

1 Quantitative Environmental Equity Analysis of
2 Perceived Accessibility to Urban Parks in Osaka
3 Prefecture, Japan

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23
24 **1. Acknowledgment**

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36 **Abstract**

37
38 Environmental equity (EE) has become internationally recognized as an important research field, but
39 in Japan limited quantitative research is available. In this paper we report the results of a quantitative
40 study that tested whether objective and perceived accessibility to parks is disproportionately
41 distributed between the affluent and the poor in Osaka Prefecture, Japan. Perceived accessibility is
42 considered to be a more accurate accessibility measure which reflects the socio-cultural background
43 of people. We find inequities in both accessibility measures, and using multiple logistic regression
44 analysis, we clarified that perceived accessibility is shaped by a range of factors (i.e., income level,
45 objective accessibility to parks, and people’s perceptions of traffic accidents, crime, and the level of
46 scenic beauty in the neighboring area). Our results provide some insight into remediation measures for
47 the environmental inequity of perceived accessibility. Simply establishing a new urban park may not
48 sufficiently increase the perceived accessibility of socioeconomically deprived groups. Identifying the
49 underlying mechanisms that could explain how poverty-related factors undermine the perceived park
50 accessibility or improving the quality of neighboring area are also important to ensure the effectiveness
51 of remediation measures.

52
53 **Keywords:** Environmental equity; Perceived accessibility; Urban parks; Geographic information
54 systems; Japan

62 **2. Introduction**

63 Environmental equity (EE) is defined as an equal burden of environmental risks or accessibility to
64 amenities regardless of population characteristics, such as age, gender, ethnicity, and poverty level
65 (EPA 1992, Jones et al. 2009a). EE is often related to health inequities and economic inequities, and
66 these can all operate together (Pearce et al. 2010, O’Neill et al. 2003). For example, a disproportionate
67 distribution of environmental risks or amenities may be a path to the magnification of health inequity
68 (O’ Neill et al. 2003, Nakaya 2011, Pearce 2005). Alternatively, a disproportionate siting of
69 environmental risks or environmental amenities may affect land prices and/or residential choice (Saha
70 and Mohai 2005, Been 1994), and consequently, magnify inequity between the affluent and the poor.

71
72 Historically, the term “Environmental Equity” originated from social movements against unequal
73 burdens of environmental risks in the US. Before the 1980s, public opposition to the siting of waste
74 facilities in several areas increased on account of more widespread awareness of the environmental
75 risks, but originally citizen opposition was predominantly organized by the white middle class, and
76 politically disempowered communities, such as minority groups, were not sufficiently represented
77 (Bullard 1990, Dunlap and Mertig 1992). Following the path of least resistance in such communities
78 due to their political vulnerability (i.e. limited access to resources and allies in governing authorities),
79 environmentally risky facilities ended up being disproportionately sited in areas occupied by minority
80 or deprived communities (Bullard and Wright 1987).

81
82 Since the 1980s, a social movement against environmental racism has developed. This has particularly
83 focused around the view that non-white communities were disproportionately burdened with
84 environmental risks from the siting of controversial facilities such as hazardous waste dumps, and this
85 phenomenon was evidenced by several early studies (e.g. GAO 1983, Zimmerman 1993). Conceptual
86 and research frameworks concerning EE were then expanded to integrate the goals of investigating
87 and remedying the unequal distribution of a range of environmental risks and amenities between social
88 groups.

89
90 A situation of environmental inequity (i.e., socially disadvantaged groups are more likely to be
91 exposed to environmental pollution) has been found in Japan as well as historically in the USA (Terada
92 2006). The trigger of a social movement aimed at remedying such unequal burdens in Japan was the
93 occurrence of several environmental pollution events that resulted from rapid industrialization. For
94 example, the Ashio Copper Mine Mineral pollution incident in the latter part of the 19th century and
95 Minamata disease in 1950s are all known as incidences of environmental contamination in which poor
96 people were disproportionately affected (Shoji and Miyamoto 1964; Iijima 1987; Harada 2007). Kajita

97 (1988) stated that, in the Japanese context, the benefits and costs of large-scale development projects
98 (e.g., industrial complexes and power stations) are prone to be disproportionately distributed in
99 socioeconomically deprived areas.

100

101 A sizeable amount of past qualitative research in Japan has demonstrated that industrial waste
102 management plants (Terada 2006), nuclear power stations (Fujikawa 2016), and industrial factories
103 (Ikuta 2007) have the tendency to be located in socioeconomically deprived areas and cause a negative
104 effect on local people's life and health. Nevertheless, quantitative research focused on the spatial
105 relationship between population characteristics and environmental quality is still relatively sparse in
106 Japan. Tanaka (2001) evaluated accessibility to a range of facilities for daily life (e.g. medical
107 facilities, financial facilities, and parks) and found that students and elderly females have inferior
108 access compared to workers and elderly males. Other quantitative case studies found a
109 disproportionate distribution of environmental quality, including objective park accessibility
110 (Yasumoto et al. 2014), access to sunlight (Yasumoto et al. 2012), and a combination of urban
111 amenities (Uesugi and Yasumoto
112 2018).

113

114 Building on this consideration, we conducted a quantitative EE analysis of both objective and
115 perceived accessibility to urban parks in Osaka Prefecture, Japan. Urban parks are one of the most
116 important amenities in a city particularly for human health and safety. For example, as a case study by
117 Takano et al. (2002) found that accessibility to green spaces was positively associated with the
118 longevity of the elderly in Tokyo, Japan. Several mechanisms have been proposed through which such
119 places might provide positive effects on health. Parks provide opportunities for physical activity
120 (Hanibuchi et al. 2011) and reduce the risk of air and noise pollution, fires, and earthquakes (Hirata
121 2004). Furthermore, they have the potential to enhance psychological health via restorative effects
122 (van den Berg 2016, Kaplan 1993). In addition, De Vries et al (2013) have identified that streetscape
123 greenery is positively associated with perceived social cohesion at the neighborhood level.

124

125 An important consideration is that socially disadvantaged populations are potentially more vulnerable
126 to deprivation of green space accessibility (Maas et al. 2006, Maas et al. 2009, van den Berg et al.
127 2016). For example, in a Dutch study it was found that perceived general health of people of lower
128 socioeconomic status was more susceptible to green space accessibility than those who were more
129 affluent (Maas et al. 2006). This is of concern given that several studies found that green space
130 (including urban park) accessibility is disproportionately distributed among social groups (Jones et al.
131 2009a, Wolch et al. 2005, Sister et al. 2007, Yasumoto et al. 2014).

132

133 Whilst the level of international research on EE of park accessibility has been rapidly expanding there
134 remains a need to better understand the policy implications. To date past studies significantly used
135 objective accessibility measures to test the EE of parks (Wolch et al. 2005; Sister et al. 2007), but
136 perceived accessibility measures have been rarely considered.

137

138 Perceived accessibility to parks describes the degree to which people perceive to have access to parks
139 within reasonable distance. Perceived accessibility reflects an individual's population characteristics,
140 lifestyle, and neighboring environment. Hence, it can be a more accurate measure of people than
141 objective accessibility (Wang et al. 2015a, Ball et al. 2008). Some research found that perceived
142 accessibility to parks may be a more optimal predictor of park usage than objective park accessibility
143 (Wang et al. 2015b). Wang et al. (2015a) found that in both Australian and Chinese cities, the poor
144 have a worse perceived accessibility to parks than the affluent. Because perceived accessibility is
145 influenced by the different sociocultural backgrounds of each area, they suggested that understanding
146 the factors that shape perceived accessibility is essential to improving people's perceived accessibility.

147

148 Considering these findings of past studies, distribution of perceived accessibility to parks should be
149 important from the perspective of EE. Jones et al. (2009b) found that in Bristol, UK, the poor had
150 better objective accessibility to parks than the affluent. Nevertheless, the poor had worse perceived
151 accessibility compared to the affluent. This study indicated that to achieve EE with respect to park
152 accessibility, comprehensive measures are necessary, not only in terms of provisions of accessibility
153 to parks, but also improvement in other factors (e.g., quality of parks and safety in neighboring areas)
154 that may influence perceived accessibility.

155

156 As stated above, in Japan, quantitative EE studies is sparse, and even studies on the factors that
157 influence perceived accessibility to parks is limited. An approach based on perceived accessibility
158 measure would play an important role in identifying the status of EE and developing recommendations
159 to enhance EE.

160

161 We set three research goals in this paper. First, we tested whether EE of objective accessibility to parks
162 existed in Osaka Prefecture, Japan. Second, as an alternative accessibility measure, we investigated
163 the situation of EE in perceived accessibility to parks. Finally, we identified what factors have a
164 statistically significant effect in shaping people's perceived accessibility. The work was undertaken in
165 the hope that it will contribute insights into efficient potential measures to reduce the unequal
166 distribution of perceived accessibility to parks.

167

168 **3. Methodology**

169 **3.1. Study area**

170 The study area of this research is the Densely Inhabited District (DID) in Osaka Prefecture, Japan
171 (Figure 1). Osaka Prefecture has the second highest population density and GDP among the 47
172 prefectures in Japan and suffers from a shortage of parks and green spaces due to intensive
173 urbanization. Many people in the highly urbanized and populated area in Osaka Prefecture deem
174 green spaces to be limited compared to suburban or mountainous areas (Osaka Prefectural
175 Government, 2012), and thus it is predicted that those areas have a potentially high demand for
176 accessibility to parks. Considering this background, DID was selected as the sample area for this
177 study. In fact, as Figure 1 shows most urban parks have been opened within the DID.

178

179 **< Figure 1 about here >**

180

181 **3.2. Data**

182 To test the objective accessibility to parks, we generated two sets of data: an urban park map of Osaka
183 Prefecture and data on the distribution of the poverty level in each area. To generate the urban park
184 map, locational information of parks in 2010 in Osaka Prefecture was obtained as point data from the
185 National Land Numerical Information download service (Geospatial Information Authority of Japan,
186 2018). This data contains names, locations, areas, and the years of operation for the urban parks in the
187 study area. From “Detailed data collection maps 2012”, provided by ESRI Japan Inc., we extracted
188 polygon data from each park, and matched it with the point data above using GIS. Because the map
189 data from ESRI Japan did not cover all parks, the parks without polygon data were assumed to have a
190 round shape. The radius of each park was calculated from the park area, and a round-shape polygon
191 was generated to represent each park (Figure 1). We generated manually the polygons of some parks
192 that have substantially different shape from a round shape.

193

194 **3.3. Analysis of objective accessibility**

195 For each small census area (called “Chocho-aza” in Japanese), the objective accessibility to parks was
196 measured. A service area analysis based on the road network (ESRI, 2018) was used to measure
197 objective park accessibility from the centroid of each small census area. The road network distance
198 was restricted to 800 m because past studies considered 800 m (approximately 10 mins walk) to be a
199 suitable walking distance (Hilsdon et al. 2015, Dalton et al. 2016). ‘Data collection road network 2012’
200 (ESRI Japan Inc.) which represents the road network in 2011 in Osaka Prefecture was applied.

201

202 Then we calculated three metrics: the number of parks, the total park area, and the park area per capita
203 within each of the 800 m road network distance. The total population of each corresponding small
204 census area was extracted from the 2010 Japanese Census. These metrics were computed using the
205 ‘container’ method. This method identified all facilities within a specific area and aggregated
206 quantitative characteristics of all of the facilities (see Talen and Anselin 1998).

207

208 In the Japanese Census white collar workers are categorized into three types (i.e. administrative and
209 managerial workers, professional and engineering workers, and clerical workers) with the first two
210 being the highest income groups. At a small census level, we extracted the percentage of the two
211 groups (called “professional and managerial workers” hereafter) from the 2010 Japanese Census
212 (Figure 1) as the affluence indicator. Then, we categorized the indicator into quintiles. From the lowest
213 quintile to the highest quintile, numbers (1 to 5) were added to each quintile (i.e., the least affluent
214 group was numbered 1, and the most affluent group was numbered 5). To test the trend of EE, we
215 examined the correlation between these numbers and the three objective accessibility measures by
216 calculating Spearman's rank correlation coefficients.

217

218 **3.4. Questionnaire survey and analysis of perceived accessibility**

219 To measure the perceived accessibility to parks and determine the factors that may affect the measure,
220 a questionnaire survey was conducted in January 2010 in Osaka Prefecture. Demographic
221 characteristics such as age, gender, and household income were also asked within the survey. A
222 twostage stratified sampling was applied to choose the target individuals who would receive the
223 questionnaire. First, Osaka Prefecture was divided into four parts: Osaka city, northern, eastern, and
224 southern areas. Then, each small census area was classified into one of 12 types in terms of Japanese
225 geodemographics, provided by Acton Wins Co., Ltd. Therefore, all small census areas were
226 categorized into 48 strata (4×12). Then 160 small census areas were chosen from the 48 strata. Based
227 on the population aged 20 or over (extracted from the 2005 Japanese census), we calculated the
228 proportional share of each small census areas assigned to each stratum. Next, from an address list for
229 direct mail, provided by Acton Wins Co., Ltd, approximately 40 households were randomly selected
230 in each small census area, and questionnaires were sent to them.

231

232 In each selected household, we requested one person (aged 20 or over), whose birthday comes first
233 after January 1, to be chosen as a respondent following the birthday selection method. As a result, a
234 total of 2527 people returned the questionnaire. The respondent rate was around 40%, excluding
235 oneperson households in which the person is less than 20 years old.

236

237 The questionnaire survey was originally designed as a part of a research project to investigate a range
238 of factors, including noise pollution and social cohesion, which may shape social inequality in health
239 in the whole Osaka Prefecture. Since our research focus is urban park accessibility, it was necessarily
240 to distinguish between urban and rural areas. Dominant green spaces in urban areas are typically urban
241 parks, whilst agricultural lands are dominant in rural settings, indicating the importance of this context
242 as a determinant of greenspace use (Parks et al. 2003). To focus on urban park accessibility, in this
243 research respondents whose residences were located within the DID were chosen. In total, 2345
244 respondents were selected as a sample for statistical analysis.

245

246 Table 1 shows the questions within the survey. We asked for information relating to gender, age,
247 household income, level of perceived accessibility to parks, and perception of their neighboring area
248 in terms of traffic accident risk, crime risk, conservation of scenic beauty, and social cohesion. Table
249 1 also reports the percentage of the number of respondents against the overall sample for each age and
250 gender group as well as the corresponding values in the study area, DID, extracted from the 2010
251 Japanese Census. The comparison showed that the percentage of people aged over 60 that responded
252 to the questionnaire is higher than the proportion of the actual population, while the percentage of
253 people aged in their 20s and 30s who responded is less. The overall sample is, therefore, slightly biased
254 toward elderly people.

255

<Table 1 about here>

257

258 Perceived accessibility to parks was measured by a question (see Table 1), and five possible answers
259 were prepared: ‘1. Sufficient’; ‘2. Relatively sufficient’; ‘3. Some, but not sufficient’; ‘4. None’; and
260 ‘5. I don’t know’. These were categorized into a binary outcome of superior vs inferior perceived
261 accessibility. Within these selections, 1 and 2 were categorized as superior perceived accessibility,
262 while 3, 4, and 5 were categorized as inferior perceived accessibility. Selection 5 was categorized into
263 the inferior perceived accessibility as this indicates a lack of recognition of neighboring parks and
264 limited perception of park accessibility.

265

266 The annual income of each household (18 categories) was asked through the mail questionnaire. To
267 adjust for household size, the reported annual household income was divided by the square root of the
268 number of household members so that an equivalent household income measure could be constructed.
269 The equivalent household income was then categorized into quintile groups. To test equity of
270 perceived accessibility, we conducted cross tabulation and constructed a line graph to identify

271 magnitudes in the perceived park accessibility across the different income groups. A test for trend was
272 also conducted using logistic regression analysis.

273

274 **3.5. Logistic regression models to predict perceived accessibility**

275 To identify the factors affecting the prediction of perceived accessibility to parks, we developed three
276 multilevel logistic regression models using the hierarchical data; individual respondents (level 1 units)
277 were clustered in small census areas (level 2 units). All three models are random intercept models to
278 control for unknown regional factors at the scale of the small census areas. The outcome variable was
279 set as the binary superior/inferior outcome variable.

280

281 The first model (model 1) incorporated quintile groups of equivalent household income to examine
282 how household income level affects perceived accessibility, after the effects of gender and age were
283 controlled for.

284

285 The second model (model 2) employed an additional explanatory variable, objective accessibility to
286 parks, to test two questions. First, we examined whether the magnitude of objective accessibility
287 affects perceived accessibility (Wang et al. 2015a). Second, after the effect of objective accessibility
288 was controlled for, we examined whether household income influences perceived accessibility.

289

290 A service area analysis based on the road network (ESRI, 2018), as stated above, was used to measure
291 objective park accessibility from the residence of each respondent. Again, the road network distance
292 from a residence was restricted to 800 m (Hilsdon et al. 2015, Dalton et al. 2016) since we predefined
293 ‘neighboring area’ on the questionnaire sheet as 10 – 15 mins walking distance from the residences of
294 the respondents (10 mins walk corresponds to approximately 800 m on foot. See Table 1). Then, the
295 ‘Container’ method as described above was used to identify the total park area within each service
296 area. For road network data, ‘Data collection road network 2012’ (ESRI Japan Inc.) was again applied.

297

298 Furthermore, several past studies have postulated or found that perceived accessibility was affected by
299 the risk perception of traffic and crime, conservation of scenic beauty, and magnitude of social
300 cohesion in the community (Wang et al. 2015a, Jones et al. 2009b, Wang et al. 2015c). Adding these
301 variables, we developed the third model (model 3). The independent variables were dichotomized for
302 brevity of the table.

303

304 In the questionnaire we asked magnitude of the risk perception of both traffic and crime (Table 1). The
305 answers ‘4. Relatively impossible’ and ‘5. Impossible’ were categorized as the group of high-risk
306 perception.

307

308 We also asked the perception of conservation of neighboring scenic beauty, (Table 1). Answers of ‘1.
309 Many exist’ and ‘2. Exist’ were categorized into the group of the perception that the community’s
310 scenery is impaired. The magnitude of social cohesion was asked (Table 1), and the answer of ‘4. We
311 have almost no communication’ was selected as the group of low social cohesion.

312

313 In this study, we used ArcGIS ver.10.5 (ESRI Japan Inc.) for GIS studies. The software package R
314 ver.

315 3.2.3. with package “lme4 (function of glmer)” (Bates 2015) was used to undertake the multilevel
316 logistic regression analysis. All other statistical analyses including the descriptive analysis and the
317 correlation test were done performed using SPSS ver. 25.0 (IBM Inc.).

318

319 **4. Result**

320 We found that there was environmental inequity in objective accessibility to parks (Table 2). The result
321 shows that small census areas with a higher percentage of professional and managerial workers tend
322 to have superior accessibility in terms of the three metrics. This trend is particularly clear when the
323 overall park area is considered. The mean value of the park area per capita shows a less clear trend,
324 partly due to several small census areas having small populations but large park areas and,
325 consequently, high per capita values. The median per capita values are therefore more reliable. The
326 result made it clear that potentially intervention is necessary to reallocate the accessibility of the
327 amenity.

328

329 **<Table 2 about here>**

330

331 Environmental inequity in perceived accessibility was also found. Figure 2 demonstrates that people
332 with lower income have a more inferior perceived accessibility, which demonstrates the inequity of
333 perceived accessibility to parks. The test for trend also shows there is a negative and statistically
334 significant trend between income level and superior perceived accessibility.

335

336 **<Figure 2 about here>**

337

338 Table 3 reports the results of logistic regression analysis. As indicated in model 1, after controlling for
339 gender and age, the poorest group has significantly lower perceived accessibility to parks compared
340 to the most affluent group.

341

342

<Table 3 about here>

343

344 In model 2, which integrated the objective accessibility to the parks demonstrated in model 1, a positive
345 association between total park area and odds of having a superior perceived accessibility was found.
346 Furthermore, even after the effect of objective accessibility of parks was controlled, income level still
347 had a significant effect (i.e. the lowest income group is significantly lower than the rest).

348

349 According to model 3, the risk perception of traffic and crime and the impaired beauty of scenery in
350 the neighboring areas had a significant negative effect on perceived accessibility, even after the income
351 levels and objective accessibility were controlled. In other words, the quality of the neighboring area
352 is important to determine perceived accessibility. A significant effect of social cohesion was not found.

353

354 All models (1–3), consistently showed that only the lowest income group has a significant and negative
355 effect compared to the reference (the highest income group), while middle income groups do not.

356 Furthermore, both gender and age were consistently insignificant across all three models.

357

358 The AIC (Akaike information criterion) improved from model 1 to 3. Also, the AIC of the random
359 intercept models were substantially better than the corresponding ones without random effect terms
360 showing that these were a more appropriate fit to the data. The size (variance) of the random effect
361 decreased successively from model 1 to 3, as anticipated, due to the integration of neighborhood
362 characteristics.

363

364 In addition, a parallel lines test using an interaction between income and objectively measured
365 accessibility was not statistically significant, indicating the assumption of parallel lines was not
366 violated.

367

368 **5. Discussion**

369 We found environmental inequity of objective accessibility to parks in Osaka Prefecture. This result
370 accords with past studies from both outside and inside Japan (e.g. Jones et al. 2009a; Wolch et al.
371 2005; Sister et al. 2007; Yasumoto et al. 2014). It was also evident that even perceived accessibility is
372 disproportionately distributed between the poor and the affluent through cross tabulation analysis

373 (Figure 2). As a more important analysis, we conducted logistic regression to clarify the factors which
374 affect perceived accessibility (Table 3).

375

376 From longitudinal evidence, Yasumoto et al. (2014) found that the establishment of parks by the
377 government in deprived areas with limited parks can be the most effective measure to remedy the
378 inequity of objective park accessibility. However, perceived accessibility is considered a more
379 accurate measure for people's park usage than objective accessibility, and simply increasing the
380 provision of parks may not result in improved perceived accessibility (Wang et al. 2015b).
381 Perceived accessibility is shaped by not only objective park accessibility, but also a range of socio-
382 cultural and personal factors, as shown in Table 3. Our findings provide some insights into potential
383 remediation measures to improve environmental inequity.

384

385 First, comparing model 1 and model 2, we found that providing urban parks in deprived areas might
386 not be a sufficient measure alone to improve perceived accessibility. Poverty at the household level
387 also negatively influences perceived accessibility, and thus it is important to understand how
388 poverty-related factors discourage perceived accessibility.

389

390 Although in this research, such causal mechanisms of how poverty negatively influences perceived
391 accessibility were not investigated, several possible reasons for this relationship can be suggested. One
392 reason may be that quality of the parks near the deprived group might be worse (e.g., not well
393 maintained or less green spaces) than the parks in other communities, and these might lower perceived
394 accessibility in these communities (Jones et al. 2009b).

395

396 Alternatively, personal characteristics of deprived people might affect accessibility, such as available
397 leisure time, lifestyle and activity levels, or general health status, which might be lower than those for
398 other groups (Wang et al. 2015a). Lack of efficient traffic modes, such as a bicycle, may also be
399 associated with lower perceived accessibility of poor people (Wang et al. 2015a). Further research is
400 required to understand these mechanisms. In this study, when compared to the most affluent group,
401 only the most deprived group had significantly lower perceived accessibility (Table 3), and research
402 should focus on this group.

403

404 Second, as model 3 clarified (Table 3), the perception of risk of traffic accidents and crime, and
405 impaired beauty of scenery in neighboring areas negatively affect perceived accessibility. Therefore,
406 decision-making regarding the establishment of new parks must consider the quality of neighboring

407 areas; otherwise, the supply of a new park may not necessarily improve local people's perceived
408 accessibility. This is important to enhance EE.

409

410 Mortality caused by traffic accidents is a major public health concern, and road safety is recognized as
411 a social equity issue (WHO 2004). In studies outside Japan, motor vehicle accidents tend to impact
412 disproportionately on poor people (Kendrick 1993, Dougherty et al. 1990). Therefore, reducing traffic
413 accidents may be particularly important in deprived areas. Such efforts may also improve the
414 perception of park accessibility in poorer communities, which could enhance the environmental equity
415 of park accessibility. Specifically, past studies show that a reduction in traffic volume and traffic
416 speeds, and provision of traffic controls, such as signals to cross the road and pedestrian crossings,
417 may contribute to reducing the perception of risk of traffic accidents (Rothmana et al. 2015; Rankavat
418 and

419 Tiwari 2016).

420

421 Likewise, reducing crime levels and improving safety and scenic aesthetics may improve perceived
422 accessibility. To mitigate the perception of risk of crime, placement of street lamps, more frequent
423 patrols by police officers, and positive interaction with citizens (Peña-García et al. 2015; Montolio and
424 Planells-Struse 2015) are suggested as potential helpful measures. Nakamata and Abe (2016) found
425 that to preserve scenic beauty there are some prevention measures against littering, such as siting a
426 security camera, flowerbed, and signboard, and removal of pre-existing littering. Waste left on the
427 streets may contribute to the perception of crime risk as well (Shimada et al. 2004).

428

429 Third, the result of model 3 indicates that provision of urban parks (more than 1ha) within an 800 m
430 road network improves the perceived accessibility of neighboring people. It may be difficult, however,
431 to consistently obtain such large open spaces in highly populated urban areas to build a park because
432 of the shortage or high price of land parcels. Nevertheless, the long-term view is that the cumulative
433 effects of a policy framework to provide parks in poor areas which have less park accessibility would
434 contribute to EE.

435

436 A concern may be that providing a park may raise land prices in the surrounding area and attract
437 affluent people to the district, and consequently backfire the remedy for the inequity. However, a study
438 by Yasumoto et al. (2014) conducted in Yokohama city, Japan, found such gentrification has little
439 effect on reallocation of social groups, although similar study is yet untested in our study area.

440

441 There are several limitations regarding the methodology. Firstly, for objective accessibility we focused
442 only on urban parks. However, in the questionnaire survey we asked a question to measure perceived
443 accessibility: “In your neighboring area, are there green spaces or open spaces with free access, such
444 as a park?” Therefore, this implies that not only urban parks, but also other types of open spaces with
445 free access such as a well-maintained riverbed are included, although such open spaces should be
446 limited in the context of DID in Osaka Prefecture, one of the most urbanized areas in Japan.

447

448 Secondly, we focused only on the number and area of parks to calculate objective accessibility; other
449 quality measures were not integrated. For example, sports facilities and ecosystems including green
450 spaces inside a park could also have important value for park users and communities (Hirata 2004).

451

452 Thirdly, perceived accessibility is often measured through a questionnaire survey, and thus it is
453 represented as categorical data (see Table 1). In this study perceived accessibility was reclassified as
454 a binary variable, and logistic regression analyses were applied, but we recognize there will be some
455 variability in perceptions within the two binary categories.

456

457 Finally, our sample is slightly biased toward elderly people (Table 1). As Kaczynski et al. (2009)
458 mentioned, elderly people are more likely to be sensitive to park accessibility compared to middleaged
459 adults because the latter group tend to work full-time away from their homes. Therefore, the
460 participants of this study may be relatively more sensitive to park provision compared to the population
461 of Osaka Prefecture. For the multiple logistic regression analysis, we controlled the effect of age using
462 the logistic regression analysis, and the results were all insignificant for the three models (Table 3).

463

464 Another important facet of the issue of EE in terms of perceived accessibility is whether characteristics
465 of neighboring areas appear to mediate the relationship between poverty and perceived accessibility
466 to parks. For example, the poor tend to live in unsafe areas, which may discourage park usage. Such
467 interdependency needs to be explored using additional tests, such as casual mediation analysis, for
468 further understanding of EE in terms of perceived accessibility. Whilst we have focused on area effects
469 using multi-level analysis within the logistic regression models, another direction of future research
470 could be the fitting of more complex spatial models to consider factors like contiguity or the distance
471 between areas.

472

473 In this paper we focused on Osaka Prefecture, Japan. It is suggested that further EE studies of perceived
474 accessibility are conducted in other areas both inside and outside the country. This is particularly
475 important as a direction for future research because perceived accessibility could be shaped by the

476 unique sociocultural background in each area (Wang et al. 2015a). Therefore, if different factors are
477 observed to have a significant effect on perceived accessibility between sample areas, it is important
478 to consider the reason and background to allow an improved understanding of EE in the accessibility
479 of parks (Wang et al. 2015a).

480

481 It is also important to note that factors may be differently associated according to poverty levels. For
482 example, it may be that associations between illegally dumped litter and perceptions of crime are
483 stronger in more deprived communities. If this is the case, the existence of one problem may
484 subsequently magnify another, and impact perceived accessibility further.

485

486 Not only distributional issues for other environmental amenities but environmental risks have been
487 often discussed based on objective measures, but the importance of perceived measures has been
488 relatively neglected in EE studies. It was found that there is discordance between objective and
489 perceived measures of air pollution and urban noise (Orru et al. 2018, Verbeek 2018). Indeed Orru et
490 al. (2018) stated that perceived measure of air pollution may be better indicator to predict health risk
491 perception, symptoms or diseases, compared to objective air pollution exposure. As our research also
492 indicated the importance of considering perceived accessibility measures to remedy environmental
493 inequity, we suggest that EE studies based on perceived environmental quality should be extended to
494 environmental risks or other urban amenities.

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498

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Table 1. Population characteristics of respondents and descriptive statistics of the questionnaire survey ('neighboring area' in the questions was defined as 10 – 15 mins distance on foot from the housing locations of the respondents and stated in the questionnaire sheet)

Population characteristics	Questionnaire		Census
	N	%	(%)
Gender Male	1294	55.2	(48.4%)
Female	994	42.4	(51.6%)
No answer	57	2.4	
Age 20s	98	4.2	(13.8%)
30s	140	6.0	(18.2%)
40s	236	10.1	(16.8%)
50s	389	16.6	(14.2%)
60s	758	32.3	(18.4%)
70 or over	658	28	(18.6%)
No answer	66	2.8	
Annual household income (million yen)			
< 200	364	15.5	
≥200, < 400	807	34.4	
≥ 400, < 600	466	19.9	
≥ 600, < 800	265	11.3	
> 800	389	16.6	
No answer	54	2.3	
Questions	N	%	
Q1. In your neighboring area, are there green spaces or open spaces with free access, such as a park?			
1. Sufficient	508	21.7	
2. Relatively sufficient	808	34.5	
3. Some, but not sufficient	774	33.0	
4. None	188	8.0	
5. I don't know	15	0.6	
No answer	52	2.2	
Q2. In your neighboring area, can you go out on foot without worrying about traffic accident risk?			
1. Possible	670	28.6	
2. Relatively possible	845	36.0	
3. Neither agree or disagree	489	20.9	

4. Relatively impossible	219	9.3
5. Impossible	75	3.2
No answer	47	2.0
Q3. In your neighboring area, can you go out at night on foot without worrying about crime risk?		
1. Possible	351	15.0
2. Relatively possible	914	39.0
3. Neither agree or disagree	700	29.9
4. Relatively impossible	262	11.2
5. Impossible	69	2.9
No answer	49	2.1
Q4. Is there any place in your neighboring area where graffiti and garbage stand out?		
1. Many exist	26	1.1
2. Exist	531	22.6
3. Few exist	1462	62.3
4. None	214	9.1
5. I don't know	60	2.6
No answer	52	2.2
Q5. How is the relationship between your family and neighbors?		
1. We have a cooperative relationship (e.g., consult other) with neighbors in daily life	474 each	20.2
2. We do not have a cooperative relationship with neighbors, but we talk to each other (e.g., a small talk, stand talking)	1097	46.8
3. We rarely talk with neighbors, but we greet each other	651 other	27.8
4. We have almost no communication	72	3.1
No answer	51	2.2

Along with the ratios of gender and age groups of the respondents, the ratios of the corresponding population characteristics of the actual population in the study area were also reported in the right row (extracted from the 2010 Japanese Census).

Table 2. The relationship between objective accessibility to parks and percentage of professional and managerial workers

Professional and managerial workers (%)	Total number of parks		Total park area (ha)		Park area per capita (m ²)	
	Average	Median	Average	Median	Average	Median
1st (least affluent)	5.7	5	5.7	1.5	394	22
2nd	5.5	5	5.7	1.5	83	16
3rd	5.6	5	7	1.6	188	17
4th	6	5	8.5	1.8	148	22
5th (most affluent)	6.3	6	10.7	2.5	303	36
Direction of trend	+ ***		+ ***		+ ***	

1st: Quintile with the lowest professional and managerial workers (%)

5th: Quintile with the highest professional and managerial workers (%)

Direction of trend (+, positive and -, negative) is also reported

*** : P < 0.01

Table3. Logistic regression models to predict superior perceived accessibility to urban parks

	Model 1		Model 2		Model 3	
	OR	95%CI	OR	95%CI	OR	95%CI
Male	1	Reference	1	Reference	1	Reference
Female	0.95	(0.80, 1.15)	0.97	(0.81, 1.16)	1.00	(0.83, 1.21)
Age group						
<40	1	Reference	1	Reference	1	Reference
≥40,<65	0.90	(0.74, 1.12)	0.92	(0.75, 1.13)	0.90	(0.73, 1.11)
≥65	1.12	(0.91, 1.39)	1.11	(0.90, 1.37)	1.06	(0.86, 1.31)
Quintiles of household income						
1st: Poorest	0.70***	(0.53, 0.95)	0.71***	(0.53, 0.95)	0.72***	(0.54, 0.97)
2nd	0.81	(0.61, 1.10)	0.81	(0.61, 1.10)	0.84	(0.62, 1.13)
3rd	0.88	(0.65, 1.20)	0.91	(0.67, 1.23)	0.92	(0.68, 1.25)
4th	1.15	(0.86, 1.54)	1.17	(0.88, 1.57)	1.19	(0.89, 1.60)
5th: Most affluent	1	Reference	1	Reference	1	Reference
Total park area within 800m						
0ha			1	Reference	1	Reference
>0ha,≤1ha			1.70	(0.89, 3.24)	1.73*	(0.91, 3.31)
>1ha,≤2ha			3.18***	(1.60, 6.33)	3.29***	(1.65, 6.57)
>2ha,≤3ha			3.72***	(1.83, 7.54)	3.84***	(1.89, 7.80)
>3ha			4.32***	(2.22, 8.43)	4.51***	(2.31, 8.82)
Risk perception on traffic					0.66***	(0.48, 0.89)
Risk perception on crime					0.74**	(0.55, 1.00)
Impaired beauty of scenery					0.81*	(0.64, 1.01)

Weak relationship with neighbors			0.83	(0.49, 1.40)
Variance of the random effect	0.981	0.614	0.61	
AIC	2889	2863	2845	

***P < 0.01 **P < 0.05 * P < 0.1

OR : Odds ratio 95%CI : 95% confidence interval

AIC: Akaike information criterion

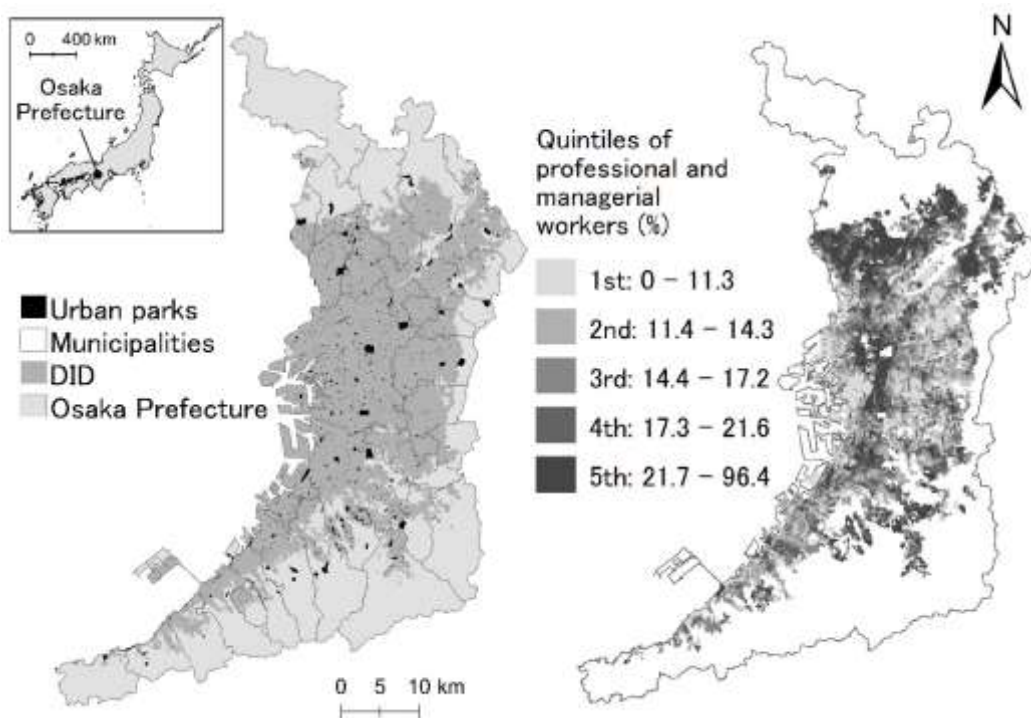


Fig. 1 Study area (DID in Osaka prefecture) and distribution of urban parks and professional and managerial workers (%)

1st: Quintile with the lowest professional and managerial workers (%)

5th: Quintile with the highest professional and managerial workers (%)

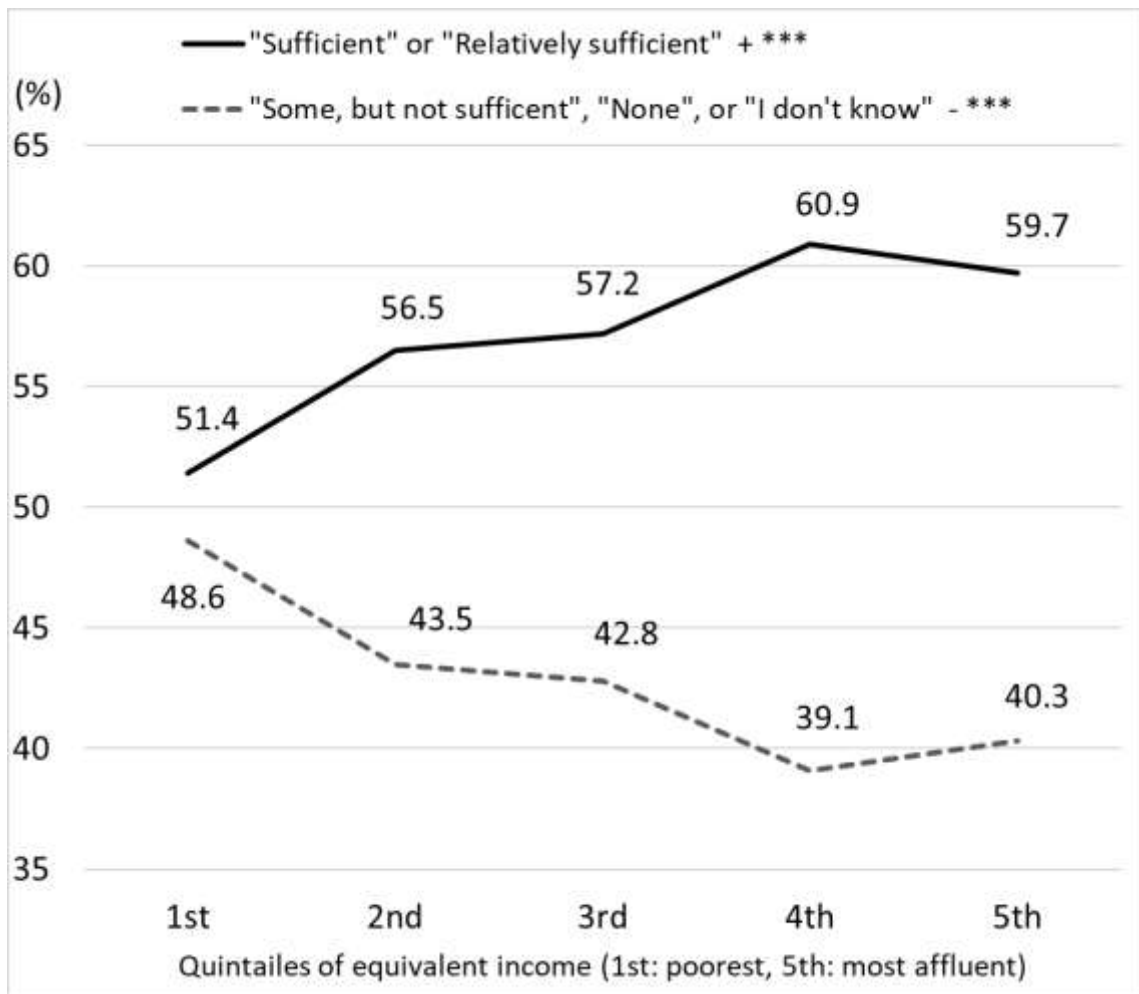


Fig. 2 The relationship between perceived accessibility to parks and equivalent household income and result of test for trend

***P < 0.01

+ : positive trend - : negative trend