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Research article

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

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ARTICLE INFO

Keywords:
- Green area
- Socioeconomic factor
- COVID-19
- Green infrastructure

ABSTRACT

Access to green areas was one of the most contested issues during Japan’s first coronavirus emergency period in 2020. The access was examined using a large-scale online questionnaire survey. An integrated analysis of socioeconomic attributes and environmental factors was conducted, and a typology of respondents, in terms of being beneficiaries of green infrastructure, was provided. Based on empirical datasets, we identified: (1) a relatively strong influence of the pandemic on the access to green areas for young females, both positively and negatively, (2) difficulties of green area access for unmarried low-income respondents in terms of aspects such as travel time, and (3) the influence of neighboring environments on green area access; for example, if there were agricultural lands near the respondents’ residential areas, they tended to visit those lands instead of other green areas. The identified typology can serve as a basis for policy targets or components within policy, to enhance the management of green infrastructure as “open” and public areas. This analysis method can be applied to different regions globally, and it contributes to policymaking for green area management to enhance social and individual well-being.

1. Introduction

1.1. The value of green areas and their access

Access to green areas, which entails access to parks, agricultural lands, and forest lands, is an essential factor for sustaining mental and physical health (Markevych et al., 2014). Regarding the environmental effects of green areas in relation to human society, they provide functions/services to purify the air, ensure groundwater retention, and provide cool or fresh air to surrounding areas (Demuzere et al., 2014). These effects reduce air pollution and mitigate flooding or heat island effects in urban and rural areas (Gill et al., 2007; Chen, 2015). Furthermore, green areas can encourage the development of species habitats and biodiversity (Kohsaka, 2010), as well as provide opportunities to experience nature (Imai et al., 2019). Additionally, green areas provide interpersonal communication opportunities for social activities such as socializing, leisure, and sport-related activities (Kabisch and Haase, 2014; Donaldson et al., 2016). Owing to the multiple roles of green areas, they are managed as green infrastructure and are key components of nature-based solutions (NbS) (Kabisch et al., 2016; Raymond et al., 2017; Frantzeskaki, 2019). However, this NbS concept needs further clarification before it can be effectively applied to urban green areas, as various factors related to social and economic differences among urban populations need to be considered.

The importance of green areas for citizens may seem self-evident. However, being able to appreciate the benefits provided by green areas tends to be limited to certain social groups for various reasons, including the numerous constraints faced by others (Yasumoto et al. 2014, 2020; Xu et al., 2017; Rigolon et al., 2018; Luz et al., 2019; Uchiyama and Kohsaka, 2020). In the fields of city planning and green area management, “green gentrification” has gained importance in ensuring equitable access to green areas (Haase et al., 2017). Currently, in the discussion of the post-2020 Global Biodiversity Framework (GBF) in the Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA) of the Convention on Biological Diversity (CBD), “access to green areas” is one of the targets. Given that green areas are a...
type of infrastructure generally supported by citizens, it is preferable that they be equitably provided to citizens. In this context, the beneficiaries of green areas under the framework of green infrastructure and NbS need to be identified in a timely and accurate manner to develop appropriate management plans for green areas. Therefore, developing methods to identify such beneficiaries is highly prioritized in academic research (Kabisch et al., 2016).

1.2. COVID-19 and green area access

Owing to the spread of COVID-19, visiting patterns in relation to green areas are changing worldwide, and the influence of visiting green areas has been analyzed (Honey-Rosés et al., 2020; Derks et al., 2020; Ugolini et al., 2020; Heo et al., 2020; Zhu and Xu, 2021; Klopfer et al., 2021). The main drivers of these changes are official policies to regulate and limit mobility in urban and rural areas. Governments are promoting a so-called new-normal lifestyle to prevent crowd formation in urban areas and to reduce long-distance travel in an effort to prevent the spread of COVID-19. City lockdowns have been implemented, and citizens have not been able to visit green areas freely. These lockdown policies have been extended even further in certain countries (as of April 2021). However, the severity of lockdowns differs among countries and regions. Citizens continue to access green areas where permitted, if it is possible for them to avoid crowds and comply with social distancing requirements. Japan has implemented relatively relaxed lockdown policies compared with other regions and countries, such as Europe and China. Thus, Japan is an interesting example in that the measures were relatively relaxed, in terms of legal or official requirements. Emerging studies have compared and examined the effectiveness of lessons learned with stricter or relaxed regulations (Oshitani, 2022). Voluntarily, the Japanese government requested that citizens avoid crowded places and not engage in any social gatherings. In this context, citizens were discouraged, in principle, from visiting public spaces, including green open spaces, at least during the first national emergency declaration period (April 16–May 14, 2020). However, a certain number of citizens visited green areas to relax or exercise if they felt the spaces were safe in terms of social distancing, despite national emergency declarations (cf. Fig. 1).

Although the regulations by various national governments tend to discourage visits to green areas, it has been reported that citizens became increasingly aware of the value of green areas during the crisis and sought to access such areas to reduce COVID-19-related stress and other health issues (Xie et al., 2020; Freeman and Eykelbosh, 2020; Weinbrenner et al., 2021; Larson et al., 2022). Following mobility restrictions imposed by national governments, the multiple values of green areas were rediscovered, and their essential roles in society were highlighted (Honey-Rosés et al., 2020; Bherwani et al., 2021). Prior to the COVID-19 pandemic, studies listed further research on green areas to identify (1) profiles of beneficiaries and stakeholder involvement, (2) trade-off and synergistic relationships between their functions, (3) countervailing factors affecting green areas in relation to institutional issues and capacity development, and (4) design methods to facilitate the promotion of their multiple functions (Kabisch et al., 2016), as the main components of green infrastructure assessment and in providing NbS. These four topics remain research priorities. For the first topic, identifying beneficiaries is a useful step in facilitating equitable access to green areas during the pandemic, especially since variations in socioeconomic status among individuals have been reported to have affected green area access, even during the COVID-19 pandemic (Uchiyama and Kohsaka, 2020). There is a risk that such socioeconomic variations in terms of access to green areas may have worsened due to official restrictions, information gaps, constraints within households or related to time, or other factors such as social norms. For example, before the pandemic, citizens with a relatively low socioeconomic status were reported to be unsatisfied with their access to green areas, in contrast to those with a higher status (Yasumoto et al., 2020). Such differences may have widened because of the pandemic’s influence on the global and national economies. Understanding who actually benefits from green areas can help clarify relevant underlying factors in relation to the effects of social and economic disparity and injustice, and further serve as a basis for devising practical countermeasures to overcome discrepancies among citizens in accessing green areas.

Most recent studies on the overall number of visitors to green areas have sought to identify the impact of the pandemic on the status of green area access. To understand the detailed profiles of visitors as the beneficiaries of green area access, their individual socioeconomic attributes have been analyzed, with sex and income being the two primary attributes surveyed and analyzed (Park, 2017; Coppel and Wüstemann, 2017; Gu et al., 2020); educational background was surveyed and analyzed as well (Wüstemann et al., 2017; Gu et al., 2020), both in pre-pandemic studies and more recently. While these socioeconomic attributes comprise the main variables in the most recent literature, environmental factors continue to play a relatively limited role, following previous research that also tended to analyze the location of residential areas within other environmental factors (Wei, 2017). To date, important environmental factors, such as land-use patterns or ratios of land use categories in residential areas, have not been included in the study focus.

By integrating environmental factors into research on green area access, insights can be obtained to assist with urban and rural planning, and to identify relevant information for use by multiple agencies, regarding areas that need improvements in terms of access to green areas. Regarding socioeconomic attributes, the relationships between individual attributes and the status of access to green areas have been the primary focus of analysis. Although this type of analysis can detect key attributes to be considered for improving green area access, relevant social groups of citizens as target social categories for green area policies need to be identified, in addition to key attributes. Relevant policies to facilitate green area access must be tailored to specific citizen groups with varying statuses in terms of green area access.

In summary, detailed information concerning the types of visitors that have benefitted from green area access needs to be explored, given that limited research has been conducted on this matter in previous studies and on the varying negative and positive effects of the COVID-19 pandemic on green area access. In particular, previously unexplored environmental factors, such as land-use patterns in residential areas, need to be analyzed from a holistic perspective to identify citizen groups with varying access to green areas, to enable a better-integrated
assessment of relevant socioeconomic attributes and environmental factors.

2. Methods

To identify the beneficiaries of green areas and the access status of citizens to green areas, this study conducted an integrated analysis of socioeconomic attributes and environmental factors and identified the extent of green area access among different citizen groups. As noted earlier, limited research has been conducted in this field, especially during the pandemic. An online survey was conducted from July 31 to August 1, 2020, among 1244 citizens in Aichi Prefecture, which includes the Nagoya City metropolitan area, one of Japan’s three largest metropolitan areas.

Aichi Prefecture historically comprises three regions, and one of them, the Owari region, has one major city and three areas, as shown in Table 1. Owari and Mikawa were two separate domains (or Kantō in Japanese) over 250 years in the centralized feudalism system during the Edo period. The locations of these regions are indicated in Fig. 2. In the Owari region, Nagoya City is the dominant and largest city in the prefecture. Other regions also have main cities; however, the population sizes are relatively small compared to those of Nagoya City. For example, the West Mikawa region has two main cities, Toyota City and Okazaki City, and their populations in 2019 were 426,162 and 386,999, respectively. These two cities are the second and third-largest cities in the prefecture. The main city of East Mikawa is Toyohashi, with a population of 373,606.

An online survey service system was used for the survey. A large number of citizens are registered in the survey system, and researchers can implement surveys to registered citizens whose age is ≥20 years. In the collection of the survey samples, the regional distribution of population and population distribution in individual age groups (people aged 20–39 years, 40–59 years, and ≥60 years) were considered. As shown in Table 1, the number of samples collected was larger than the planned number, and the planned number of samples was decided considering the sample size computed at the 95% confidence interval with a 5% sampling error using Cochran’s formula (Bartlett et al., 2001). It was calculated based on statistical data from 2019 using the following formula: n = n₀/(1 + n₀/N), where n₀ = (1 + p * q)/(d²), p is the value of the selected alpha level (α = 0.05, critical value 1.96), q is the possible proportion of the population that has the attribute in question (0.5), q = 1−α, d is acceptable margin of error (0.05), and N is population size. The calculated sample size was 384, and the sample size was larger than that size.

In a preliminary study (Uchiyama and Kohsaka, 2020), basic variables such as sex, age, household income, and whether respondents visited green areas during the first emergency declaration period (April 16 to May 14, 2020) of the COVID-19 pandemic in Japan were included. In this study, other sets of variables were used, such as the frequency and purpose of visits to green areas, to identify relevant details concerning the status of access to green areas among different citizen groups.

This study was conducted to analyze the status of green area visits under the influence of the first emergency declaration in detail. The first declaration had a certain impact on the behavior of citizens, although the number of confirmed COVID-19 cases at that time was relatively limited compared to that during other emergency declaration periods (Fig. 3). There were four emergency declarations in Japan (as of June 2022). To understand the impacts of the four declarations, the daily data of park visitors were supplied based on the COVID-19 Community Mobility Reports provided by Google LLC. These data have been applied in academic research on the global trends of park visitors during the COVID-19 pandemic (Geng et al., 2021). The data show the ratios of the number of park visitors compared to that of the reference period (January 3rd–February 6th, 2020) daily. To analyze the impacts of the declarations, the differences in the average change ratios of park visitors during the emergency declaration periods and those of the same durations immediately before the periods, were calculated (Table 2). For the first declaration, its impact on park visits was relatively strong, although there was a spring national holiday week from the last week of April to the first week of May every year in Japan. The third declaration also had a similar impact; however, it was immediately after the spring national holiday week, and the impact can be shown to be stronger than the actual impact because the average number of park visitors can be larger during the holiday week, and after the holiday week, the ratio of visitors is smaller compared with those in the holiday week. For the second and fourth declarations, their impacts on park visits were weak, even though they were declared immediately after the holiday weeks. There are holiday weeks during the week of January 1st and the week of August
confirmed cases from the reports of each prefecture and provided time-series data. Google LLC and the daily number of confirmed COVID-19 cases provided by the Japan Broadcasting Corporation (NHK). The NHK collected the daily number of cases among different citizen groups. The following variables were analyzed in relation to the effects of certain socioeconomic attributes and environmental factors on access to green areas, and the actual access status immediately before the periods.

15th. These circumstances and the data of park visitors, suggest that the first declaration on which this research focused had a strong impact on park visits at the study site. The results of this study show the status of green area visits under the influence of the emergency declaration, which had a relatively strong impact on citizens.

This study aimed to identify the detailed status of green area access, in relation to the effects of certain socioeconomic attributes and environmental factors on access to green areas, and the actual access status among different citizen groups. The following variables were considered:

- Socioeconomic attributes: Sex, age, annual household income, number of children in the household, and marital status.
- Environmental factors: Zip code area (to compute the ratios of land use categories in individual zip code areas), population density, household density in zip code areas, and whether there were accessible gardens near respondents’ houses or apartments (Yes/No)
- Status of access to green areas: whether respondents visited green areas (parks, agricultural lands, public or private gardens, and other green areas) during the emergency period (yes/no), frequency of access to green areas, partners with whom respondents visited green areas, purpose in visiting green areas, and modes of travel to visit green areas.
- Change in the status of access to green areas: whether there were changes in access to green areas compared with the same period during the previous year, and whether the frequency of visits changed compared with the same period during the previous year.

A discriminant analysis was conducted to quantify the effects of individual attributes and environmental factors on the status of green area access, to determine the influential variables affecting whether the respondents visited green areas during the pandemic period. Statistical tests were performed to identify the most influential variables affecting green area visits. Principal component analysis (PCA) and hierarchical cluster analysis were performed to identify the characteristics of citizen groups that could be usefully targeted as part of the green area management policies and practices. The PCA was conducted using socioeconomic and environmental variables, and the principal components identified were used to implement the cluster analysis. The cluster analysis detected citizen groups to analyze the status of green area access. Discriminant analysis identified the overall effects of the individual attributes and environmental factors on green area access, whereas PCA and cluster analysis detected distinctive citizen groups, using these attributes and factors to identify each group’s characteristics in relation to green area access.

3. Results

First, the results of the discriminant analysis showing the overall effects of specific socioeconomic attributes and environmental factors on green area access were set out, after which the results of PCA and cluster analysis were provided, followed by a presentation of the analysis results on the status of green area access, in terms of citizen groups detected using cluster analysis. Of the 1244 respondents initially involved in the survey, data obtained from 953 respondents were analyzed in relation to socioeconomic and environmental factors.

3.1. Discriminant analysis

The discriminant analysis provided a model to identify respondents who had visited and those that had not visited green areas during the emergency period. The results of the model were statistically significant (Tables 3 and 4). A total of 63.5% of the respondents were categorized into two groups: those who had visited green areas and those who had not. Although the percentage that could be identified among the respondents was not high, the results showed that basic socioeconomic attributes and environmental factors clearly influenced green area

### Table 2

| Emergency Declarations | Periods of Emergency Declarations | Differences of Average Change Ratios of Numbers of Park Visitors Before and During the Periods |
|------------------------|-----------------------------------|-----------------------------------------------------------------------------------------------|
| 1st                    | 4/16, 2020–5/14, 2020             | – 9.10                                                                                       |
| 2nd                    | 1/14, 2021–2/28, 2021             | – 1.59                                                                                       |
| 3rd                    | 5/12, 2021–6/20, 2021             | – 10.25                                                                                      |
| 4th                    | 8/27, 2021–9/30, 2021             | 4.17                                                                                         |

Note: Differences in the average change ratios of park visitors before and during these periods were computed using the average change ratios of park visitors during the emergency declaration periods and those of the same durations immediately before the periods.

### Table 3

| Wilks’ Lambda | Chi-square | df | Sig. |
|---------------|------------|----|------|
| .911          | 87.625     | 12 | .000 |

A discriminant analysis was conducted to quantify the effects of individual attributes and environmental factors on the status of green area access, to determine the influential variables affecting whether the respondents visited green areas during the pandemic period. Statistical tests were performed to identify the most influential variables affecting green area visits. Principal component analysis (PCA) and hierarchical cluster analysis were performed to identify the characteristics of citizen groups that could be usefully targeted as part of the green area management policies and practices. The PCA was conducted using socioeconomic and environmental variables, and the principal components identified were used to implement the cluster analysis. The cluster analysis detected citizen groups to analyze the status of green area access. Discriminant analysis identified the overall effects of the individual attributes and environmental factors on green area access, whereas PCA and cluster analysis detected distinctive citizen groups, using these attributes and factors to identify each group’s characteristics in relation to green area access.
access.

The detailed effects of the specific variables are listed in Table 4. The data in Table 4 show the correlation coefficients between the variables and scores in the discriminant analysis model. The presence of accessible gardens near houses or apartments, marital status, number of children, and household income are relatively influential. The results indicated that married respondents who had gardens, children, and a high income tended to visit green areas. This finding implies that citizens belonging to certain social groups could access green areas relatively easily during the emergency period, whereas citizens who did not belong to such groups may have had difficulty accessing green areas. The influence of environmental factors, such as the ratio of forest land in residential areas, was weak compared to socioeconomic attributes. This finding suggests that those citizens who were not married and those who did not have a high income could not easily visit green areas, or that they did not have the motivation to visit them, even if they were living in areas with high ratios of forest land.

To identify the most influential variables affecting green area access, statistical tests, including Fisher’s exact test, the Mantel–Haenszel test, and Mann–Whitney U test, were performed. These statistical test methods were selected based on the type of variable. The results of these tests are listed in Table 5. The results suggest that accessible gardens near houses or apartments, marital status, number of children, and household income were relatively strong influential variables among the socioeconomic attributes. Forestland was a major influential variable among the environmental factors.

The following subsection provides the results in terms of respondent categorization. The identified citizen groups that were characterized in terms of differing socioeconomic attributes and environmental factors were analyzed, and the results of the analysis in relation to green area access for the identified groups, are discussed in Subsection 3.3.

### 3.2. Principal component analysis and hierarchical cluster analysis

The PCA was conducted to identify the principal components used in the cluster analysis. In this PCA, variables related to socioeconomic attributes and environmental factors were used, but not the green area access variable, because that variable was analyzed as an independent variable in relation to citizen groups identified by cluster analysis using principal component scores, as set out in Subsection 3.3. The four components listed in Table 4 were identified based on the PCA. The cumulative contribution of these components was 67.1%. Component 1 was correlated with the ratios of urban areas, population density, and household density, and negatively correlated with agricultural land ratios. Component 2 was correlated with socioeconomic attributes such as marital status, number of children, and household income. Component 3 was correlated with the size of the zip-code areas and forestland ratios. Component 4 was correlated with the average age and sex.

Using the scores of these components, cluster analysis was performed, and five groups were detected (Fig. 4). Fig. 4 shows the scores for the individual components of the groups. The average values of the socioeconomic and environmental factors derived from the respondents’ data are provided in Table 7. These five groups can be described as follows:

1. Semiurban, young female respondents
2. Semiurban, unmarried, low-income respondents
3. Rural (with forest) respondents
4. Urban, married, high-income respondents

### Table 4
Structure matrix of the discriminant analysis.

| Variable | Categories or Averages | Visitors | Nonvisitors |
|----------|------------------------|----------|-------------|
| Accessible garden near the house or apartment (Yes:1, None:2) | -0.821 | | |
| Marital status (Unmarried:1, Married:2) | 0.442 | | |
| Number of children (None:1, One or more than one:2) | 0.433 | | |
| Household income (1: <200, 2: 200-400, 3: 400-600, 4: 600-800, 5: 800-1000, 6: 1000-1200, 7: 1200-1500, 8: 1500-2000, 9: ≥2000 (Unit: 10 thousand JPY)) | 0.181 | | |
| Age (year) | -0.105 | | |
| Forest land (%) | 0.092 | | |
| Zip code area (ha) | 0.083 | | |
| Urban area (%) | -0.061 | | |
| Household density (household/ha) | -0.056 | | |
| Gender (Male:1, Female:2) | 0.039 | | |
| Population density (people/ha) | -0.037 | | |
| Agricultural land (%) | 0.034 | | |

### Table 5
Cross tabulations and average values of variables for green area visitors and nonvisitors.

| Variables | Categories or Averages | Visitors | Nonvisitors |
|-----------|------------------------|----------|-------------|
| Accessible garden near the house or apartment | Yes | 450 | 181 |
| | None | 148 | 174 |
| Marital status | Unmarried | 131 | 122 |
| | Married | 467 | 253 |
| Number of children | None | 159 | 140 |
| | One or more than one | 439 | 215 |
| Household income (Unit: 10 thousand JPY) | <200 | 32 | 37 |
| | 200-400 | 145 | 89 |
| | 400-600 | 171 | 95 |
| | 600-800 | 120 | 59 |
| | 800-1000 | 61 | 45 |
| | 1000-1200 | 32 | 13 |
| | 1200-1500 | 24 | 7 |
| | 1500-2000 | 10 | 6 |
| | ≥2000 | 3 | 4 |
| Age (year) | Average | 51.3 | 52.3 |
| Forest land (%) | Average | 5.0 | 4.2 |
| Zip code area (ha) | Average | 165.6 | 149.4 |
| Urban area (%) | Average | 66.0 | 67.2 |
| Household density (household/ha) | Average | 20.2 | 20.7 |
| Gender (Male:1, Female:2) | Male | 343 | 208 |
| | Female | 255 | 147 |
| Population density (people/ha) | Average | 44.3 | 45.0 |
| Agricultural land (%) | Average | 23.3 | 22.8 |

Note: Variables in bold letters indicate statistically significant results of Fisher’s exact test (FE), the Mantel-Haenszel test (MH), or the Mann-Whitney U test (MW). Accessible gardens near houses or apartments, marital status, and the number of children were significant (p < 0.01) in FE. Household income was significant (p < 0.1) in the MH group. Forestland was significant (p < 0.05) for MW.

### Table 6
Result of PCA: Four principal components.

| Principal Components | 1 | 2 | 3 | 4 |
|----------------------|---|---|---|---|
| Gender (Male:1, Female:2) | -0.033 | 0.092 | -0.072 | -0.726 |
| Average age (year) | 0.017 | 0.181 | 0.013 | 0.826 |
| Marital status (Unmarried:1, Married:2) | -0.096 | 0.847 | -0.005 | 0.109 |
| Number of children (None:1, One or more than one:2) | -0.131 | 0.774 | -0.043 | 0.302 |
| Household income (1: <200, 2: 200-400, 3: 400-600, 4: 600-800, 5: 800-1000, 6: 1000-1200, 7: 1200-1500, 8: 1500-2000, 9: ≥2000 (Unit: 10,000 JPY)) | 0.119 | 0.553 | 0.095 | -0.212 |
| Accessible garden near the house or apartment (Yes:1, None:2) | 0.304 | -0.238 | -0.030 | -0.312 |
| Zip code area (ha) | -0.260 | 0.044 | 0.822 | 0.050 |
| Urban area (%) | 0.821 | 0.013 | -0.389 | -0.036 |
| Agricultural land (%) | -0.855 | -0.007 | -0.028 | 0.016 |
| Forest land (%) | -0.162 | 0.016 | 0.894 | 0.054 |
| Population density (people/ha) | 0.868 | -0.043 | -0.216 | 0.015 |
| Household density (household/ha) | 0.865 | -0.068 | -0.179 | 0.004 |
5. Rural (with agricultural land), older male respondents

These groups have distinct socioeconomic and environmental characteristics. In the next subsection, the analysis results of the status of green area access in relation to these groups are provided.

3.3. Status of green area access according to respondent groups

3.3.1. Travel time, purpose of visits, types of green areas visited, and mode of travel

In terms of the status of green area access among these citizen groups, Fig. 5 shows the relationships between the ratio of green area visitors in each group and the average travel time to green areas visited by them. The ratio of visitors in Group 2 to green areas was relatively low compared to the other groups. Furthermore, the average travel time to green areas in this group was the longest among the groups. This result suggests that the respondents in Group 2 lived relatively far from green areas. Due to this constraint, it is possible that they were not able to access green areas easily. Although the average travel time to access green areas differed among the other groups, the ratios of green area visitors were similar between Groups 1, 3, 4, and 5. This result further supports the explanation that longer travel time might hinder citizens from visiting green areas.

The ratios of respondents who visited green areas with family members were relatively high in all groups, except Group 2 (Fig. 6). In Group 1, 71% of the visitors went to green areas with family members. In Groups 2, 3, and 5, respondents who visited green areas were largely alone. Half of the visitors in Group 4 visited green areas with their family members, whereas approximately half visited green areas alone. In Group 2, >60% of the green area visitors were alone, with <20% visiting green areas with their family members or friends. Group 2 had a relatively long travel time to visit green areas, as shown in Fig. 5, which may help to explain why they tended to visit green areas without family members or friends.

The major activities undertaken in the green areas were walking, playing, and exercising. Fig. 7 shows the ratio of the activities in each group. Although exercising and playing were the two primary activities, the ratios of exercising or playing were relatively low in Groups 2 and 5, while walking was the predominant activity. In contrast, the ratios of walking, exercising, or playing in Group 1 were relatively high, with the ratio of exercising or playing being especially high. Relatively younger generations were categorized into Group 1, which may explain why they were more active in engaging in such activities, compared to the respondents in the other groups.

The types of green areas visited by the respondents in each group during the emergency period are shown in Fig. 8. No major differences were observed between the groups. However, it is noteworthy that the respondents in Groups 3 and 5 were more likely to visit agricultural lands and gardens than those in the other groups. Respondents whose residences were located in rural areas did not tend to visit parks, suggesting that the neighboring environment influenced respondents’ choices of green areas to visit.

The major modes of travel were “walk” and “private car” (cf. Fig. 9; Modes of travel to green areas). The ratios of respondents who used public transportation were lower than those who used the other modes. Bicycles were also not a major mode of travel at the research site. The ratios of respondents who walked to green areas were the highest, and Groups 4 and 5 had higher ratios. In contrast, Groups 1, 2, and 3 had relatively high ratios of respondents who used private cars. It can be assumed that the modes were related to the types of green areas visited by the respondents and the frequency of green area visits. For example, respondents in Group 5 tended to visit gardens, and the frequency of visiting green areas was relatively high, suggesting that they frequently

Table 7
Five groups of respondents and their related socioeconomic attributes and environmental factors.

|                          | Semi-urban young female | Semi-urban unmarried low-income | Rural (with forest) | Urban married high-income | Rural (with agricultural land) old male |
|--------------------------|-------------------------|--------------------------------|---------------------|---------------------------|----------------------------------------|
|                          | 1                       | 2                              | 3                   | 4                         | 5                                      |
| Male (%)                 | 7%                      | 77%                            | 78%                 | 70%                       | 89%                                    |
| Female (%)               | 93%                     | 23%                            | 22%                 | 30%                       | 11%                                    |
| Average age (year)       | 35.8                    | 52.1                           | 57.7                | 56.6                      | 63.1                                   |
| Unmarried (%)            | 29%                     | 78%                            | 15%                 | 2%                        | 0%                                     |
| Married (%)              | 71%                     | 22%                            | 85%                 | 98%                       | 100%                                   |
| Number of children(0)    | 43%                     | 79%                            | 19%                 | 2%                        | 3%                                     |
| Number of children(≥1)   | 57%                     | 21%                            | 81%                 | 98%                       | 97%                                    |
| Household income         | 3.7                     | 2.7                            | 3.5                 | 3.8                       | 3.2                                    |
| Garden (Yes)             | 59%                     | 70%                            | 89%                 | 81%                       | 91%                                    |
| Garden (None)            | 41%                     | 30%                            | 11%                 | 19%                       | 9%                                     |
| Zip code area (ha)       | 138.0                   | 83.8                           | 1,084.7             | 55.6                      | 250.6                                  |
| Urban area (%)           | 65.0                    | 74.2                           | 13.1                | 85.7                      | 38.1                                   |
| Agricultural land (%)    | 26.8                    | 20.0                           | 25.2                | 8.5                       | 46.7                                   |
| Forest land (%)          | 2.7                     | 1.1                            | 55.5                | 1.0                       | 6.9                                    |
| Population density (people/ha) | 40.6            | 55.2                           | 7.5                 | 58.7                      | 23.7                                   |
| Household density (household/ha) | 18.5             | 26.2                           | 3.1                 | 26.7                      | 9.7                                    |
| Total number of respondents | 251                | 202                            | 42                  | 289                       | 169                                    |
| Respondents who visited green areas | 167                     | 98                             | 27                  | 196                       | 110                                    |
visited gardens. The average travel time to green areas was the shortest among the groups. The survey results regarding the frequency of green area visits are provided in the following paragraph.

3.3.2. Frequency of green area access

Concerning the frequency of visiting green areas during the emergency period, the ratio of respondents who visited these areas once or twice a week was the highest in all groups, except Group 5, where the ratio of respondents who visited green areas every day was the highest (Fig. 10). In contrast, Group 1 had the highest ratio of respondents who visited green areas once a month. Although Group 1 had relatively high ratios of respondents who exercised or played in green areas, compared with the respondents in the other groups who mainly walked in green areas, the frequency of green area access among the respondents in Group 1 was lower than that in the other groups. This result suggests that exercise or play in green areas was not included as a regular feature in the respondents’ daily lives in Group 1 during the emergency period.

The survey results on changes in the frequency of green area access showed that the ratio of respondents whose frequency of visiting green areas changed was relatively high in Group 1. As shown in Fig. 11, visits were less frequent for 20% of the respondents in Group 1 compared with the same period the year before. In contrast, 29% of the respondents in Group 1 visited green areas more frequently than they did in the same period the year before. This result suggests that the frequency of visiting green areas among Group 1 respondents was more influenced by the pandemic than that among the other groups’ respondents; it also suggests that, as an overall trend, the frequency of visits among the respondents in Group 1 rose even higher, despite official discouragement with regard to going out and visiting places during the emergency period.

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Fig. 5. Ratio of green area visitors in each group and the average travel time to green areas
1: Semiurban, young female; 2: Semiurban, unmarried, low-income; 3: Rural (with forest); 4: Urban, married, high-income; 5: Rural (with agricultural land), older male. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)
4. Discussion and conclusions

Our results comply with those of previous research, such as the study by Yasumoto et al. (2020), which showed that socioeconomic differences were reflected in green area access. This study offers the following original contributions: (1) the relatively significant influence of the pandemic on green area access among young females, as evidenced by Group 1; (2) difficulties concerning green area access experienced by unmarried, low-income respondents (Group 2); and (3) the influence of the neighboring environment on green area access; for example, if there were agricultural lands near the respondents’ residences, they tended to visit those lands instead of other green areas. Specifically, an integrated analysis of socioeconomic attributes and environmental factors was conducted, and a typology of respondents as beneficiaries of green infrastructure was constructed. This typology could be considered when setting policy targets or components within a policy to enhance the management of green areas as green infrastructure. For holistic research on policies for improving the relationships between citizens and green infrastructure, the status of nature experience and environmental conservation activities by the citizen groups identified in this study can be

Fig. 8. Types of green areas that the respondents in each group visited
1: Semiurban, young female; 2: Semiurban, unmarried, low-income; 3: Rural (with forest); 4: Urban, married, high-income; 5: Rural (with agricultural land), older male. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 9. Mode of travel to green area
1: Semiurban, young female; 2: Semiurban, unmarried, low-income; 3: Rural (with forest); 4: Urban, married, high-income; 5: Rural (with agricultural land), older male. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 10. Frequency of visiting green areas among the respondents in each group during the emergency period
1: Semiurban, young female; 2: Semiurban, unmarried, low-income; 3: Rural (with forest); 4: Urban, married, high-income; 5: Rural (with agricultural land), older male. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)
analyzed in the future. The analytical method used in this study can be applied to different regions of the world and contribute to policymaking for green area management. One limitation of this study is the online survey in terms of the age groups represented. A greater number of older female participants should be included in future research, possibly through additional face-to-face or questionnaire surveys using postal mail.

The results of this study indicate that certain social groups of citizens are likely to experience difficulty accessing green areas, because socioeconomic disparities can be reflected in green area access even in cities with relatively less marked economic variations among citizens, such as the target site of this research in Japan. Although providing opportunities to access green areas for those who cannot easily access such areas can be challenging, some steps can be taken to address inequitable green area access. Developing new parks or forests is difficult, especially in high-density urban areas. However, providing opportunities to access existing green areas for those who have difficulty accessing such areas, and enhancing their awareness of green areas could be more plausible options to consider, as well as revitalizing existing green areas to make them more attractive and user-friendly. Providing increased opportunities for identified target groups could be facilitated through policies that consider how employment conditions could be better tailored to improve green access. Furthermore, educational policies need to be developed to enhance awareness of green areas.

With the COVID-19 pandemic, issues concerning socioeconomic inequity have become increasingly evident, with worsening effects in several areas such as green area access, due to imposed lockdowns in many urban areas globally. Constraints on green area access are easily noticeable in daily life, with readily determinable effects, as indicated by the survey results. Furthermore, as citizens’ needs and perceptions of green areas change, the value of green areas is being increasingly acknowledged. Therefore, more appropriate policies and practices are needed to address citizens’ needs in this area. As a readily perceptible key issue within socioeconomic inequity and linked to environmental management, discrepancies in green area access among different citizen groups require addressing, to enhance the sustainability of urban and rural areas in terms of integrating responses to critical environmental, economic, and social challenges.

In future research, cross-scale approaches that address green area access issues related to green gentrification (Haase et al., 2017) should be adopted. Although green gentrification is likely to critically affect urban sustainability and related green policies (Wolff and Haase, 2019), this aspect is frequently not included or considered in relevant discussions and policymaking. To help ensure that current socioeconomic and environmental discrepancies do not become more serious, communication concerning the various issues that confront social groups with differing socioeconomic and environmental opportunities and constraints, needs to occur to reduce discrepancies. Green gentrification involves the selective movement of population and capital at the local, national, and global levels. Recently, urban development through international investment and its relationship with green gentrification has been highlighted, both theoretically and empirically (Blok, 2020). In discussions concerning governance for urban sustainability and the application of green policy, ecological democracy has become a related academic field, and cross-scale approaches have been recommended as a necessary component of governance in ecological democracy (Pickering et al., 2020). In addition to helping us understand the current status of socioeconomic and environmental discrepancies as they relate to green area access, a cross-scale approach is required to analyze the proposed policies and practices to address such discrepancies. Future studies are required on the long-term sustainable participatory management of green infrastructure, to identify the processes involved in green gentrification and to develop appropriate and effective measures to enhance green area access. Future research could also survey the detailed characteristics of green areas and their access by asking questions about the exact names and locations of green areas visited by them, and by measuring the distance to the green areas.

Author contributions
Conceptualization, R.K. and Y.U.; Methodology, R.K.; Validation, Y. U. and R.K.; Formal analysis, Y.U.; Investigation, R.K. and Y.U.; writing—original draft preparation, Y.U.; writing—review and editing, R. K.; Funding acquisition, R.K. All authors have read and agreed to the publication of the manuscript.

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.

Acknowledgment
This research was funded by the Japan Society for the Promotion of Science: JSPS KAKENHI Grant Numbers: JP16KK0053; JP17K02105; JP20K12398, 22H03852, JST RISTEX Grant Number JPMJR20B3, as well as the Kurita Water and Environment Foundation:20C002. Thanks are extended for Dr. Yasushi Shoji who gave us valuable comments when compiling the questionnaire.
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