and identified that more than 20 studies detected stronger protective associations between green areas and human health in high urbanicity contexts than in low urbanicity contexts, with only six studies reporting contrasting results. Sarkar et al. (2018) identified relatively strong protective effects of green areas in high urbanicity and deprived contexts. They suggested that the stronger restorative potential of green areas can be pronounced in communities under high levels of stress owing to their highly urbanized neighborhood environment. Because of the importance of urbanicity in the association between nature relatedness and well-being, it should be added as a variable in the analysis model of well-being and nature relatedness.

Managing the socioeconomic and environmental factors of individuals and considering social capital are important in the analysis of nature relatedness and well-being (Zhang et al., 2020). Social capital can be defined as "the resource available to actors as a function of their location in the structure of their social relations" (Adler & Kwon, 2002). Through the enhancement of social factors, such as place attachment and citizen participation, social capital can be a pathway to contribute to improving well-being (Jennings & Bamkole, 2019). To develop social capital through green spaces in urban areas where diverse communities exist, urban planners must consider the perceptions of people with different backgrounds when planning urban green spaces (Jennings et al., 2024). The factors, including place attachment and citizen participation, are also related to nature relatedness and local environmental conditions (Brown & Raymond, 2007; Raymond et al., 2010; Kiss et al., 2022; Yoshida et al., 2022) and should be considered in the analysis of nature relatedness and well-being.

In the context of socioeconomic and environmental inequality and its associations with well-being, global urbanization is continuing and urban development is accelerating, particularly in large Asian cities, leading to the formation of megacities with a population of more than 10 million (Uchiyama & Okabe, 2012; Zhao et al., 2017; Li et al., 2018). In megacities, the degradation of nature and socioeconomic inequality is increasing in severity (Wang et al., 2020; Kidokoro et al., 2022; Shahaboonin et al., 2023; Wu et al., 2024). Socioeconomic inequality is reflected in spatial segregation in large cities (Uesugi, 2021). Even in relatively high-income countries, problems of inequality are serious. For example, in Japan, relative poverty is a serious concern because of its correlation with poor health conditions (Saito et al., 2014). The COVID-19 pandemic exacerbated the factors of health inequality correlated with socioeconomic disparities (Kyan & Takakura, 2022, 2023), with more severe impacts in large cities owing to the poor initial status of inequality. Analysis of the relationships among objective and subjective relatedness to nature, the residential environment, and well-being can

provide a basis for policy making to effectively improve residents' well-being in large cities experiencing serious inequality in various aspects.

Studies have identified that proximity to green spaces and frequency of green space visits, which can be indicators of objective relatedness to nature, are correlated with the health conditions of residents with relatively low socioeconomic status in urban settings (Rigolon et al., 2021; Fian et al., 2024). Mitchell et al. (2015) suggested that the socioeconomic inequality in psychological well-being was narrow among urban residents who had subjectively good access to green or recreational areas. Two explanations for the positive correlations between objective nature relatedness and the well-being of communities with low socioeconomic status have been suggested. The first explanation is that green spaces provide strong psychological restoration effects for people under substantial levels of stress (Mitchell et al., 2015). The second explanation is that people living in such communities depend on neighborhood green spaces to improve their health because of poor access to other resources (Rigolon et al., 2021). However, the relative importance of subjective nature relatedness on well-being compared with that of objective relatedness to nature remains poorly understood (Martin et al., 2020; Liu et al., 2022). Furthermore, social factors, including place attachment and citizen participation, should be controlled in the analysis model of well-being to accurately identify the association between objective and subjective nature relatedness and well-being.

This study analyzed the relationships between objective and subjective relatedness to nature and the well-being of people with various socioeconomic and environmental backgrounds in the context of megacities in Japan while considering the social capital indicators as independent variables in analysis models. Our study considered three variables to analyze the associations between nature relatedness and well-being: (i) area-level deprivation, (ii) objective and subjective nature relatedness, and (iii) well-being. Research addressing the interplay between the three variables remains limited, although it is important to understand relationships between well-being and the two types of nature relatedness in the different conditions of area-level deprivation. We aimed at addressing this gap by simultaneously analyzing those three variables. Moreover, we considered urbanicity in our analysis models as a factor to show environmental backgrounds of people and examined whether the associations between nature relatedness and well-being in different urbanicity contexts were consistent between our study and past studies.

We tested the following hypotheses (H1–4):

H1. The correlation between objective relatedness to nature and well-being is stronger for residents in areas with high urbanicity.
H2. The correlation between objective relatedness to nature and well-being is stronger for residents in areas with high area deprivation index values.
H3. Subjective relatedness to nature is correlated with the well-being of residents in any residential area.
H4. Components of social capital are correlated with the well-being of residents in any residential area.

These hypotheses were generated considering existing studies. For H1, Sarkar et al. (2018) found that the correlation between nature visitation and well-being in the United Kingdom tended to be stronger in areas with a relatively high degree of urbanicity. However, such a tendency might not be found in other regional contexts, requiring analysis in the Asian context. In addition, the study did not consider subjective nature relatedness, which was incorporated in our analysis models. For H2, research conducted in Austria showed that the correlation between green area visits and the well-being of people with low household income tended to be stronger than that of people with high household income (Fian et al., 2024). However, the study was conducted in Europe and did not consider area-level deprivation. By contrast, in the present study, we focused on the Asian context and used ADI to test the hypothesis. For H3, the association between nature relatedness and well-being of individuals with various socioeconomic statuses has been analyzed using NR (Zelenski & Nisbet, 2014; Dean et al., 2018); however, studies conducted outside Europe and North America are limited, rendering testing the hypothesis in Asia and other regional contexts vital. For H4, the association between social capital and well-being has been analyzed (Jennings & Bamkole, 2019; Yoshida et al., 2022); however, existing studies tended not to empirically analyze both social capital and relatedness to nature in a correlation analysis with well-being. When analyzing the indicators of such relatedness to nature and well-being, social capital indicators should be controlled in the analysis model to understand the relative importance of those individual indicators for well-being.

The existing studies mostly analyzed relevant variables separately. For example, research on the associations between objective relatedness to nature and well-being tends to not consider subjective relatedness to nature and vice versa (Liu et al., 2022). Past studies typically controlled sociodemographic factors in the analysis models; however, social capital factors have tended to be overlooked and not controlled, even in the limited studies that analyzed both objective and subjective nature relatedness in a regression model for well-being (Martin et al., 2020; Liu et al., 2022).

The originality of our research is the identification of the relative importance of both objective and subjective relatedness to nature to well-being in different levels of area deprivation and urbanicity by controlling individual demographic attributes and social capital components. We focused on megacities in Japan to fill the gap in relevant empirical research on the relationships between well-being and objective and subjective nature relatedness.

2. Methodology

2.1. Study sample

To analyze the associations among objective and subjective relatedness to nature, residential environment, and human well-being, we implemented an online survey in the Tokyo-Yokohama and Osaka-Kobe metropolitan areas, the first and second most populated areas in Japan, respectively, from March 24 to 28, 2023. The Tokyo-Yokohama metropolitan area comprises 23 wards in Tokyo and Yokohama City. The Osaka-Kobe metropolitan area comprises Osaka City, Kobe City, and eight surrounding municipalities (Fig. 1).

The respondents were registered panel members of MyVoice Communications Inc. This survey company had 1,079,274 registered members in Japan in February 2024. Online surveys conducted using this survey company have been used in studies in different academic fields, including social science and medicine (Ida et al., 2015; Takeuchi et al., 2021; Kambara et al., 2023). The respondents in our study were recruited using online advertisements, and after registering, they could respond to online surveys. The questionnaire was distributed to the registered members residing in the target areas. In the survey sample collection, the percentages of the population per 10-year intervals were used to create age groups. We set the target gender ratio to 1:1. Before starting the survey, the purpose of the survey and topics of the questions were shared with respondents, and we obtained their informed consent to participate. In any phase of the survey, the freedom to quit the survey was guaranteed. Respondents who did not answer seriously were removed from the study sample. For example, respondents who answered the questions too quickly or those who repeated the same answers were excluded.

After screening the survey results, the number of valid responses was 3500 (Table 1). We set this target number of responses to fulfil the minimum number of responses computed using Cochran's formula (Bartlett et al., 2001), even if we categorized the responses into several groups and separately analyzed them to test the hypotheses. The minimum number of samples computed at the 95 % confidence interval with

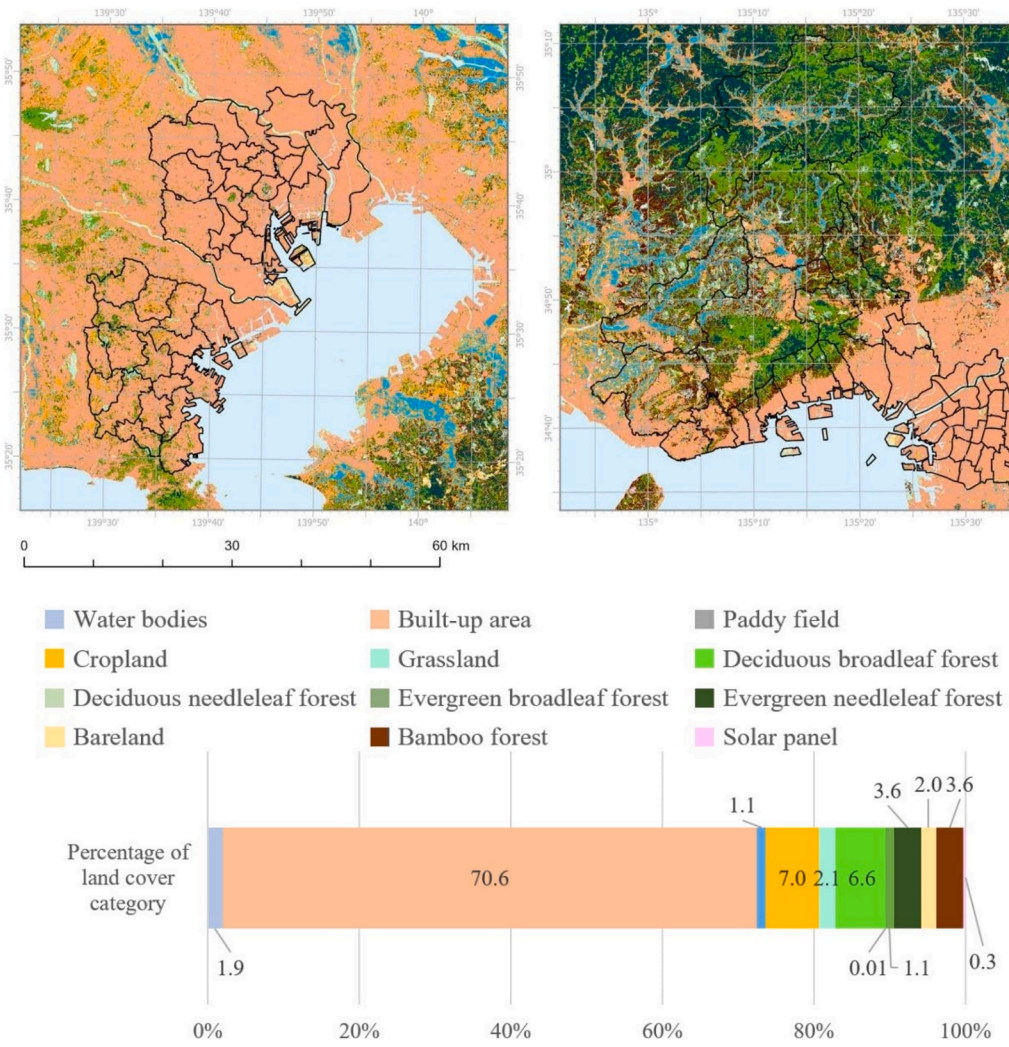


Fig. 1. Land cover maps of the research site (Tokyo-Yokohama and Osaka-Kobe metropolitan areas) and percentages of landcover categories.

Table 1
Number and percentage of population and respondents in each age group.

Age group	Total population in 2020	Survey respondents
20–39	5,314,051 (32.4 %)	1,140 (32.6 %)
40–59	5,620,479 (34.3 %)	1,220 (34.9 %)
>60	5,471,098 (33.3 %)	1,140 (32.6 %)
Total > 20 years	16,405,628 (100 %)	3,500 (100 %)

Note: Data on population were obtained from Japan's 2020 population census.

a 5 % sampling error using the formula was 384. The formula we used based on the population census in 2020 was $n = n_0/(1 + n_0/N)$, where $n_0 = (t^2 \times p \times q)/d^2$, t is the value of the selected alpha level ($\alpha = 0.05$, critical value = 1.96), p is the possible proportion of the population that has the attribute in question (0.5), $q = 1 - p$, d = acceptable margin of error (0.05), and N = population size.

2.2. Measurements

The variables used in this research are provided in Table 2. Individual attributes, including (1) age, (2) gender, (3) household income, (4) occupation type, (5) educational background, (6) number of children in household, (7) marital status, (8) status of physical activities (Murase et al., 2002; Craig et al., 2003; IPAQ: International Physical Activity Questionnaire, 2005), and (9) length of free time on weekends (Shan, 2020), were obtained. The variables of objective relatedness to nature were (10) frequency of nature visitation on weekends and (11) percentages of land cover categories except built-up areas in residential districts. The variables of subjective relatedness to nature were (12) childhood nature experience (Aoshima et al., 2023; Barrable et al., 2024) and (13) NR (Nisbet and Zelenski, 2013). These were analyzed as independent variables. Childhood nature experience was analyzed as a subjective nature relatedness variable because it was not the exact frequency of the experience but the subjective amount of the experience based on a 4-point Likert scale (see Appendix). It was interpreted as a part of respondents' identity related to nature. NR comprised six questions; we computed Cronbach's alpha for the responses to the questions, and the value was 0.909, indicating internal consistency. As another category of independent variables that indicate social aspects of respondents, data on social capital-related indicators, including (14) citizen participation and (15) place attachment, were collected based on a conceptual framework proposed by Acedo et al. (2017) for the sense of place and social capital. We used questions to collect the responses for these two variables by using the questions tested by Saito et al. (2017).

The data of well-being indicators collected and analyzed as dependent variables were (a) self-rated health (Jylhä, 2009), (b) psychological health status (K6) (Kessler et al., 2002), (c) life satisfaction (Weber et al., 2015), and (d) indicator related to purpose of life (Janicke-Bowles et al., 2019). Self-rated health was used as an indicator to assess total health conditions, including physical and psychological health aspects (Jylhä,

Table 2
Variables and their references and sources.

Dependent/ Independent	Variable categories	Variables	References	Sources
Dependent variables	Overall health	(a) self-rated health	Jylhä, 2009	Online survey of this research
	Psychological Health	(b) K6	Kessler et al., 2002	
	Hedonic well-being	(c) life satisfaction	Weber et al., 2015	
	Eudaimonic well-being	(d) indicator related to purpose of life	Janicke-Bowles et al., 2019	
Independent variables	Basic individual attributes	(1) age		Online survey of this research
		(2) gender		
		(3) household income		
		(4) occupation type		
		(5) educational background		
		(6) number of children in the household		
		(7) marital status		
		(8) status of physical activities	Murase et al., 2002; Craig et al., 2003	
		(9) length of free time on weekends	Shan, 2020	
	Objective relatedness to nature	(10) frequency of nature visitation on weekends		
		(11) percentages of land cover categories except built-up areas in residential districts		Land cover GIS data
	Subjective relatedness to nature	(12) childhood nature experience	Barrable et al., 2024; Aoshima et al., 2023	Online survey of this research
		(13) NR-6	Nisbet & Zelenski, 2013	
	Social capital-related indicators	(14) citizen participation	Acedo et al., 2017; Saito et al., 2017	
		(15) place attachment		
	Area deprivation index	(16) ADI	Nakaya et al., 2014; Hanibuchi and Nakaya, 2020	Computed based on population census

2009). K6 is a reliable indicator to assess psychological health conditions such as anxiety disorder (Furukawa et al., 2003). K6 comprised six questions and we computed Cronbach's alpha for the answers, achieving a value of 0.936, indicating internal consistency. In addition to the indicators directly related to health conditions, we used eudaimonic and hedonic well-being indicators, with the former being an indicator for the purpose of life and the latter being an indicator for life satisfaction.

Using the online survey, we collected data on these indicators, except for Indicator (11): percentages of land cover categories. High-resolution land cover data provided by the Japan Aerospace Exploration Agency were used to calculate the percentages of land cover categories, except built-up area, in the residential districts. We focused on nature, including different types of ecosystems such as agricultural lands, forestlands, and waterbodies, because such complex nature is widely recognized as a socioecological landscape, so-called *Satoyama* by the residents in the research site (Kohsaka et al., 2013). The grid resolution of the land cover data was 10 m. The zip code district was used as a residential district in the analysis. The respondents provided the zip code of their residential district in the survey. The Zonal Statistics function in ArcGIS Pro (version 2.6.2) was used to aggregate areas of the land cover categories into zip code districts. To manage these data, ArcGIS Pro was used. In addition to those indicators, the ADI was used in the analysis. The index values were computed using the method of Nakaya et al. (2014). An area-based approach was necessary to consider the inequality in access to nature and in building proper relatedness with nature. We used the ADI as an independent variable and to categorize the respondents. The list of variables and supplementary materials for analysis results are provided in Appendix.

2.3. Statistical analysis

The collected data were analyzed using ordinal logistic regression models for the well-being indicators except K6 and linear regression models for K6 (Section 3.1). To identify the overall relationships between the dependent and independent variables, we performed redundancy analysis (RDA) (Section 3.1). RDA has been used in various academic fields, including ecology and social science (Legendre et al., 2011; Zhang et al., 2023). RDA can be used to analyze a relationship between a response matrix and an explanatory matrix (Rao, 1964), meaning that associations between multiple dependent variables and independent variables can be analyzed in an RDA model. After applying these analysis methods to all the respondents, we categorized the respondents based on the ADI and percentages of built-up areas in their residential districts. This categorization was conducted because studies have suggested that the correlations between nature access or nature relatedness and well-being can be moderated by socioeconomic status and the degree of urbanicity of residential areas (Sarkar et al., 2018; Fian et al., 2024).

First, based on the quartiles of the ADI, respondents were categorized into four groups. Second, each group was categorized into two subgroups based on the median of the percentages of built-up areas in each group. By using the first and second steps, the respondents were categorized into eight subgroups. Next, we developed the ordinal logistic regression models and linear regression model for each subgroup. While the urbanicity as a context of residents has been analyzed in existing studies (Sarkar et al., 2018), residents of areas with different ADI values have not been compared. Considering these circumstances, we first analyzed the eight subgroups comprising four categories based on the ADI and two categories based on urbanicity (Section 3.2.1). Furthermore, to confirm the trend detected by the analysis of the eight subgroups, we analyzed another set of eight subgroups comprising two categories based on the ADI and four categories based on urbanicity (Section 3.2.2). To complement these analyses, we analyzed four subgroups comprising two categories based on the ADI and two categories based on urbanicity. The analysis result of the four subgroups is provided in the Appendix. To fulfill the minimum number of responses calculated in Section 2.1, we limited the number of subgroups to eight.

3. Result

3.1. Analysis of all respondents

The results of the analyses on each well-being indicator are provided in Table 3. The detailed results of the logistic and linear regressions are listed in Appendix. We found no multi-collinearity in the variables (variance inflation factor (VIF) < 2, tolerance > 0.5). Regarding the basic individual attributes, respondents who were married and had higher household incomes tended to have better well-being. Age and

Table 3
Analysis results of all respondents.

Independent variables	K6 (psychological health)	Self-rated health	Life satisfaction	Purpose of life
Gender (1: male, 2: female)		(+)**	(+)**	(+)**
Age	(−)**	(−)**		
Income	(−)**	(+)**	(+)**	(+)**
% of non-built-up areas	(−)*			
Frequency of nature visits		(+)**	(+)**	(+)**
Degree of physical activities	(+)†	(+)*		(+)*
Childhood nature experience	(−)†	(+)**		(+)*
Nature relatedness (NR-6)			(+)*	(+)*
Citizen participation			(+)**	(+)**
Place attachment	(−)**	(+)**	(+)**	(+)**
Length of free time	(−)**	(+)†		
Having children or not				
Educational backgrounds			(+)*	
Having a stable job or not		(+)**		
Marital status	(−)**	(+)**	(+)**	(+)**
ADI (area deprivation index)			(−)†	

Note: **: $p < 0.01$, *: $p < 0.05$, †: $p < 0.1$. Reference levels: Gender—1: male, 2: female; Having children or not—0: do not have, 1: have; Educational backgrounds—0: up to high school, 1: university or graduate school; Having a stable job or not—0: part time/student/unemployed, 1: full-time employed or self-employed; Marital status—0: unmarried, 1: married.

gender also correlated with well-being: for K6 (psychological health status), the younger the respondent, the higher the K6 value, suggesting that older respondents had better psychological health conditions. By contrast, younger generations tended to have better self-rated health than older generations, including physical and psychological health aspects. By gender, female respondents demonstrated better values than male respondents for three well-being indicators: self-rated health, life satisfaction, and purpose of life.

Length of free time positively correlated with self-rated health and psychological health assessed by K6. Furthermore, respondents with relatively stable jobs tended to have better self-rated health conditions. Respondents with higher educational backgrounds tended to have higher life satisfaction. The degree of physical activity was positively correlated with self-rated health and the indicator of purpose of life. However, physical activity intensity was negatively correlated with psychological health. K6 positively correlated with the degree of physical activity.

Regarding the social capital indicators, place attachment had correlations with all the well-being indicators. The higher the place attachment, the better the well-being assessed by the four indicators. Citizen participation had positive correlations with two well-being indicators: life satisfaction and purpose of life. ADI had a negative correlation with life satisfaction. Respondents living in areas with higher area-level deprivation tended to have lower life satisfaction.

Among the indicators of objective relatedness to nature, frequency of nature visits had positive correlations with self-rated health conditions, life satisfaction, and the indicator of purpose of life. Percentages of land cover categories except built-up area had a positive correlation with psychological health conditions, as K6 had a negative correlation with the percentages of the land cover categories. Among the indicators of subjective nature relatedness, frequency of childhood nature experience had positive correlations with psychological and self-rated health conditions and the indicator of purpose of life. The NR had positive correlations with life satisfaction and the indicator of purpose of life. Although the combinations of significant indicators of objective and subjective relatedness to nature for each well-being indicator differed, indicators of both types of nature relatedness had positive correlations with each well-being indicator.

The RDA scatter plot shows that indicators had positive correlations if they were plotted in similar directions from the origin. We conducted permutation tests to examine the significance of the model and axes. The RDA model, x-axis (RDA1), and y-axis (RDA2) were significant ($p < 0.01$). The proportions explained by RDA1 and RDA2 were 13 % and 2 %, respectively. The overall trend shown in Fig. 2 is consistent with the result indicated in Table 3. Frequency of nature visits and the NR were located in relatively similar directions as the locations of self-rated health, life satisfaction, and the indicator of purpose of life. The percentages of the land cover categories, except for built-up area and frequency of childhood nature experience, were plotted in the opposite direction of the location of K6; thus, these two indicators of objective and subjective nature relatedness were positively correlated with better psychological health conditions.

The results, thus, suggest a difference between the psychological health indicator (i.e., K6) and other well-being indicators. Only K6 had a negative correlation with the land cover indicator, with the other three well-being indicators exhibiting positive correlations with frequency of nature visits.

3.2. Analysis of eight subgroups

3.2.1. Analysis of eight subgroups (ADI: four categories, Urbanicity: two categories)

The analysis results of the eight subgroups (ADI: four categories, Urbanicity: two categories) are indicated in Table 4, and the detailed results of the individual logistic and linear regressions are listed in the Appendix. Four groups in the ADI (Highest, Higher, Lower, and Lowest) were categorized based on the quartiles of the ADI values. High urbanicity indicated that the percentages of built-up areas in residential districts were higher than the median of the percentages in each group. Low urbanicity indicated that the percentages were lower than the median. The overall trends of correlations of basic individual attributes with well-being indicators were consistent with the analysis results of all respondents. Having children was not significant in the models of all respondents. In the models of Higher ADI + High Urbanicity and Highest ADI + Low Urbanicity, having children had significant positive correlations with self-rated health conditions.

Correlation patterns of frequency of nature visitations with well-being indicators differed between subgroups with different urbanicity and ADI values. The High Urbanicity subgroups' numbers of well-being indicators correlated with frequency of nature visits tended to be larger than those of Low Urbanicity subgroups. In the High Urbanicity context, nature visits were more significant for various aspects of well-being than those in the Low Urbanicity context. Regarding the difference between subgroups with different ADI values, self-rated health conditions tended to have positive correlations with frequency of nature visits of Higher ADI and Highest ADI subgroups except for Higher ADI + Low Urbanicity. By contrast, for Lower ADI and Lowest ADI subgroups, self-rated health conditions had positive correlations only with Lower ADI + High Urbanicity's frequency of nature visits. Regarding the life satisfaction and indicator of purpose of life, Lower ADI and Lowest ADI subgroups, except Lowest ADI + Low Urbanicity's indicator of purpose of life, had positive correlations with frequency of nature visits. For Higher ADI and Highest ADI subgroups, only life satisfaction of Higher ADI + High Urbanicity and the indicator of purpose of life of Highest ADI + High Urbanicity and Highest ADI + Low Urbanicity were correlated with frequency of nature visits. Thus, the High Urbanicity

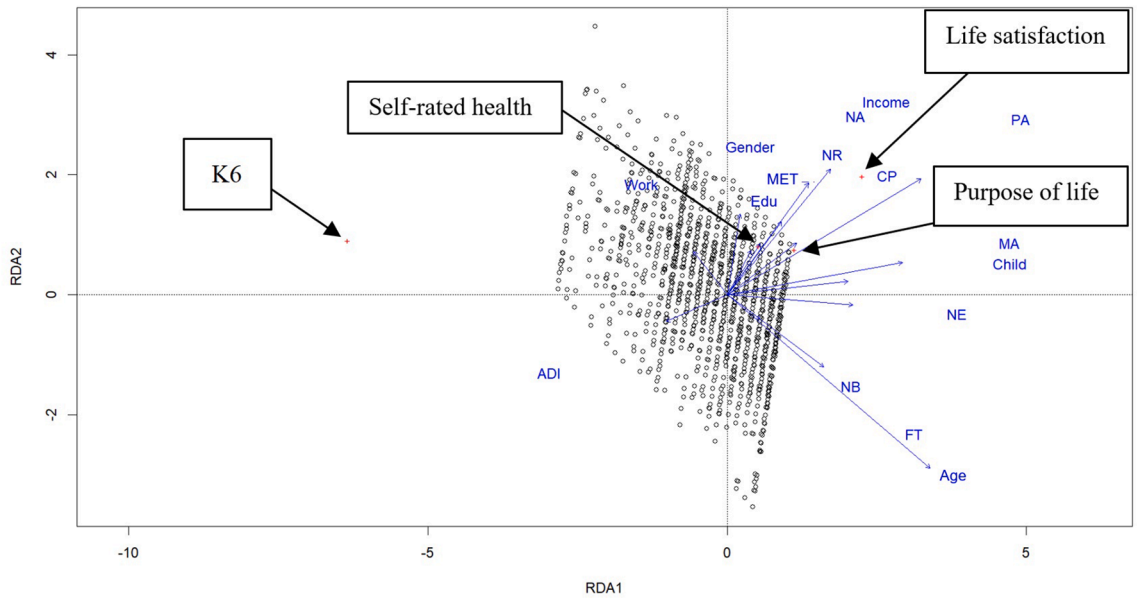


Fig. 2. Redundancy analysis of all respondents. Dependent variables: K6 (psychological health), self-rated health, life satisfaction, indicator of purpose of life. Independent variables: Age, gender, income (household income). NA: frequency of nature visits, NB: percentage of non-built-up areas, NE: childhood nature experience, NR: nature relatedness, MET: degree of physical activities, PA: place attachment, CP: citizen participation, FT: length of free time on weekends, Edu: educational backgrounds, Work: having stable job or not, MA: marital status, Child: having children or not, ADI: area deprivation index.

subgroups' frequency of nature visits tended to have correlations with various well-being indicators. The frequency of nature visits of subgroups with high ADI values tended to be correlated with the indicator directly related to health (self-rated health). The nature visits of subgroups with low ADI values tended to be correlated with the indicators of other aspects of well-being, such as life satisfaction.

Several subgroups of the percentages of land cover categories, except built-up areas, were correlated with the well-being indicators. K6 of Lower ADI + Low Urbanicity, self-rated health and life satisfaction of Higher ADI + High Urbanicity, and the indicator of purpose of life of Higher ADI + Low Urbanicity were correlated with the percentages of the land cover categories. The correlations between the land cover indicator and well-being indicators were observed in the groups with intermediate ADI values.

The frequency of childhood nature experience of several subgroups was also correlated with well-being indicators: K6 and self-rated health. The correlation between K6 and frequency of the experience was detected only in the Lowest ADI + Low Urbanicity subgroup. The correlations between self-rated health and the frequency of the experience were observed in four subgroups: Lowest ADI + High Urbanicity, Lower ADI + High Urbanicity, Higher ADI + Low Urbanicity, and Highest ADI + Low Urbanicity.

The NR tended to be correlated with life satisfaction and the indicator of purpose of life of certain subgroups. The number of subgroups with low ADI values that had correlations between the NR and those well-being indicators was greater than the number of subgroups with high ADI values. Furthermore, the High Urbanicity subgroups had more subgroups that had correlations between NR and those well-being indicators than the Low Urbanicity subgroups.

Among the subjective nature relatedness indicators, the frequency of the nature experience tended to have complex patterns of correlations. The frequency of the nature experience was correlated with K6 only in the model of the subgroup (Lowest ADI + Low Urbanicity) and with self-rated health in the models of the two High Urbanicity subgroups with low ADI values and in the models of the two Low Urbanicity subgroups with high ADI values. The NR tended to have correlations with the well-being indicators of subgroups with low ADI values and High Urbanicity subgroups.

Negative correlations between the nature relatedness indicators and well-being indicators were also detected in two subgroups. Lowest ADI + High Urbanicity's indicator of purpose of life had a negative correlation with the land cover indicator. Higher ADI + Low Urbanicity's K6 had positive correlations with the frequency of nature visits and with NR, meaning that their psychological health conditions assessed by K6 tended to be negatively correlated with these nature relatedness indicators.

3.2.2. Analysis of eight subgroups (ADI: two categories, Urbanicity: four categories)

The analysis results of the eight subgroups (ADI: two categories, Urbanicity: four categories) are shown in Table 5. The detailed results of the individual regression models are listed in the Appendix. High ADI indicated that the ADI values were higher than the median of the ADI values in each group. Low ADI indicated that the ADI values were lower than the median. Four groups regarding Urbanicity (Highest, Higher, Lower, and Lowest) were categorized based on quartiles of percentage of non-built-up areas. The overall trends of correlations of basic individual attributes with well-being indicators were consistent with the analysis results of all respondents. Having children, which was not significant in the models of all respondents, had significant positive correlations with self-rated health conditions in two subgroups with High ADI and significant negative correlations with self-rated health conditions in two subgroups with Low ADI.

Frequency of nature visits tended to be positively correlated with diverse well-being indicators of Higher Urbanicity subgroups. Furthermore, self-rated health conditions tended to have positive stronger correlations with frequency of nature visits of High ADI subgroups. In particular, the frequency of nature visits of subgroups with higher ADI values and higher urbanicity tended to be relatively strongly correlated with self-rated health. Regarding life satisfaction and the indicator of purpose of life, Low ADI subgroups had positive stronger correlations with frequency of nature visits. These results are consistent with the results in the previous subsection.

The percentage of non-built-up areas was positively correlated with the well-being indicators of Lower and Lowest Urbanicity subgroups. Psychological health condition assessed by K6 of Low ADI + Lowest

Table 4
Subgroups (Area Deprivation Index [ADI]: four categories, Urbanicity: two categories).

HU subgroup	Independent variables	K6	Self-rated health	Life satisfaction	Purpose of life	LU subgroup	Independent variables	K6	Self-rated health	Life satisfaction	Purpose of life
	Gender		(F)*	(F)**	(F)†		Gender	(M)*	(F)*	(F)**	(F)**
	Age	(-)**	(-)**				Age	(-)**			
	Income	(-)*	(+)†	(+)*			Income	(-)**	(+)*	(+)**	(+)**
	% of non-built up areas				(-)†		% of non-built up areas				
	Frequency of nature visits			(+)*	(+)†		Frequency of nature visits			(+)*	
	Degree of physical activities						Degree of physical activities				(+)*
Lowest	Childhood nature experience		(+)†			Lowest	Childhood nature experience	(-)*			
ADI	Nature relatedness (NR-6)			(+)*	(+)†	ADI	Nature relatedness (NR-6)				(+)*
High	Citizen participation			(+)†		Low	Citizen participation		(+)†		(+)*
Urbanicity	Place attachment	(-)**	(+)**	(+)**	(+)**	Urbanicity	Place attachment	(-)*	(+)**	(+)**	(+)**
	Length of free time	(-)**	(+)**		(+)†		Length of free time	(-)†		(+)†	(+)*
	Having children or not						Having children or not				
	Educational backgrounds						Educational backgrounds				
	Having stable job or not						Having stable job or not				
	Marital status		(+)*	(+)**	(+)**		Marital status				
	Gender						Gender				
	Age	(-)**	(-)**				Age	(-)**			
	Income		(+)*	(+)**			Income		(+)†	(+)**	
	% of non-built up areas						% of non-built up areas	(-)†			
	Frequency of nature visits		(+)†	(+)*	(+)*		Frequency of nature visits			(+)*	(+)†
	Degree of physical activities		(+)*				Degree of physical activities	(+)†			
Lower	Childhood nature experience		(+)*			Lower	Childhood nature experience				
ADI	Nature relatedness (NR-6)					ADI	Nature relatedness (NR-6)				(+)**
High	Citizen participation				(+)*	Low	Citizen participation				
Urbanicity	Place attachment	(-)**	(+)**	(+)**	(+)**	Urbanicity	Place attachment			(+)**	(+)**
	Length of free time						Length of free time				
	Having children or not						Having children or not				
	Educational backgrounds						Educational backgrounds		(+)†		
	Having stable job or not						Having stable job or not	(-)*			
	Marital status	(-)*	(-)†		(+)**		Marital status				(+)**
	Gender		(F)*	(F)*			Gender				
	Age	(-)**	(-)**				Age	(-)**	(-)**		
	Income			(+)†	(+)†		Income		(+)†	(+)**	(+)*
	% of non-built up areas		(+)*	(+)*			% of non-built up areas				(+)**
	Frequency of nature visits		(+)**	(+)*			Frequency of nature visits	(+)*			
	Degree of physical activities						Degree of physical activities				
Higher	Childhood nature experience					Higher	Childhood nature experience		(+)*		
ADI	Nature relatedness (NR-6)				(+)†	ADI	Nature relatedness (NR-6)	(+)†			
High	Citizen participation			(+)**	(+)*	Low	Citizen participation				(+)*
Urbanicity	Place attachment	(-)*	(+)**	(+)**	(+)**	Urbanicity	Place attachment	(-)**	(+)**	(+)**	(+)**
	Length of free time	(-)†					Length of free time				
	Having children or not		(+)†				Having children or not				
	Educational backgrounds						Educational backgrounds			(+)*	(+)*
	Having stable job or not						Having stable job or not				
	Marital status		(+)*	(+)*	(+)†		Marital status	(-)**	(+)**	(+)**	(+)**
	Gender		(F)*	(F)†	(F)**		Gender	(F)*		(F)**	(F)*
	Age	(-)*	(-)**				Age	(-)**	(-)**		
	Income	(-)*		(+)**			Income			(+)**	(+)†
	% of non-built up areas						% of non-built up areas				
	Frequency of nature visits		(+)†		(+)*		Frequency of nature visits		(+)†		(+)†
	Degree of physical activities						Degree of physical activities				(+)*
Highest	Childhood nature experience					Highest	Childhood nature experience		(+)†		
ADI	Nature relatedness (NR-6)				(+)†	ADI	Nature relatedness (NR-6)				
High	Citizen participation		(-)*			Low	Citizen participation				
Urbanicity	Place attachment	(-)**	(+)**	(+)**	(+)**	Urbanicity	Place attachment	(-)**	(+)**	(+)**	(+)**
	Length of free time	(-)†					Length of free time	(-)†			
	Having children or not						Having children or not		(+)†		
	Educational backgrounds						Educational backgrounds				
	Having stable job or not						Having stable job or not		(+)*		
	Marital status	(-)**	(+)†				Marital status			(+)**	(+)*

Note: **: $p < 0.01$, *: $p < 0.05$, †: $p < 0.1$. Reference levels: Gender—1: male, 2: female; Having children or not—0: do not have, 1: have; Educational backgrounds—0: up to high school, 1: university or graduate school; Having a stable job or not—0: part time/student/unemployed, 1: full-time employed or self-employed; Marital status—0: unmarried, 1: married.

Urbanicity, self-rated health of High ADI + Lowest Urbanicity, and the indicator of purpose of life of High ADI + Lower Urbanicity were correlated with the percentage of non-built-up areas. The positive correlations between this land cover indicator and the well-being indicators were observed in the groups with relatively low urbanicity.

Frequency of childhood nature experience was correlated with well-being indicators mainly in two types of subgroups: subgroups with High ADI and a subgroup with Low ADI. The correlations between K6 and the frequency of the experience were detected in High ADI + Lowest Urbanicity and Low ADI + Lowest Urbanicity subgroups. The correlation between self-rated health and the frequency of the experience was observed in High ADI + Lower Urbanicity subgroup. The correlation between purpose of life indicator and the frequency of the experience was observed in Low ADI + Lowest Urbanicity subgroup.

Table 5
Subgroups (Area Deprivation Index [ADI]: two categories, Urbanicity: four categories).

Subgroup	Independent variables	K6	Self-rated health	Life satisfaction	Purpose of life
Low ADI Highest Urbanicity	Gender	(M)†		(F)**	
	Age	(-)**	(-)*		
	Income			(+)**	(+)**
	% of non-built up areas				
	Frequency of nature visits				(+)*
	Degree of physical activities		(+)†		
	Childhood nature experience				
	Nature relatedness (NR-6)				
	Citizen participation			(+)†	(+)†
	Place attachment	(-)**	(+)**	(+)**	(+)**
	Length of free time	(-)*			
	Having children or not				
	Educational backgrounds				
	Having stable job or not				
	Marital status				(+)†
Low ADI Higher Urbanicity	Gender				
	Age	(-)*	(-)**		(-)†
	Income				
	% of non-built up areas	(+)**	(-)**		
	Frequency of nature visits		(+)†	(+)**	(+)*
	Degree of physical activities		(+)†		
	Childhood nature experience				
	Nature relatedness (NR-6)				(+)†
	Citizen participation				
	Place attachment	(-)*	(+)**	(+)**	(+)**
	Length of free time	(-)**	(+)**		
	Having children or not				
	Educational backgrounds			(+)†	
	Having stable job or not				
	Marital status	(-)**	(+)**	(+)**	(+)**
High ADI Highest Urbanicity	Gender		(F)*		(F)*
	Age		(-)**	(-)†	
	Income			(+)**	(+)*
	% of non-built up areas				
	Frequency of nature visits		(+)*		
	Degree of physical activities				
	Childhood nature experience			(-)†	
	Nature relatedness (NR-6)				(+)†
	Citizen participation		(-)†	(+)**	
	Place attachment	(-)*	(+)**	(+)**	(+)**
	Length of free time	(-)†			
	Having children or not				
	Educational backgrounds				
	Having stable job or not				
	Marital status	(-)†		(+)**	(+)†
High ADI Higher Urbanicity	Gender		(F)*		(F)*
	Age		(-)**		
	Income				
	% of non-built up areas				
	Frequency of nature visits		(+)*	(+)†	(+)†
	Degree of physical activities				
	Childhood nature experience				
	Nature relatedness (NR-6)				(+)*
	Citizen participation				
	Place attachment	(-)**		(+)**	(+)**
	Length of free time	(-)†			
	Having children or not		(+)*		
	Educational backgrounds				
	Having stable job or not				
	Marital status	(-)†	(+)†		(+)†
High ADI Lower Urbanicity	Gender		(F)†		(F)†
	Age	(-)**	(-)**		(+)*
	Income		(+)*	(+)**	(+)*
	% of non-built up areas				
	Frequency of nature visits			(+)**	
	Degree of physical activities			(+)*	
	Childhood nature experience				
	Nature relatedness (NR-6)				
	Citizen participation				
	Place attachment	(-)**	(+)**	(+)**	(+)**
	Length of free time	(-)†			
	Having children or not				
	Educational backgrounds			(+)*	
	Having stable job or not				
	Marital status	(-)**	(+)*	(+)*	(+)**
Low ADI Lowest Urbanicity	Gender		(F)*	(F)†	(F)**
	Age				
	Income		(+)**	(+)**	
	% of non-built up areas				
	Frequency of nature visits		(+)*	(+)*	(+)*
	Degree of physical activities				
	Childhood nature experience				(+)†
	Nature relatedness (NR-6)				(+)**
	Citizen participation				(+)*
	Place attachment			(+)**	(+)**
	Length of free time		(-)†		
	Having children or not		(-)†		
	Educational backgrounds				
	Having stable job or not		(+)†		
	Marital status			(+)**	(+)**
High ADI Lowest Urbanicity	Gender	(F)†	(F)*	(F)†	(F)*
	Age	(-)**	(-)**		
	Income	(-)*		(+)**	(+)**
	% of non-built up areas		(+)†		
	Frequency of nature visits			(+)†	(+)*
	Degree of physical activities			(+)†	
	Childhood nature experience	(-)†			
	Nature relatedness (NR-6)				(+)†
	Citizen participation				
	Place attachment	(-)**	(+)**	(+)**	(+)**
	Length of free time				(+)*
	Having children or not		(+)†		
	Educational backgrounds				
	Having stable job or not				
	Marital status			(+)**	(+)**

Note: **: $p < 0.01$, *: $p < 0.05$, †: $p < 0.1$. Reference levels: Gender—1: male, 2: female; Having children or not—0: do not have, 1: have; Educational backgrounds—0: up to high school, 1: university or graduate school; Having a stable job or not—0: part time/student/unemployed, 1: full-time employed or self-employed; Marital status—0: unmarried, 1: married.

NR tended to be positively correlated with the indicator of purpose of life of several subgroups with High and Low ADI values. The Low ADI subgroups tended to have stronger correlations between NR and the well-being indicator than the High ADI subgroups. This result is consistent with the result in the previous subsection. The clear difference between higher and lower urbanicity subgroups was not observed in this subsection.

As in the previous subsection, negative correlations between the nature relatedness indicators and the well-being indicators were detected. The percentage of non-built-up areas had a positive correlation with K6 of the Low ADI + Higher Urbanicity subgroup and a negative correlation with self-rated health of the subgroup, suggesting that their psychological health conditions assessed by K6 were negatively correlated with the objective nature relatedness indicator. Furthermore, High ADI + Highest Urbanicity's indicator of life satisfaction had a negative correlation with childhood nature experience.

4. Discussion

4.1. Testing of hypotheses

The overall results showed that subjective and objective nature relatedness had different associations with well-being, depending on the types of well-being, ADI, and urbanicity. For H1, among the indicators of objective relatedness to nature, frequency of nature visits of higher urbanicity subgroups in Sections 3.2.1 and 3.2.2 tended to have correlations with diverse well-being indicators. This result supports H1 and is consistent with the results of existing studies (Sarkar et al. 2018; Browning et al., 2022), showing the relatively high importance of nature visits in high urbanicity contexts. Another indicator of objective nature relatedness, the percentage of non-built-up area, did not exhibit a clear correlation pattern (Section 3.2.1). The percentage of non-built-up areas correlated with well-being indicators of the Lower and Lowest Urbanicity subgroups (Section 3.2.2), suggesting that the result of the analysis on the land cover indicator related to nature exposure might not support H1.

H2 is supported by the analysis results of frequency of nature visits and self-rated health conditions. The frequency of nature visits of subgroups with higher ADI values tended to have significant positive stronger correlations with their self-rated health conditions, especially in higher urbanicity contexts. This result is consistent with those of existing studies that analyzed individual socioeconomic status (Rigolon et al., 2021; Fian et al., 2024). For the well-being indicators not directly related to health aspects (life satisfaction and purpose of life), more correlations with nature visits were observed in the subgroups with lower ADI values. The result suggests that the positive correlations of nature visits with well-being aspects directly related to health can be stronger for respondents living in areas with higher ADI values and higher urbanicity. Whether the percentage of non-built-up areas correlated with the well-being of residents in areas with higher ADI values was unclear in Sections 3.2.1 and 3.2.2; however, it was positively correlated with diverse well-being indicators of Higher ADI subgroups (Section 3.2.1) and with well-being indicators of the two subgroups with High ADI and lower urbanicity in Section 3.2.2.

For H3, the result differed from what we expected. Childhood nature experience was correlated with the well-being indicators, notably with health-related indicators. We identified significant correlations while controlling various variables, including socioeconomic attributes, frequency of nature visits, and percentage of non-built-up areas in residential areas. Studies have shown the correlation between childhood nature experience and frequency of outdoor activities (Wells & Lekies, 2006; Sugiyama et al., 2021); however, the studies did not analyze the correlations between such nature experience and well-being in an analysis model of subjective and objective nature relatedness. Our detection of the positive correlations between past childhood nature experience and current well-being is one of our unique findings. Furthermore, we identified complex patterns of correlations between the indicators of subjective nature relatedness and the well-being indicators of the subgroups. The frequency of childhood nature experience had correlations with self-rated health in mainly the subgroups with higher and lower ADI values. Among the indicators of subjective nature relatedness, the NR tended to have correlations with well-being indicators not directly related to health (e.g., the life purpose indicator related to eudaimonic well-being), and stronger correlations were observed in subgroups with lower ADI values in Sections 3.2.1 and 3.2.2. Martin et al. (2020) showed that subjective nature relatedness was correlated with eudaimonic well-being and is consistent with our analysis results on the NR.

The analysis results of the social capital-related indicators and well-being indicators lend support to the last hypothesis (H4). Place attachment had positive correlations with all the well-being indicators. Citizen participation had correlations with various well-being indicators,

although it was not correlated with K6. These positive correlations between the social capital-related indicators and well-being are consistent with the findings and concepts of existing studies (Jennings & Bamkole, 2019; Yoshida et al., 2022). Our unique contribution is to demonstrate such correlations in the analysis models of objective and subjective relatedness to nature and well-being.

4.2. Possible reasons and background for results

A possible reason for the correlation between frequency of nature visits and the well-being indicator values of residents in high ADI value areas is that nature visitation is an important option for those under substantial stress levels who are aiming to improve their health conditions (Mitchell et al., 2015; Rigolon et al., 2021; Fian et al., 2024). Improved health conditions can be a basis for other aspects of well-being. In this regard, the result suggests that nature visitation is a relatively important factor for those residents. Residents in low ADI value areas might be able to access additional options to enhance their health conditions by using their resources (Rigolon et al., 2021). Regarding the life satisfaction indicator, residents in high ADI value areas might not be able to feel the strong effect of nature visits as leisure activities to enhance their life satisfaction because of hindrances to the effects, such as insufficient basic socioeconomic resources and opportunities. Regarding the environmental backgrounds of the effects of nature visitation on well-being, the effects seemed stronger for residents in areas with higher urbanicity. This result aligns with that in an existing study (Sarkar et al., 2018), possibly because natural areas are limited, and the relative importance is higher in the higher urbanicity contexts (Browning et al., 2022).

Monsoon Asian cities provide more opportunities than European cities for nature access because of the former's mosaic-pattern landscape comprising different land cover categories and close distance between urban and rural areas (Kohsaka et al., 2013; Uchiyama & Hayashi, 2021). Nonetheless, as in European cities, inequality in nature access exists and is interlinked with inequality in health conditions in the targeted cities in Japan. This result suggests that similar trends of access inequality and its connection with health inequality might be observed in other Monsoon Asian cities within close distance to rural areas, complex landscapes, and similar socioeconomic inequality issues.

Percentage of non-built-up areas, which can be an indicator to show the existence of natural elements, did not have correlations with the well-being indicators in the models of the Highest ADI subgroups, and there was no positive correlation with the well-being indicators in the Lowest ADI subgroups. Specifically, the Lowest ADI subgroup's indicator of purpose of life had a negative correlation with the percentage of non-built-up areas. This finding suggests that living in areas with rural elements, including nature, can be a hindrance to well-being (Cosby et al., 2019), and the relative importance of nature might be less important for affluent people than for other people because there are many other options for the former to improve their well-being (Rigolon et al., 2021). For example, the areas with high percentage of non-built-up might not have high accessibility to places such as shopping places and workplaces because of their low-dense urban development. Residents living in low ADI value areas might be sensitive and not easily satisfied by low accessibility to those places (Wachs et al., 2020). By contrast, residents in high ADI value areas might not have sufficient capacity to acknowledge the existence of nature, although it can be an element to improve their well-being, as shown in the results of Higher ADI subgroups.

Subjective nature relatedness assessed by the NR can be important for any subgroup; however, correlations between NR and the well-being indicators were detected only in certain subgroups, especially in subgroups with lower ADI values. A possible explanation for this correlation pattern is that a certain capacity might be necessary to make nature relatedness effective for improving well-being (Milliron et al., 2022). Such capacity can be enhanced by environmental education and learning about the value systems focusing on nature-human relationships. Notably, certain components of the NR can have negative effects on well-being (Dean et al., 2018). Some people strongly connected to nature are deeply concerned about the current conditions of nature, and as a result, a strong NR can have negative effects on their well-being.

A possible reason for the correlation between childhood nature experience and health-related indicators while controlling variables related to nature visits and nature exposure is that childhood nature experience may provide support for subjective aspects of people and facilitate healthier decisions in different life stages, making people aligned with nature (Wood & Smyth, 2020). Furthermore, childhood nature experience showed a complex pattern of correlations with the well-being indicators. There might be different backgrounds for lower and higher ADI value areas for this correlation pattern. For the areas with lower ADI values, the nature experience is effective for self-rated health conditions in the context of High Urbanicity; however, in the context of Low Urbanicity, people are surrounded by nature and have the capacity to access natural lands (Fig. 3); as a result, the relative importance of nature experience for them can be low. Regarding the areas with High Urbanicity and higher ADI values, people have limited nature experiences (Fig. 3), and they cannot have the same effect on their self-rated health as do residents in areas with High Urbanicity and lower ADI values. For the areas with Low Urbanicity and higher ADI values, people have a certain level of nature experience (Fig. 3), and they are surrounded by nature; however, they do not have capacities or opportunities to access or acknowledge nature; as a result, the relative importance of the experience for them can be high.

5. Conclusion

Through the analyses of all respondents and the subgroups, we identified that each indicator of objective and subjective relatedness to nature correlated with different well-being indicators. Furthermore, the correlations were associated with ADI values and urbanicity of respondents' residential districts. Regarding the objective relatedness to nature, the frequency of nature visits of high urbanicity subgroups tended to have positive correlations with more diverse types of well-being indicators. The nature visits of subgroups with high ADI values tended to have positive correlations with their self-rated health. The percentage of non-built-up areas correlated with various well-being indicators of subgroups with relatively high ADI values. However, the correlation between the land cover indicator and well-being in different ADI contexts requires further investigation. Regarding the subjective relatedness to nature, childhood nature experience was positively correlated with self-rated health and negatively correlated with a psychological health indicator (i.e., K6). The NR positively correlated with well-being indicators not directly related to health, and correlations were observed mainly in subgroups with lower ADI values. The analysis results suggested that objective and subjective relatedness to nature are positively correlated with the well-being of residents of deprived areas. Regarding residents in relatively affluent areas, subjective nature relatedness tended to positively correlate with well-being.

Regarding policy recommendations to reduce inequality in human well-being related to objective and subjective nature relatedness, opportunities for nature visits in high ADI value areas are important because nature visits tend to be positively correlated with self-rated health conditions of residents. Strategically enhancing the quality of existing natural spaces such as parks and riverside places can be an approach for high ADI value areas. Creating new walkable natural spaces can also be an option in these areas. Percentage of non-built-up areas were important for the well-being of the subgroup with relatively high ADI values, implying that accessible natural spaces and the existence of natural spaces are positively correlated with well-being. Conserving and restoring natural spaces can be another approach for the health of residents in areas with relatively high ADI values. Those interventions can be combined with community events, which can

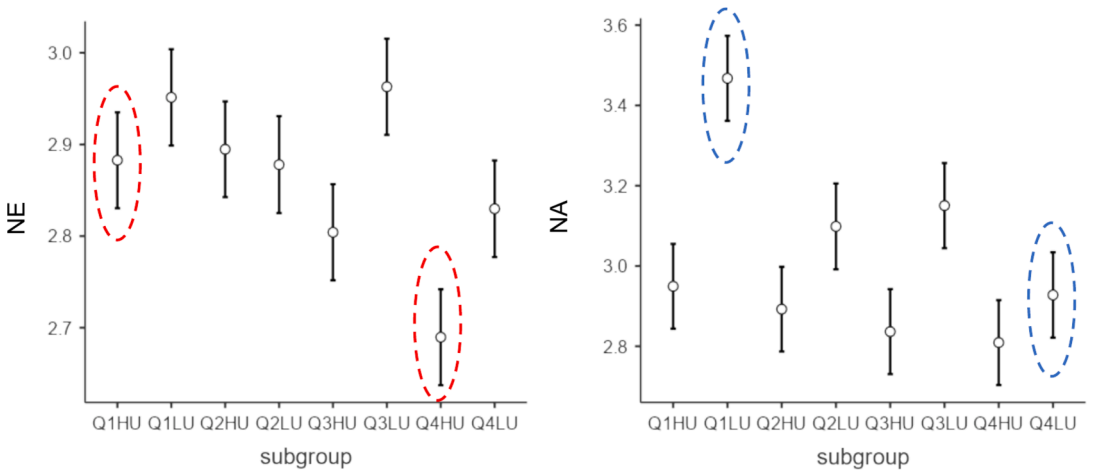


Fig. 3. Average frequency of childhood nature experience (NE) (left) and nature visits (NA) (right) in subgroups in Section 3.2.1. Note: Lowest ADI + High Urbanicity (Q1HU) subgroup's childhood nature experience is relatively high, although their nature visit frequency is low. Highest ADI + High Urbanicity (Q4HU) subgroup's nature experience and nature visit frequency are low. Lowest ADI + Low Urbanicity (Q1LU)'s nature experience and nature visit frequency are high. Highest ADI + Low Urbanicity (Q4LU) subgroup's nature experience is relatively high, but their nature visit frequency is low, although their residential areas have relatively high percentage of non-built-up areas. In these circumstances, relative importance of nature experience is high for Lowest ADI + High Urbanicity and Highest ADI + Low Urbanicity subgroups that have a certain nature experience and less nature visit frequency.

include visiting natural areas in neighborhoods, and positive effects for participants' well-being can be expected because community events positively influence the psychological well-being of participants based on their social networks (Harada et al., 2021). Raising awareness of and interests in nature through community events is also important (Boyd et al., 2018).

Childhood nature experience is also a key factor positively correlated with self-rated health; however, we observed that a certain frequency of the experience might be necessary to have associations with self-rated health. Distributing opportunities for childhood nature experience can be an option for future adults' health in high and low ADI value areas. Although redesigning and creating parks and the promotion of nature experience can be implemented in a top-down manner, bottom-up approaches and reflecting residents' perceptions on relevant policies and environmental education are necessary (Sato et al., 2023).

As our findings are basically consistent with the results of studies conducted in different local contexts, the interventions for objective and subjective nature relatedness might be applicable to other countries and regions, particularly for other Monsoon Asian cities with similar socio-ecological contexts; however, further research is necessary in Asian contexts and cultural and environmental differences should be considered. Furthermore, in the implementation phase of the interventions, local conditions, including administrative processes of site selection to create or improve natural areas and land use regulations, should be considered. Regarding the findings on childhood nature experience, the results were obtained in the context of Japan experiencing a significant decrease in nature experience, especially among young generations (Uchiyama et al., 2022). Further research to test the correlations between childhood nature experience and human health in different local contexts is required.

Regarding the limitations of this research and further research, relationships between the independent variables were not analyzed. For example, place attachment seems compatible with high percentages of greenery in residential areas (Jennings & Bamkole, 2019); however, Uchida et al. (2022) reported contrasting results, warranting further analysis. We conducted a cross-sectional study, and it could not implicate causal relationships between the variables. In further research, time series analysis of key factors for well-being would also be useful. People can move between residential areas with different ADI values and local environments. In this circumstance, their experience of house-moving might change the key factors (e.g., nature visits and nature experience) for their well-being, such as self-rated health and life satisfaction.

We focused on the ADI in this paper to implicate the area-based interventions; however, comparisons between the analysis results focusing on area-level and individual-level deprivations could be conducted in further research to understand the significance of deprivation at different levels. We analyzed household income as an individual-level deprivation variable and detected positive correlations between income and life satisfaction. This finding suggests that an income-related inequality of life satisfaction exists in each ADI subgroup. Furthermore, in the Lowest ADI subgroups in Section 3.2.1, correlations were observed between the income and psychological health assessed by K6 and self-rated health, suggesting that an income-related inequality of health conditions exists in relatively affluent districts. For individual-level supports, supports for the health of people with a low income but residing in affluent areas are necessary.

The background of nature visits, such as motivation and purpose of nature visits, was not included in our research focus. However, these are important factors that require analysis in further research. As suggested by research on physical activities and self-rated health (Harada et al., 2024), the motivation and purpose of activities can affect their efficacy. In addition, we did not consider the detailed types of ecosystems or natural elements. People value nature differently depending on the natural elements and their combinations (Tsurumi et al., 2018). Thus, further analysis of the effects of various types of ecosystems on the well-being of people with different socioeconomic status and environmental backgrounds is necessary. Finally, the potential bias of the data obtained through online surveys should be considered and postal mail surveys and interview surveys should be conducted to complement the results of online surveys.

CRediT authorship contribution statement

Yuta Uchiyama: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Akira Kyan:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Masayuki Sato:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Atushi Ushimaru:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Toshifumi**

Minamoto: Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Kazuhiro Harada:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Minoru Takakura:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Ryo Kohsaka:** Writing – review & editing, Methodology, Funding acquisition. **Mieko Kiyono:** Writing – review & editing, Methodology, Investigation, Funding acquisition. **Tetsuya Tsurumi:** Writing – review & editing, Methodology, Funding acquisition. **Atsuhiko Uchida:** Writing – review & editing, Methodology. **Tatsuya Saga:** Writing – review & editing, Methodology. **Kenta Yamamoto:** Writing – review & editing, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by the Japan Society for the Promotion of Science: JSPS KAKENHI Grant Numbers: JP22H03813; 22H03852; 23H03605; 23H03608, Environment Research and Technology Development Fund by the Ministry of the Environment, Japan (1FS-2201), and Asia-Pacific Network for Global Change Research (CRRP2023-10MY-Uchiyama).

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2025.105377.

Data availability

Data will be made available on request.

References

Acedo, A., Painho, M., & Casteleyn, S. (2017). Place and city: Operationalizing sense of place and social capital in the urban context. *Transactions in GIS, 21*(3), 503–520.

Adler, P. S., & Kwon, S. W. (2002). Social capital: Prospects for a new concept. *Academy of Management Review, 27*(1), 17–40.

Aoshima, I., Nakao, R., Minamoto, T., Ushimaru, A., & Sato, M. (2023). Heterogeneous preference for biodiversity in Japanese urban blue spaces based on people's nature experiences: Analysis using eDNA and satisfaction data. *City and Environment Interactions, 18*, Article 100101.

Astell-Burt, T., Navakatikyan, M. A., & Feng, X. (2023). Why might urban tree canopy reduce dementia risk? A causal mediation analysis of 109,688 adults with 11 years of hospital and mortality records. *Health & Place, 82*, Article 103028.

Barrable, A., Friedman, S., & Beloyianni, V. (2024). Nature connection in adulthood: The role of childhood nature experiences. *People and Nature, 6*(4), 1571–1580.

Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal, 19*, 43–50.

Boyd, F., White, M. P., Bell, S. L., & Burt, J. (2018). Who doesn't visit natural environments for recreation and why: A population representative analysis of spatial, individual and temporal factors among adults in England. *Landscape and Urban Planning, 175*, 102–113.

Brown, G., & Raymond, C. (2007). The relationship between place attachment and landscape values: Toward mapping place attachment. *Applied Geography, 27*(2), 89–111.

Browning, M. H., Rigolon, A., & McAnirlin, O. (2022). Where greenspace matters most: A systematic review of urbanicity, greenspace, and physical health. *Landscape and Urban Planning, 217*, Article 104233.

Cosby, A. G., McDoom-Echebiri, M. M., James, W., Khandekar, H., Brown, W., & Hanna, H. L. (2019). Growth and persistence of place-based mortality in the United States: The rural mortality penalty. *American Journal of Public Health, 109*(1), 155–162.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381–1395.

Dean, J. H., Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Barber, E., … Fuller, R. A. (2018). Is nature relatedness associated with better mental and physical health? *International Journal of Environmental Research and Public Health, 15*(7), 1371.

Elliott, L. R., Pasanen, T., White, M. P., Wheeler, B. W., Grellier, J., Cirach, M., … Fleming, L. E. (2023). Nature contact and general health: Testing multiple serial mediation pathways with data from adults in 18 countries. *Environment International, 178*, Article 108077.

Fian, L., White, M. P., Arnberger, A., Thaler, T., Heske, A., & Pahl, S. (2024). Nature visits, but not residential greenness, are associated with reduced income-related inequalities in subjective well-being. *Health & Place, 85*, Article 103175.

Furukawa, T. A., Kessler, R. C., Slade, T., & Andrews, G. (2003). The performance of the K6 and K10 screening scales for psychological distress in the Australian National Survey of Mental Health and Well-Being. *Psychological Medicine, 33*(2), 357–362.

Garrett, J. K., Rowney, F. M., White, M. P., Lovell, R., Fry, R. J., Akbari, A., … Wheeler, B. W. (2023). Visiting nature is associated with lower socioeconomic inequalities in well-being in Wales. *Scientific Reports, 13*, 9684.

Hanibuchi, T., & Nakaya, T. (2020). Associations of neighborhood socioeconomic conditions with self-rated health, mental distress, and health behaviors: A nationwide cross-sectional study in Japan. *Preventive Medicine Reports, 18*, Article 101075.

Harada, K., Izawa, S., Nakamura-Taira, N., Yoshikawa, T., Akamatsu, R., Ikeda, H., & Kubo, T. (2024). Cross-sectional associations of weekly time, social context, and motivation of exercise with mental health among workers. *International Archives of Occupational and Environmental Health, 97*(1), 23–33.

Harada, K., Masumoto, K., Katagiri, K., Fukuzawa, A., Touyama, M., Sonoda, D., … Okada, S. (2021). Three-year effects of neighborhood social network intervention on mental and physical health of older adults. *Aging & Mental Health, 25*(12), 2235–2245.

Hong, S. K., Lee, S. W., Jo, H. K., & Yoo, M. (2019). Impact of frequency of visits and time spent in urban green space on subjective well-being. *Sustainability, 11*(15), 4189.

IPAQ: International Physical Activity Questionnaire. (2005). Guidelines for data processing and analysis of international standardized physical activity questionnaires —Short version · Long version— November 2005] accessed 2024-03-17) (in Japanese) http://www.tmu-ph.ac/news/data/180327_1.pdf?t.

Ida, T., Takemura, K., & Sato, M. (2015). Inner conflict between nuclear power generation and electricity rates: A Japanese case study. *Energy Economics, 48*, 61–69.

Janicke-Bowles, S. H., Rieger, D., & Connor, W. (2019). Finding meaning at work: The role of inspiring and funny YouTube videos on work-related well-being. *Journal of Happiness Studies, 20*, 619–640.

Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. *International Journal of Environmental Research and Public Health, 16*(3), 452.

Jennings, V., Rigolon, A., Thompson, J., Murray, A., Henderson, A., & Gragg, R. S. (2024). The Dynamic Relationship between Social Cohesion and Urban Green Space in Diverse Communities: Opportunities and Challenges to Public Health. *International Journal of Environmental Research and Public Health, 21*(6), 800.

Jones, A., Hillsdon, M., & Coombes, E. (2009). Greenspace access, use, and physical activity: Understanding the effects of area deprivation. *Preventive Medicine, 49*(6), 500–505.

Jylhä, M. (2009). What is self-rated health and why does it predict mortality? Towards a unified conceptual model. *Social Science & Medicine, 69*(3), 307–316.

Kambara, K., Hihara, S., & Kornacka, M. (2023). The bidirectional associations of rumination with values-based action and depression among young adults in the school-to-work transition. *Journal of Affective Disorders, 324*, 300–308.

Keaulana, S., Kahili-Heede, M., Riley, L., Park, M. L. N., Makua, K. L., Vegas, J. K., & Antonio, M. C. (2021). A scoping review of nature, land, and environmental connectedness and relatedness. *International Journal of Environmental Research and Public Health, 18*(11), 5897.

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., Mroczek, D. K., Normand, S. L., & Zaslavsky, A. M. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*(6), 959–976.

Kidokoro, T., Matsuyuki, M., & Shima, N. (2022). Neoliberalization of urban planning and spatial inequalities in Asian megacities: Focus on Tokyo, Bangkok, Jakarta, and Mumbai. *Cities, 130*, Article 103914.

Kiss, B., Sekulova, F., Hörschelmann, K., Salk, C. F., Takahashi, W., & Wamsler, C. (2022). Citizen participation in the governance of nature-based solutions. *Environmental Policy and Governance, 32*(3), 247–272.

Kohsaka, R., Shih, W., Saito, O., & Sadohara, S. (2013). Local assessment of Tokyo: Satoyama and Satoumi–traditional landscapes and management practices in a contemporary urban environment. *Urbanization, biodiversity and ecosystem services: Challenges and opportunities: A global assessment*, 93–105.

Korpela, K., De Bloom, J., Sianoja, M., Pasanen, T., & Kinnunen, U. (2017). Nature at home and at work: Naturally good? Links between window views, indoor plants, outdoor activities and employee well-being over one year. *Landscape and Urban Planning, 160*, 38–47.

Krols, J., Aerts, R., Vanlessen, N., Dewaelheyns, V., Dujardin, S., & Somers, B. (2022). Residential green space, gardening, and subjective well-being: A cross-sectional study of garden owners in northern Belgium. *Landscape and Urban Planning, 223*, Article 104414.

Kyan, A., & Takakura, M. (2022). Socio-economic inequalities in physical activity among Japanese adults during the COVID-19 pandemic. *Public Health, 207*, 7–13.

Kyan, A., & Takakura, M. (2023). Impact of the COVID-19 pandemic on the socioeconomic inequality of health behavior among Japanese adolescents: A 2-year repeated cross-sectional survey. *Journal of Physical Activity and Health, 20*(6), 538–546.

Kövi, Z., Kim, H., Kamble, S., Mészáros, V., Lachance, D., & Nisbet, E. (2023). Cross-cultural validity of the Nature Relatedness Scale (NR-6) and links with wellbeing. *International Journal of Wellbeing, 13*(2), 45–76.
Law, A., Carrasco, L. R., Richards, D. R., Shaikh, S. F. E. A., Tan, C. L., & Nghiem, L. T. P. (2022). Leave no one behind: A case of ecosystem service supply equity in Singapore. *Ambio, 51*(10), 2118–2136.
Legendre, P., Oksanen, J., & ter Braak, C. J. (2011). Testing the significance of canonical axes in redundancy analysis. *Methods in Ecology and Evolution, 2*(3), 269–277.
Li, D., Ma, J., Cheng, T., van Genderen, J. L., & Shao, Z. (2018). Challenges and opportunities for the development of MEGACITIES. *International Journal of Digital Earth, 12*(12), 1382–1395.
Liu, H., Nong, H., Ren, H., & Liu, K. (2022). The effect of nature exposure, nature connectedness on mental well-being and ill-being in a general Chinese population. *Landscape and Urban Planning, 222*, Article 104397.
Loos, J., Benra, F., Berbés-Blázquez, M., Bremer, L. L., Chan, K. M., Egoh, B., … Winkler, K. J. (2023). An environmental justice perspective on ecosystem services. *Ambio, 52*(3), 477–488.
Lopez, B., Kennedy, C., Field, C., & McPhearson, T. (2021). Who benefits from urban green spaces during times of crisis? Perception and use of urban green spaces in New York City during the COVID-19 pandemic. *Urban Forestry & Urban Greening, 65*, Article 127354.
Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *Journal of Environmental Psychology, 68*, Article 101389.
Milliron, B. J., Ward, D., Granche, J., Mensinger, J., Stott, D., Chenault, C., & Ellis, E. V. (2022). Nature relatedness is positively associated with dietary diversity and fruit and vegetable intake in an urban population. *American Journal of Health Promotion, 36*(6), 1019–1024.
Mitchell, R. J., Richardson, E. A., Shortt, N. K., & Pearce, J. R. (2015). Neighborhood environments and socioeconomic inequalities in mental well-being. *American Journal of Preventive Medicine, 49*(1), 80–84.
Mohan, G., & Barlow, P. (2023). Area-level deprivation, neighbourhood factors and associations with mental health. *Plos one, 18*(1), Article e0281146.
Mouratidis, K. (2020). Neighborhood characteristics, neighborhood satisfaction, and well-being: The links with neighborhood deprivation. *Land Use Policy, 99*, Article 104886.
Murase, N., Katsumura, T., Ueda, C., Inoue, S., & Shimomitsu, T. (2002). Validity and reliability of Japanese version of International Physical Activity Questionnaire. *Journal of Health and Welfare Statistics, 49*(11), 1–9 (in Japanese).
Nakaya, T., Honjo, K., Hanibuchi, T., Ikeda, A., Iso, H., Inoue, M., … Japan Public Health Center-based Prospective Study Group. (2014). Associations of all-cause mortality with census-based neighbourhood deprivation and population density in Japan: A multilevel survival analysis. *PLoS ONE, 9*(6), Article e97802.
Nisbet, E. K., & Zelenski, J. M. (2013). The NR-6: A new brief measure of nature relatedness. *Frontiers in Psychology, 4*, 63438.
Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2011). Happiness is in our nature: Exploring nature relatedness as a contributor to subjective well-being. *Journal of Happiness Studies, 12*, 303–322.
Preston, B. J. (2024). The nature, content and realisation of the right to a clean, healthy and sustainable environment. *Journal of Environmental Law, 36*, 159–185.
Raanaas, R. K., Patil, G. G., & Hartig, T. (2012). Health benefits of a view of nature through the window: A quasi-experimental study of patients in a residential rehabilitation center. *Clinical Rehabilitation, 26*(1), 21–32.
Rao, C. R. (1964). The use and interpretation of principal component analysis in applied research. *Sankhyā: The Indian Journal of Statistics, Series A*, 329–358.
Raymond, C. M., Brown, G., & Weber, D. (2010). The measurement of place attachment: Personal, community, and environmental connections. *Journal of Environmental Psychology, 30*(4), 422–434.
Remme, R. P., Frumkin, H., Guerry, A. D., King, A. C., Mandle, L., Sarabu, C., & Daily, G. C. (2021). An ecosystem service perspective on urban nature, physical activity, and health. *Proceedings of the National Academy of Sciences, 118*(22), Article e2018472118.
Rigolon, A., Browning, M. H., McAnirlin, O., & Yoon, H. (2021). Green space and health equity: A systematic review on the potential of green space to reduce health disparities. *International Journal of Environmental Research and Public Health, 18*(5), 2563.
Saito, M., Kondo, K., Kondo, N., Abe, A., Ojima, T., Suzuki, K., … JAGES group. (2014). Relative deprivation, poverty, and subjective health: JAGES cross-sectional study. *PLoS ONE, 9*(10), Article e111169.
Saito, M., Kondo, N., Aida, J., Kawachi, I., Koyama, S., Ojima, T., & Kondo, K. (2017). Development of an instrument for community-level health related social capital among Japanese older people: The JAGES Project. *Journal of Epidemiology, 27*(5), 221–227.
Sarkar, C., Webster, C., & Gallacher, J. (2018). Residential greenness and prevalence of major depressive disorders: A cross-sectional, observational, associational study of 94 879 adult UK Biobank participants. *The Lancet Planetary Health, 2*(4), e162–e173.
Sato, M., Minamoto, T., & Ushimaru, A. (2023). An interdisciplinary approach to environmental conservation policy: A case of Satoyama redevelopment in the peri-urban area. *International Journal of Economic Policy Studies, 17*(2), 403–419.
Shahaboonin, F., David, O. O., & Van Wyk, A. (2023). Historic spatial inequality and poverty along racial lines in South Africa. *International Journal of Economics and Financial Issues, 13*(1), 102.
Shan, X. Z. (2020). Association between the time patterns of urban green space visitations and visitor characteristics in a high-density, subtropical city. *Cities, 97*, Article 102562.
Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Dean, J., Barber, E., & Fuller, R. A. (2016). Health benefits from nature experiences depend on dose. *Scientific Reports, 6*, 28551.
Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2014). Socio-economic inequalities in access to nature on public and private lands: A case study from Brisbane, Australia. *Landscape and Urban Planning, 130*, 14–23.
Shentova, R., De Vries, S., & Verboom, J. (2022). Well-being in the time of corona: Associations of nearby greenery with mental well-being during COVID-19 in The Netherlands. *Sustainability, 14*(16), 10256.
Sia, A., Tan, P. Y., Wong, J. C. M., Araib, S., Ang, W. F., & Er, K. B. H. (2022). The impact of gardening on mental resilience in times of stress: A case study during the COVID-19 pandemic in Singapore. *Urban Forestry & Urban Greening, 68*, Article 127448.
Sugiyama, N., Hosaka, T., Takagi, E., & Numata, S. (2021). How do childhood nature experiences and negative emotions towards nature influence preferences for outdoor activity among young adults? *Landscape and Urban Planning, 205*, Article 103971.
Takeuchi, E., Fujisawa, D., Miyawaki, R., Yako-Suketomo, H., Oka, K., Mimura, M., & Takahashi, M. (2021). Cross-cultural validation of the cancer stigma scale in the general Japanese population. *Palliative & Supportive Care, 19*(1), 75–81.
Tsurumi, T., Imauji, A., & Managi, S. (2018). Greenery and subjective well-being: Assessing the monetary value of greenery by type. *Ecological Economics, 148*, 152–169.
Uchida, A., Ise, T., Minoura, Y., Hitokoto, H., Takemura, K., & Uchida, Y. (2022). Correspondence between feelings towards neighbors and appearance of neighborhood: Analysis by combining a mail survey and Google Street View. *Psychologia, 64*(2), 112–135.
Uchiyama, Y., & Hayashi, K. (2021). Generation of urban morphologies through long-term evolution of socio-ecological urban systems: regional characteristics and sustainable management of megacities. *Living in the Megacity: Towards Sustainable Urban Environments*, 105–125.
Uchiyama, Y., & Kohsaka, R. (2022). Examining who benefited from green infrastructure during the coronavirus pandemic in 2020: Considering the issues of access to green areas from socioeconomic and environmental perspectives. *Journal of Environmental Management, 322*, Article 116044.
Uchiyama, Y., & Okabe, A. (2012). Categorization of 48 mega-regions by spatial patterns of population distribution: the relationship between spatial patterns and population change. 48th ISOCARP congress (pp. 1–13).
Uchiyama, Y., Takatori, C., & Kohsaka, R. (2022). Designing participatory green area management and biodiversity conservation strategies in the era of population shrinkage: Empirical analysis of multi-generational perceptions on Satoyama rare species in central Japan. *Landscape and Ecological Engineering, 18*(3), 321–339.
Uesugi, M. (2021). Socio-spatial segregation in the era of growing economic disparities: The case of Tokyo. *Geographical Review of Japan Series B, 94*(1), 18–30.
Wachs, M., Chesney, P. S., & Hwang, Y. H. (2020). A Century of Fighting Traffic Congestion in Los Angeles. UCLA Luskin Center for History and Policy. Retrieved October, 16, 2024.
Wang, W., Wu, T., Li, Y., Xie, S., Han, B., Zheng, H., & Ouyang, Z. (2020). Urbanization impacts on natural habitat and ecosystem services in the Guangdong-Hong Kong-Macao "megacity". *Sustainability, 12*(16), 6675.
Weber, M., Harzer, C., Huebner, E. S., & Hills, K. J. (2015). Measures of life satisfaction across the lifespan. In *Measures of personality and social psychological constructs* (pp. 101–130). Academic Press.
Wells, N. M., & Lekies, K. S. (2006). Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. *Children, Youth and Environments, 16*(1), 1–24.
White, M. P., Alcock, I., Grellier, J., Wheeler, B. W., Hartig, T., Warber, S. L., … Fleming, L. E. (2019). Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Scientific Reports, 9*, 7730.
Wood, C. J., & Smyth, N. (2020). The health impact of nature exposure and green exercise across the life course: A pilot study. *International Journal of Environmental Health Research, 30*(2), 226–235.
Wu, D., Zheng, L., Wang, Y., Gong, J., Li, J., & Chen, Q. (2024). Characteristics of urban expansion in megacities and its impact on water-related ecosystem services: A comparative study of Chengdu and Wuhan, China. *Ecological Indicators, 158*, Article 111322.
Xu, C., Miao, L., Turner, D., & DeRubeis, R. (2023). Urbanicity and depression: A global meta-analysis. *Journal of Affective Disorders, 340*, 299–311.
Yoshida, Y., Matsuda, H., Fukushi, K., Takeuchi, K., & Watanabe, R. (2022). The missing intangibles: Nature's contributions to human wellbeing through place attachment and social capital. *Sustainability Science, 17*(3), 809–822.
Zelenski, J. M., & Nisbet, E. K. (2014). Happiness and feeling connected: The distinct role of nature relatedness. *Environment and Behavior, 46*(1), 3–23.
Zhang, J., Yu, Z., Zhao, B., Sun, R., & Vejre, H. (2020). Links between green space and public health: A bibliometric review of global research trends and future prospects from 1901 to 2019. *Environmental Research Letters, 15*(6), Article 063001.
Zhang, Z., Liu, Q., Gao, G., Shao, J., Pan, J., He, G., & Hu, Z. (2023). Integrating ecosystem services closely related to human well-being into the restoration and management of deep lakes facing multiple stressors: Lessons from long-term practice in Qiandao Lake, China. *Science of the Total Environment, 902*, Article 166457.
Zhao, S. X., Guo, N. S., Li, C. L. K., & Smith, C. (2017). Megacities, the world's largest cities unleashed: Major trends and dynamics in contemporary global urban development. *World Development, 98*, 257–289.