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Original article

The aesthetic value of natural vegetation remnants, city parks and vacant lots: The role of ecosystem features and observer characteristics

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ABSTRACT

Physical and mental well-being are linked to exposure to ecosystems perceived as aesthetically pleasing. However, the perceived aesthetic value is shaped by both ecosystem features and observer characteristics. This study explores the relationships between these two influential factors, and perceptions across three Canadian urban greenspace types: natural vegetation remnants (forest stands, marshes and peatlands), city parks, and vacant lots. We administered an online photo-questionnaire, completed by 514 respondents, who assessed the beauty of 45 greenspaces on a five-point Likert scale. Respondents were university students and staff, members of the general public, and specialists in ecosystem services. They also answered questions on socio-demographic factors, pro-environmental attitudes, nature-related travel habits, and ecological knowledge. We calculated five variables from each greenspace photo: vegetation structural complexity, visual complexity, percentage of green pixels, percentage of canopy cover, and presence/absence of artificial structures. On average, natural vegetation remnants and city parks were preferred over vacant lots. Among natural remnants, forests were preferred over semi-open peatlands. Different ecosystem features were associated with perceived beauty across the three greenspace types. For natural remnants and city parks, visual complexity was positively related to appreciation scores, whereas for vacant lots, the presence of artificial structures was associated with lower appreciation scores. Respondents who self-identified as environmental defenders, had greater knowledge of flora, and travelled to observe fauna gave higher appreciation scores to vacant lots compared to other respondents. Younger respondents, and those who engaged in frequent nature-related travelling attributed higher scores to natural remnants. We conclude that aesthetic preferences for natural vegetation remnants, city parks, and vacant lots are influenced by a complex interplay of ecosystem features and observer characteristics. Understanding these intricate relationships can guide the management of vacant lots and promote more inclusive engagement with greenspaces, by considering the varying preferences of diverse segments of the population.

1. Introduction

Humans enjoy and benefit from observing natural landscapes. Increased self-reported well-being, stress recovery, and physical health have been associated with exposure to natural areas of high perceived

aesthetic value (Sang et al., 2016; Wang et al., 2019). The strong influence of nature's aesthetic qualities on peoples' wellbeing supported the inclusion of landscape aesthetics as an essential ecosystem service in the Millennium Ecosystem Assessment, a significant study by the United Nations which assessed the consequences of ecosystem change for

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1618-8667/© 2024 Elsevier GmbH. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

human wellbeing and popularized the term ecosystem services (MA, 2005). As the recognition of the benefits of nature's aesthetic qualities grows, so does interest in exploring which ecosystem features drive human preferences for different landscapes. Furthermore, people's appreciation of nature's aesthetic qualities can play a crucial role in their willingness to support conservation plans, underscoring the role of ecosystem's aesthetic qualities in public engagement and cooperation towards its conservation (Gobster et al., 2007; Nassauer, 1992).

A substantial body of evidence supports the connection between aesthetic preferences and specific ecosystem features such as species diversity, ecosystem health, visual (e.g. number of colors) and vegetation complexity (e.g. number of vegetation layers), and openness (extension of the unobstructed view of a landscape) (Cottet et al., 2013; Fügler et al., 2021; Hägerhäll et al., 2018; Hofmann et al., 2012; Wang et al., 2019). These preferences have been hypothesized to relate to an intrinsic human inclination to perceive wilderness as a source of food and shelter (Appleton, 1984). However, it has also been argued that aesthetic preferences are highly shaped by local context (e.g. rural versus urban landscapes), cultural values, and life experiences (Arsénio et al., 2019; Jorgensen, 2011). Factors influencing how humans rate landscape aesthetics include professional background, gender, place of residence, pro-environmental attitudes, cultural background, ecological knowledge, and time spent in nature (Alcock et al., 2020; Gunnarsson et al., 2017; Hägerhäll et al., 2018; Hofmann et al., 2012; Sang et al., 2016). For example, individuals who value biodiversity tend to find natural ecosystems more aesthetically appealing (Gunnarsson et al., 2017). Similarly, life-course experiences, such as exposure to natural landscapes throughout life and local wildlife knowledge, can alter aesthetic preferences (Jorgensen, 2011; Tomasso et al., 2022). Thus, generalizing aesthetic preferences without considering observer characteristics may not provide meaningful information about the complexity of the perceived aesthetic value of nature (Gobster et al., 2007; Jorgensen, 2011). This understanding is especially important in urban landscapes, where aesthetic perceptions significantly impact their valuation (Fügler et al., 2021). Understanding which ecosystem features and observer characteristics influence greenspace appreciation significantly contributes to urban planning, fostering the wellbeing of city residents.

Urban landscapes feature abrupt shifts in land use, such as transitions between buildings, managed gardens, water bodies, and groves, making it challenging to understand the human connection with greenspace aesthetics (Gobster et al., 2007). Despite this, understanding greenspace preferences is essential for the well-being of the ever-increasing global urban population. Differences in human management and ecological features have a strong effect on greenspace appreciation. Natural vegetation remnants, areas of native vegetation minimally impacted by human activities, or which have undergone ecological restoration, connect urban dwellers to nature, and are valued for perceived wilderness and diversity (Fügler et al., 2021; Hofmann et al., 2012; Sang et al., 2016). On the other hand, city parks, which are recreational urban greenspaces with a combination of well-maintained turfgrass, sparse trees, flowerbeds, benches, paths, and sports fields, are preferred aesthetically when highly maintained, with flowers and higher tree cover (Bertram et al., 2017; Jahani and Saffariha, 2020; Wang et al., 2019).

Contrary to natural vegetation remnants and city parks, vacant lots are often underappreciated as greenspaces (Hofmann et al., 2012). Vacant lots refer to unused land where the original vegetation has been removed (Pagano and Bowman, 2000), typically covered by spontaneous herbaceous vegetation and shrubs, often dominated by invasive species. Due to mowing, their vegetation usually does not follow ecological succession (Anderson and Minor, 2020). Studies suggest that vacant lots are more tolerated when managed, for example, with trimmed trees, flowers, gardens with weed control, mowed turf, and neatly arranged plants (Hadavi et al., 2021; Nassauer and Raskin, 2014). Other studies suggest that unmanaged, species-rich spontaneous vegetation is

more appreciated than mowed turf, although not specifically in vacant lots (Southon et al., 2017). Managing vacant lots to improve aesthetics can promote social interaction and community sense (Stewart et al., 2019). Understanding residents' aesthetic preferences for vacant lots is a key step for their effective management and revitalization. Despite extensive research showing preferences for natural-looking and species-rich greenspaces (Gobster et al., 2007; Tribot et al., 2018), there is still much to explore regarding the nuanced relationships between personal backgrounds and preferences for greenspaces with different ecological and structural features (Brady and Prior, 2020; Jorgensen, 2011). This is particularly relevant for typically underappreciated ecosystems, such as vacant lots, which have been less studied and demand more rigorous management interventions (Brady and Prior, 2020). This understanding is also important for the effective management of city parks, which are expected to meet public standards of visual appeal (Hofmann et al., 2012). For natural vegetation remnants, this information can inform the establishment of scenic routes and hiking trails (Fügler et al., 2021). Overall, understanding characteristics that lead to the underappreciation of these three types of greenspaces can help identify best management practices and strategies for raising public awareness about their ecological and social benefits.

In this study, we used an online photo-questionnaire to answer: 1) Which ecosystem features influence appreciation of three types of greenspaces in Quebec City, Canada: natural vegetation remnants, city parks, and vacant lots? 2) How do observer characteristics and ecosystem features interact influencing aesthetic preferences across these three different types of greenspaces? Participants were asked to rate the beauty of 45 images of greenspaces (Fig. 1). To address the first question, we tested the assumption that the three types of greenspaces are appreciated differently (Fig. 2A-B). Then, for each greenspace type, we tested the influence of five ecosystem features on appreciation scores (Fig. 2C-D). For the second question, we tested how preferences for different ecosystem features were associated to respondents' characteristics (Fig. 2E-G). For this, we borrowed an approach from ecological studies, called community-weighted means (Laliberté and Legendre, 2010), to create a matrix of ecosystem features weighted by the appreciation scores, which could be correlated with the respondents' characteristics matrix (Fig. 2E). To our knowledge, this is the first study to adapt this method to analyse appreciation data. Finally, we tested if the urbanization level of the respondents' location explains appreciation for the three types of greenspaces (Fig. 2H). By using uniform metrics to assess appreciation across natural remnants, city parks, and vacant lots, this innovative approach allowed us to compare greenspace management outcomes. The results inform the discussion on optimal strategies for greenspace management decisions, especially for undervalued ecosystems such as vacant lots.

2. Methodology

2.1. Study Area and image selection

We conducted an online survey using a photo-questionnaire that featured 45 images of three different types of greenspaces (Fig. 1): natural vegetation remnants (16 images), city parks (14 images), and vacant lots (15 images). The images were selected from a collection of photographs primarily taken in Quebec City, Canada. This region belongs to the Northern temperate vegetation zone and has a population of approximately 570,000 (Census Program, Statistics Canada). The presence of natural vegetation remnants, city parks, and vacant lots makes this area a good choice for a case study investigating the aesthetic perception of various types of greenspaces.

Natural vegetation remnants included patches three types of native vegetation which are common and visually distinct in the study region: temperate forest, marshes, and peatlands. For the photographed forest patches, we followed the definition of forest stand as minimally covering 0.5 ha with trees taller than five meters (FRA, 2018). The photographed

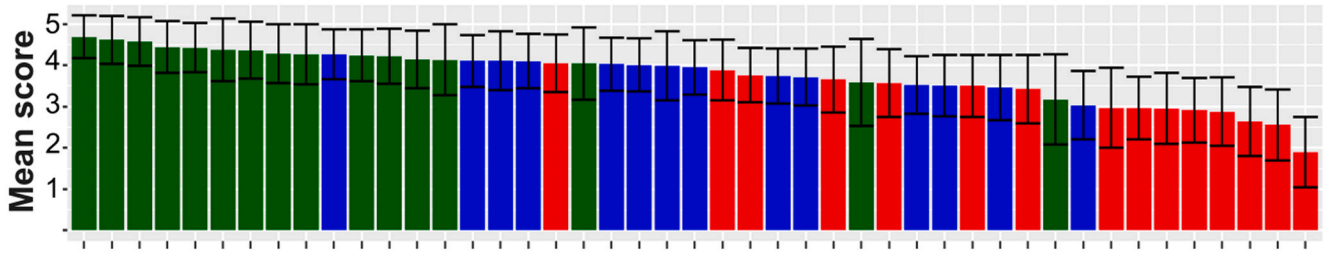
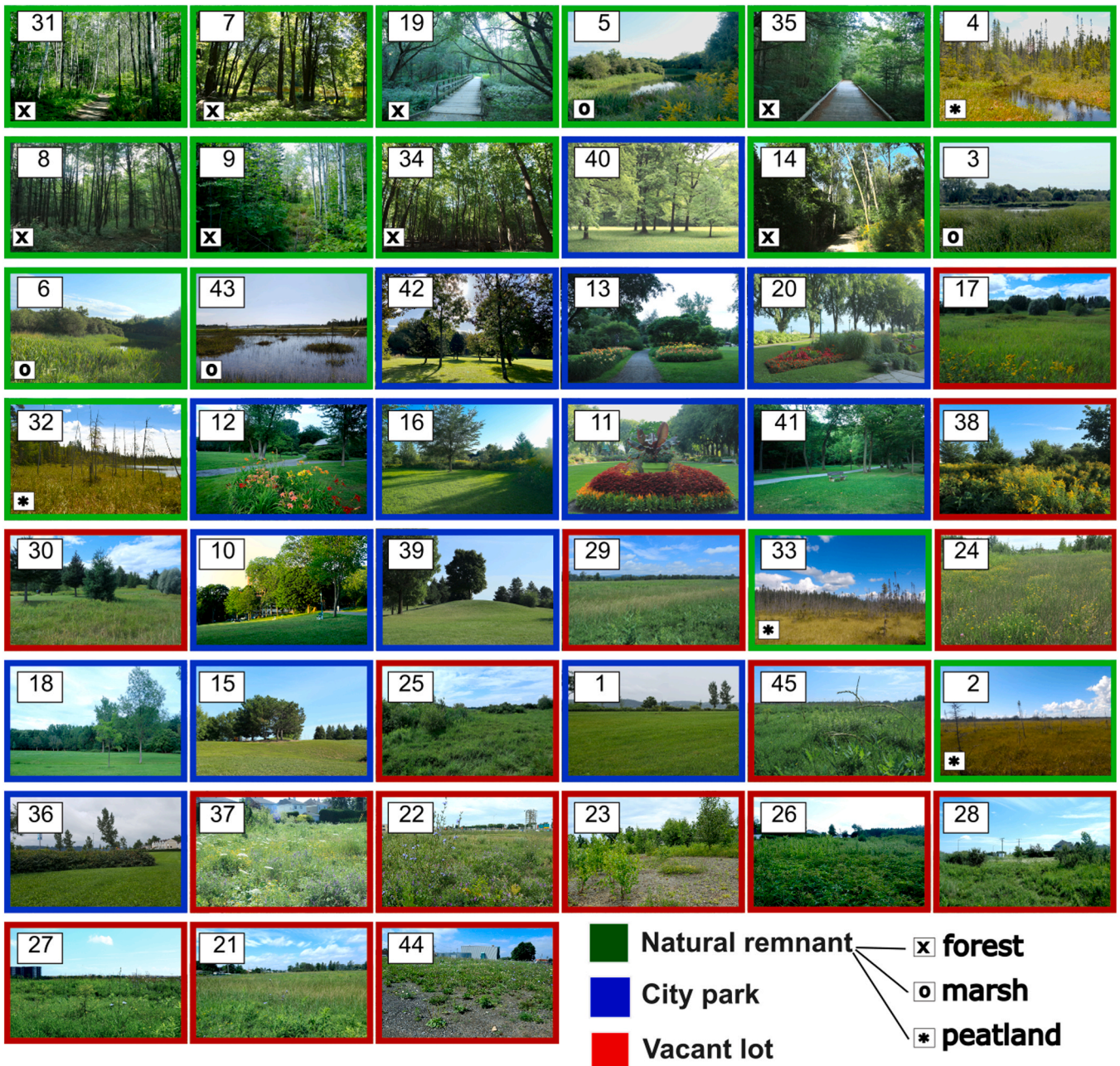


Fig. 1. The images are organized from the highest to the lowest average appreciation scores given by respondents, from left to right and top to bottom. The mean and standard deviation of the appreciation (Likert-scale) scores are presented in the bottom graph, ordered from the highest to the lowest, moving left to right. Numbers on the top left of each photo represent the photo identification number in the dataset (Supplementary Material).

marshes were all inundated, presented emergent vegetation (i.e. sedges and reeds), and lacked woody vegetation (although some was visible in the background of certain photographs). All of the photographed peatlands presented peat mosses, were semi-open (woody vegetation covering < 50 % of the image) and had a yellowish-brown colour. City

parks included recreational areas with well-maintained turfgrass and sparse trees, with some images also including flowerbeds. Vacant lots were characterized as unused land with spontaneous herbaceous vegetation, as well as occasional sparse trees and shrubs. We did not inform respondents if they were evaluating a natural vegetation remnant, city

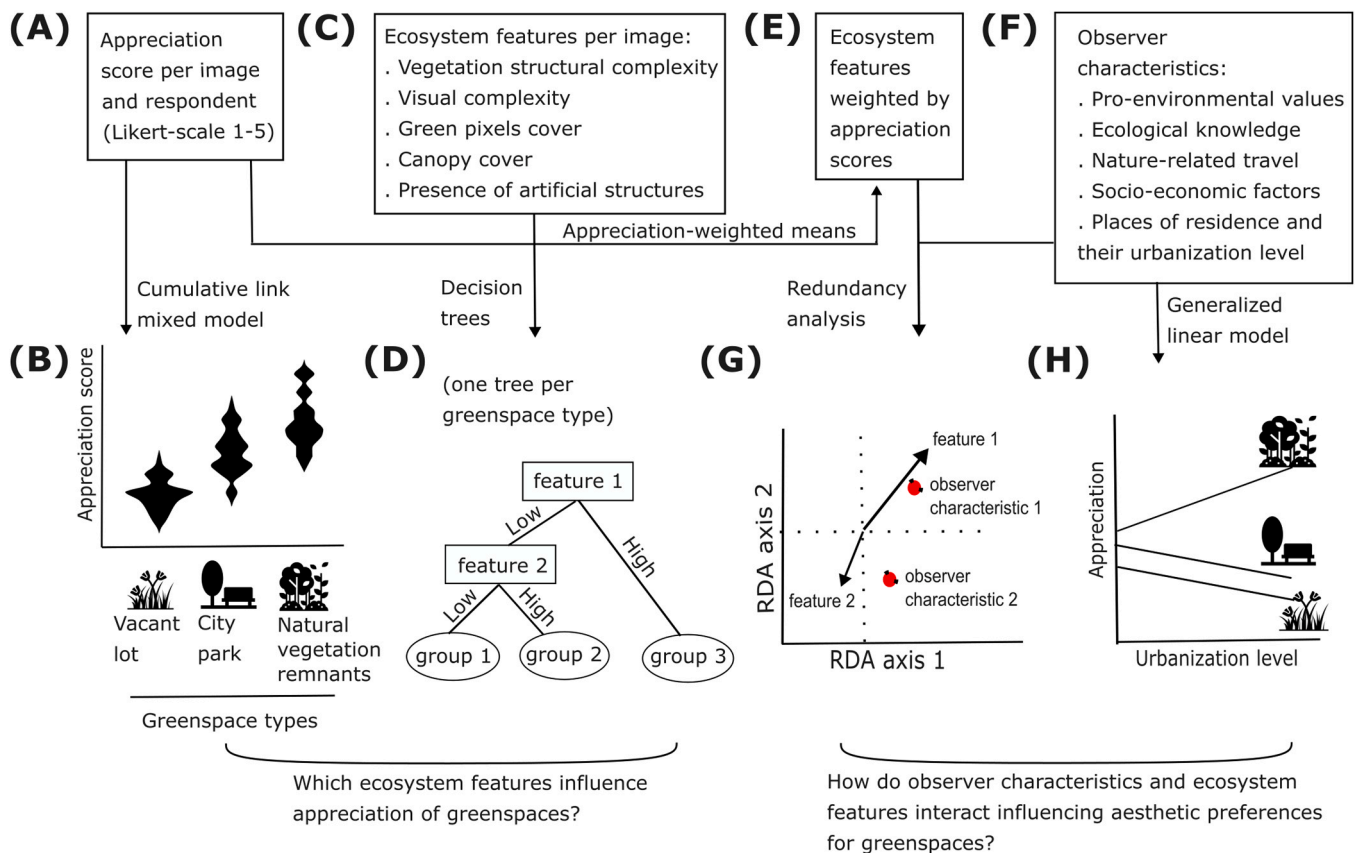


Fig. 2. Methodological design of the study. Respondents evaluated the beauty of ecosystems from 45 images (A). We fitted a cumulative link mixed model to evaluate if appreciation scores were different for vacant lots, city parks, and natural vegetation remnants (B). Five ecosystem features were obtained from the ecosystems shown in each image (C), then we used decision trees to investigate the influence of ecosystem features on appreciation scores (D). We calculated appreciation-weighted means of the ecosystem features of the images (E), which were correlated to the respondents’ characteristics matrix (F) using a redundancy analysis (G). Finally, we tested if the urbanization level of the participants’ location was associated with appreciation scores (H).

park or vacant lot, since we wanted to test if those categories of sites would be evaluated differently by them.

All images depicted the ecosystems in the summertime and under daylight conditions, with no rain, minimizing cloud coverage as much as possible (see Fig. 1). The 45 images were chosen to ensure a balanced representation of the three types of greenspaces. This balance was maintained across two main criteria: the presence/absence of artificial structures and the degree of visual complexity in each image (detailed description of the image selection in the Supplementary Material – Image Selection; Fig. S1).

2.2. Photo-questionnaire

The survey was conducted online using a photo-questionnaire on the platform Lime Survey (<https://www.limesurvey.org/>) from December 2020 to July 2021. Respondents rated the beauty of various ecosystems in 45 images using a Likert scale ranging from “very ugly” to “very beautiful/magnificent” with the photo sequence randomized by the platform Lime Survey. The questionnaire also included questions related to respondents’ characteristics about socio-demographic factors, ecological knowledge, nature-related travel habits, pro-environmental attitudes, and place of residence of respondents. Table 1 shows all the questions asked to participants in the same order as they were asked, along with possible answers. Q4 was removed due to high correlation with Q3 ($r = 0.73$; Fig. S2). Most questions were single-answer questions, except for Q6 which was a multiple-choice question where responses were treated as dummy variables in the analyses. To determine the place of residence of respondents, the first three letters of their Canadian postal code were requested, hereafter called postal area,

ensuring privacy by not identifying street or address. Respondents could skip any questions they did not feel comfortable answering. All respondents were anonymous.

We targeted respondents who are familiar with landscapes of Quebec. Respondents were from three groups covering a gradient of ecological knowledge and environmental interest: the general public, the university community, and specialists in ecosystem services. We launched a dedicated Facebook page to share the survey with the general public. We searched for Quebec City neighborhood names within Facebook groups to share the survey. We encouraged group members to further extend our survey’s reach by sharing it within their networks and other groups. Posts were shared from November 2020 to January 2021 (see posts, recruitment letter, and information sheet in Supplementary Material 2). To reach the Laval University community, we distributed the survey via the university’s email list. Specialized researchers were contacted through ResNet, a Canadian ecosystem services research network (<https://www.nsercresnet.ca/>), utilizing network meetings and newsletters. These specialists were also encouraged to share the survey with their peers.

Respondents were mostly from the metropolitan region of Quebec City (Capitale-Nationale, $n=305$, Fig. 3), followed by other regions of the province of Quebec ($n=150$), Ottawa-Canada ($n=2$), France ($n=2$), Calgary-Canada ($n=1$), Belgium ($n=1$), Tunisia ($n=1$), and Norway ($n=1$). Fifty-one respondents skipped the question about their place of residency. Respondents from Ottawa-Canada, Calgary-Canada, France, Belgium, and Tunisia were reached through the Laval University e-mail list; therefore, we did not exclude them from the dataset since we can assume that they, at least temporally, live or have lived in the region of Quebec. Regarding the only respondent from Norway, who was reached

Table 1

Questions asked, possible answers and ordinal codes used for statistical analyses – in between parentheses. The original survey, in French, the official and common language in Quebec, Canada, can be found in [Table S1](#). Questions are shown in the same order as they were provided to participants.

| Category | Questions | Possible Answers |
|---------------------------|---|---|
| Pro-environmental values | Q1- Do you agree with the following statement “The beauty of my neighborhood is important for my well-being”? Q2- Do you agree with the following statement “Greenspaces in my neighborhood are important to me”? | (5) Strongly Agree, (4) Agree, (3) Neither agree nor disagree, (2) Disagree, (1) Strongly disagree |
| Ecological knowledge | Q3- How do you evaluate your knowledge of the native flora of Quebec? Q4- How do you evaluate your knowledge of the native fauna of Quebec? | (4) Excellent, (3) Good, (2) Average, (1) Limited |
| Nature-related travel | Q5- How many trips of at least a half-day to the countryside have you taken within the last 12 months, including farms, natural parks, campsites, and cottages? Q6- What were your reasons for travelling to the countryside, including farms, natural parks, campsites, and cottages within the last 12 months? You can choose more than one response: <ul style="list-style-type: none"> because of the pleasant landscapes for physical activities, such as swimming, hiking, biking, running, climbing, etc. to hunt or fish fauna observation, such as bird watching to foster creativity, such as painting and photography for economical reasons, such as agriculture, forestry, commercial activities, and professional trips for spiritual reasons to feel better physically or mentally for a learning opportunity, such as a school trip to visit family or friends to escape the stress of the city to enjoy local products to stay at a cottage | (5) 20 trips or more, (4) 10–19 trips, (3) 5–9 trips, (2) 1–4 trips, (1) None (1) Marked, (0) Non-Marked |
| Appreciation | Q7- Do you consider yourself an environmental defender? Picture 1–45- What do you think about the landscape presented in this photo? [Image 1–45, random order] | (3) Yes, (2) Sort of, (1) No (5) Very beautiful/Magnificent, (4) Beautiful, (3) Neither beautiful nor ugly, (2) Ugly, (1) Very Ugly |
| Socio-demographic factors | Q8- What is your highest completed educational degree? Q9- What is your age? Q10- How do you define your gender? Q11- What was your annual income for the past year? | (5) Graduate school, (4) Bachelor, (3) College, (2) Secondary, (1) Primary, (0) Other/None (5) 61 years old or older, (4) 46–60 years old, (3) 31–45 years old, (2) 16–30 years, (1) 15 years or younger (3) Female, (2) Non-Binary, (1) Male, (X) Other (4) Higher than \$100,000, (3) \$70,000 to \$100,000, (2) \$40,000 to \$70,000, (1) 0 to \$40,000 |

Table 1 (continued)

| Category | Questions | Possible Answers |
|--------------------|---|--|
| Place of residence | Q12- Do you consider yourself part of a visible minority? Q13- If you live in Canada, please indicate the first three letters of your postal code. Otherwise, in which city do you live? | (1) Yes, (0) No Free Answer (latitude and longitude were extracted from postal areas) |

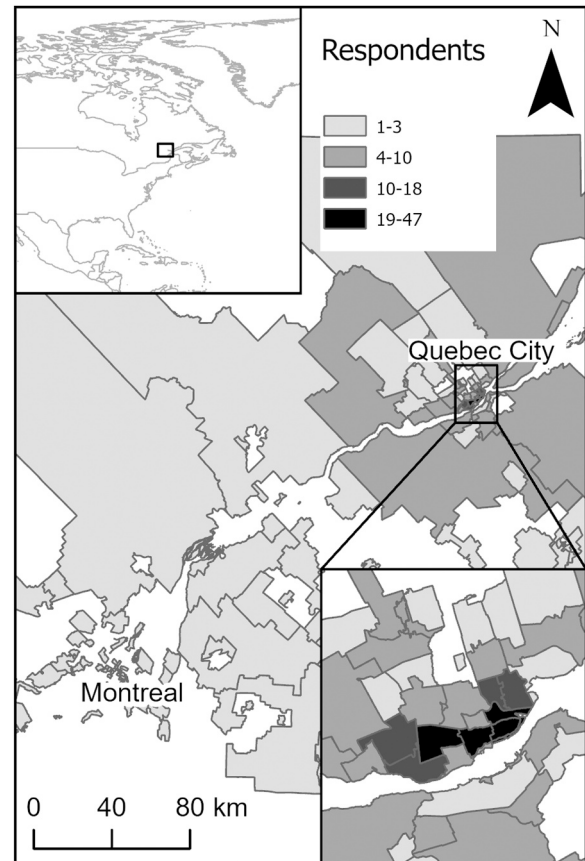


Fig. 3. Number of respondents for each postal area. Most respondents reside in the metropolitan region of Quebec City (Capitale-Nationale, n=305), followed by other regions within the province of Quebec (n=150), other Canadian provinces (n=3), and international locations (n=5). All but one of the respondents outside Quebec are affiliated with Laval University, situated in Quebec City, suggesting familiarity with the region. Fifty-one respondents preferred to not indicate where they reside.

through the specialist list, preliminary tests showed alteration in the results when including their data. Consequently, we decided to remove their data from our study, reducing our dataset from 514 respondents to 513.

2.3. Ecosystem features

Five ecosystem features were measured: vegetation structural complexity, percentage of green pixels, visual complexity, canopy cover and presence of artificial structures. These variables were chosen based on previous literature indicating that complexity vs. simplicity, openness vs. clutteredness, and naturalness vs artificiality are important gradients determining the aesthetic qualities of ecosystems (Hägerhäll et al., 2018; Jahani and Saffariha, 2020; Sang et al., 2016).

Vegetation structural complexity was assessed using the mean

information gain (MIG) index, which is based on Shannon's entropy equation and is related to spatial heterogeneity of color properties. The MIG index can be calculated for the intensity (grey-level value), color (or hue), or chroma (or saturation) of images. We selected the intensity index as it represents the heterogeneity of different levels of brightness, caused by shade from vegetation and light filtering through in between it, and can be associated with vertical heterogeneity in the vegetation (Proulx and Parrott, 2009). Furthermore, this index is related to species richness in forest images, and is a good predictor of habitat changes (Proulx and Parrott, 2008). Vegetation structural complexity was calculated using the R package "imagometrics" (Proulx and Parrott, 2008). Structural complexity, reflecting variations in vegetation height, is expected to correlate with aesthetic value, as studies have shown in meadows and tree-covered areas (Southon et al., 2017; Wang et al., 2019).

Percentage of green pixels, representing the vegetation cover in each photo, was also calculated using the same R package. This variable was chosen because it represents a simple measure of the amount of vegetation within an image, and because previous research has indicated that vegetation is usually appreciated by humans (Brady and Prior, 2020; Gobster et al., 2007).

Visual complexity was measured as the ratio between the compressed and uncompressed JPEG sRGB image file sizes using the zip algorithm with deflate compression in the R package 'imagefluency' (Mayer and Landwehr, 2018). The ZIP/deflate-compression is a lossless data compression algorithm, meaning that information is not lost in the compression process (Donderi, 2006). In a simplified way, this compression process identifies repetitive patterns in the image and combines them, reducing the length of the information necessary to describe it (Donderi, 2006). Consequently, images with more redundant pixels in terms of color and brightness tend to receive higher visual complexity indices. For greenspaces, high visual complexity will translate as high interspersed of different elements, such as water, rocks, and different types of plants. Aesthetic preferences are commonly correlated to the visual complexity/simplicity gradient in arts and natural landscapes (Marin and Leder, 2013; Mayer and Landwehr, 2018).

Canopy cover was calculated by laying a grid of 15 by 10 cells over the images and calculating the percentage of the number of cells covered by trees or shrubs, excluding those covered by the sky, following the method used by Tveit (2009). A 50 % rule was used to determine which cells were considered covered by tree canopy/shrub. Research findings vary concerning preferences for ecosystems with canopy cover. While some studies indicate a preference for landscapes with greater number of trees, others suggest that semi-open landscapes are preferred (Füger et al., 2021; Hägerhäll et al., 2018; Jahani et al., 2023; Tveit, 2009; Wang et al., 2019).

Finally, the **presence of artificial structures** is a binary variable that indicates the presence of trails or bridges in images of natural vegetation remnants, buildings in the background of images of vacant lots, and benches, light poles, gravel, trails, or flowerbeds in images of city parks. We expected that artificial structures in natural vegetation remnants and city parks would be positively associated with aesthetics because of the prospect of recreational use associated with those structures (Alcock et al., 2020). However, in vacant lots, the presence of buildings in the background would contrast with the vegetation, lowering the aesthetic value, as has been shown for city parks with buildings in the background (Jahani and Saffariha, 2020).

2.4. Statistical Analyses

To test if natural vegetation remnants, city parks, and vacant lots received distinct appreciation scores (Likert-scale scores), we used cumulative link mixed models (CLMM) with the logit function (Fig. 2A-B). CLMMs are robust models for dealing with ordinal response variables (Taylor et al., 2022) and were created using the R package "ordinal" (Christensen, 2023). Because each respondent evaluated the same 45

photos, we included photo and respondent as crossed random intercepts (Supplementary Material - Selection of random factors for CLMMs). The same method was used to test if the three types of natural vegetation remnants (forests, marshes, and peatlands) received distinct appreciation scores. For post hoc comparisons between categories, we used Tukey-contrasts, calculated using the R package "emmeans" (Lenth et al., 2023).

To investigate whether ecosystem features influence the appreciation score given to images of natural vegetation remnants, city parks, and vacant lots separately, we used Random Effects/ Expectation Maximization (RE-EM) trees (Fig. 2C-D). All ecosystem features were included as fixed factors. For the RE-EM trees of natural remnants, the type of ecosystem (forest, marsh, peatland) was also included as a fixed factor. Respondent was kept as a random factor (Supplementary Material - Selection of random factors for RE-EM trees). RE-EM trees were built using the R package "REEMtree" (Sela and Simonoff, 2012), which uses 10-fold cross-validation to prune trees. To evaluate the predictive performance of the trees, we created training (80 % of data) and test datasets (20 % of data), and calculated the root mean square error (RMSE) and coefficient of determination (R^2) of models. Pearson correlation (r) was lower than 0.7 for all pairs of ecosystem features; therefore, we opted to keep all variables in the analysis (Fig. S3).

To test if respondents' characteristics were related to the appreciation scores, considering their ecosystem features, we conducted a Redundancy Analysis (RDA). RDA examines the effect of an explanatory matrix on a response matrix (Fig. 2E-G). The explanatory matrix comprised the dataset of respondents' characteristics, and latitude and longitude of the centroid of respondents' postal areas. We also included the group of respondents, whether specialists in ecosystem services, Laval University students or staff, or general public. The response matrix comprised the ecosystem features matrix weighted by the appreciation scores. This response matrix was generated using the "functcomp" function of the "FD" R package (Laliberté and Legendre, 2010), originally designed to investigate the association of environmental variables with species traits weighted by their abundance on different sites. In this study, the method was adapted to explore the association of respondents' characteristics with ecosystem features weighted by the appreciation score given to each image. RDAs were conducted using the "vegan" R package (Oksanen et al., 2009). For these analyses, we excluded the data from respondents who did not evaluate all 45 images, as the analysis did not allow for missing values in the response matrix.

To evaluate if there was a spatial structure in the scores given by respondents to images of natural vegetation remnants, city parks, and vacant lots separately, we used Moran's I index, calculated with the "spdep" R package (Bivand, 2022). This analysis was conducted for a subset of data that only included respondents from the metropolitan region of Quebec City, as this was the location of most respondents, and avoided outliers in the spatial analyses (Fig. 3). Finally, to evaluate whether population density was an important factor in determining how images were evaluated, we used generalized linear models relating population density and scores given to images (Fig. 2H). Population density data was obtained from the 2016 Census by Statistics Canada and estimated as the number of inhabitants per square kilometer within each postal area.

3. Results

3.1. Description of respondents

Out of the 514 respondents who evaluated at least one image, 460 evaluated all 45 images. Most respondents were Laval University students and staff (436 respondents), while 95 were members of the general public, and 20 were specialists in ecosystem services research. Respondents' answers varied in regard to their pro-environmental attitudes, socio-demographic factors, ecological knowledge, and nature-related travel habits. The majority of respondents agreed that the

beauty and presence of greenspaces in their neighborhood are important (Fig. 4A-B). They also considered themselves to be environmental defenders (Fig. 4C), acknowledged having low to medium levels of knowledge of local flora (Fig. 4D), and only engaging in a few nature-related trips per year (1–4; Fig. 4E). The majority of respondents were 16–30 years old (Fig. 4F), female (Fig. 4G), had an annual income lower than \$40 K CAD (Fig. 4H), were highly educated (college or higher; Fig. 4I), and not part of a visible minority (Fig. 4J). Regarding reasons for nature-related travel in the past 12 months (to destinations including farms, natural parks, camping sites, and cottages, see questions in Table 1), the most common responses were to feel better, to see pleasant landscapes, to participate in sports, and to visit acquaintances (Fig. 5A-M).

3.2. Appreciation for the three greenspace types

Appreciation scores (Likert-scale) differed among greenspaces ($\chi^2 = 31.307$; $p < 0.001$; Fig. 6). On average, the appreciation scores given to natural vegetation remnants (mean = 4.22), were significantly higher than those for vacant lots (mean = 3.17; z -ratio = 5.54; $p < 0.001$), but not significantly different from those for city parks (mean = 3.82; z -ratio = 1.848; $p = 0.154$). City parks received higher appreciation scores than vacant lots (z -ratio = 3.669; $p = 0.001$). Appreciation scores differed among natural remnants ($\chi^2 = 10.075$; $p = 0.006$; Fig. 6A). Compared to peatlands (mean = 3.79), forest stands (mean = 4.43) were considered most attractive, with significantly higher appreciation scores (z -ratio = 3.737; $p = 0.001$). Meanwhile, appreciation scores given to marshes (mean = 4.23) did not differ from the ones given to forest stands (z -ratio = 1.425; $p = 0.328$), and to peatlands (z -ratio = 2.005; $p = 0.111$; Fig. 6B).

3.3. Ecosystem features related to appreciation

The RE-EM regression trees (RMSE = 0.748; $R^2 = 0.19$) indicated that natural vegetation remnants with higher visual complexity, canopy cover, and green pixel coverage received the highest appreciation scores (Fig. 7). Artificial structures (trails and bridges), type of natural remnant, and vegetation structural complexity neither reduced nor increased the scores given to natural vegetation remnants. For city parks, RE-EM regression trees (RMSE = 0.707; $R^2 = 0.17$) indicated that higher scores were associated with increased visual complexity (Fig. 7). Among the city parks with lower visual complexity (< 0.7), higher scores were associated with higher canopy cover (Fig. 7). Artificial structures (benches, light poles, sculptures, etc.) and vegetation structural complexity neither reduced nor increased the scores given to city parks. For vacant lots, RE-EM regression trees (RMSE = 0.811; $R^2 = 0.32$) indicated that the absence of artificial structures (buildings in the background) was associated with higher scores (Fig. 7). Vacant lots with no artificial structures received higher scores when green pixels coverage was higher but vegetation structural complexity was lower (Fig. 7). Meanwhile, vacant lots with artificial structures received higher scores when both vegetation structural complexity and green pixel coverage were lower (Fig. 7).

3.4. Relationships between observer characteristics and ecosystem features weighted by appreciation

Nine respondents' characteristics significantly explained the matrix of ecosystem features weighted by appreciation scores via a redundancy analysis ($F = 3.169$; $p = 0.001$; Constrained variance explained = 19.5 %; Adjusted $R^2 = 0.134$; Table 2). The first axis of the RDA mainly reflected the differences between natural remnants and city parks; as well as greenspaces with and without artificial structures (Fig. 8). The second axis mainly reflected the differences between vacant lots and the other types of greenspaces (Fig. 8). Respondents who engaged in nature-related travel more frequently, and who travelled for learning

opportunities attributed higher scores to natural remnants and greenspaces with no artificial structures, compared to the other respondents. Respondents with greater knowledge of flora, who traveled in the past year for fauna observation, and self-identified more strongly as environmental defenders attributed higher appreciation scores to vacant lots (Fig. 8; Fig. S4). On the other hand, respondents with higher income gave higher scores to city parks. Older respondents and those who self-identified as part of a visible minority gave higher scores to greenspaces with artificial structures (including trails, bridges, benches, statues, light poles, etc.).

3.5. Relationship between population density and appreciation

No overall spatial autocorrelation was observed for the appreciation scores given to images of natural remnants (Moran I = -0.677 ; $p = 0.751$), city parks (Moran I = -0.459 ; $p = 0.677$), and vacant lots (Moran I = -0.139 ; $p = 0.555$; Fig. S6 and S7). Similarly, no relationship was observed between population density and the appreciation scores given to natural vegetation remnants (t -value = -0.085 ; $p = 0.933$), city parks (t -value = -0.272 ; $p = 0.787$), and vacant lots (t -value = 0.121 ; $p = 0.904$).

4. Discussion

4.1. Ecosystem features and aesthetic value

The higher average aesthetic value attributed to natural vegetation remnants and city parks compared to vacant lots aligns with the findings of previous studies that demonstrated human preference for both seemingly undisturbed ecosystems and manicured greenspaces (Gobster and Westphal, 2004; Southon et al., 2017). Interestingly, the lower preference for peatlands compared to forests underlines how perceptions of natural ecosystems can diverge (Arsénio et al., 2019). Despite the multitude of ecosystem services provided by peatlands, they have historically been viewed as unappealing, since, through the eyes of a lay observer, they may appear disorganized and cluttered (Lee, 2017).

High complexity is often associated with ecosystem health and high aesthetic value (Füger et al., 2021; Gobster and Westphal, 2004; Hofmann et al., 2012; Tribot et al., 2018). We found a positive correlation between visual complexity and aesthetic preferences in both natural vegetation remnants and city parks, while a negative correlation was observed in vacant lots when accompanied by buildings in the background and high green pixel coverage. Regarding vegetation structural complexity, respondents preferred less complex vacant lots, while no preference was observed on this variable for natural vegetation remnants and city parks. Here, "visual complexity" refers to the heterogeneity of patches of different colors and brightness within each ecosystem's image, while vegetation structural complexity is related to the vertical heterogeneity of vegetation layers. Higher variability of colors has been associated with more scenic forests, while in urban greenspaces, variability of colors is considered indicative of vibrancy and care (Tomitaka et al., 2021; Wang et al., 2019). High structural and visual complexity in vacant lots can be associated with infrequent mowing and hindered visibility, hence safety concerns (Baran et al., 2018; Hofmann et al., 2012), which could explain the negative association with aesthetic value. In forests, on the other hand, high vegetation structural complexity, caused by multiple layers of vegetation, could be identified by observers as a common feature of the native vegetation (Füger et al., 2021), which could explain the absence of a relationship between structural complexity and aesthetic value.

No correlation was found between the presence of trails and aesthetic appreciation of natural vegetation remnants, nor did the presence of benches, flowerbeds, gravel, light poles, sculptures, and trails correlate with aesthetic appreciation of city parks. These elements represent functional structures which allow access to greenspaces, and the fact that they did not contribute to aesthetic appeal may suggest that

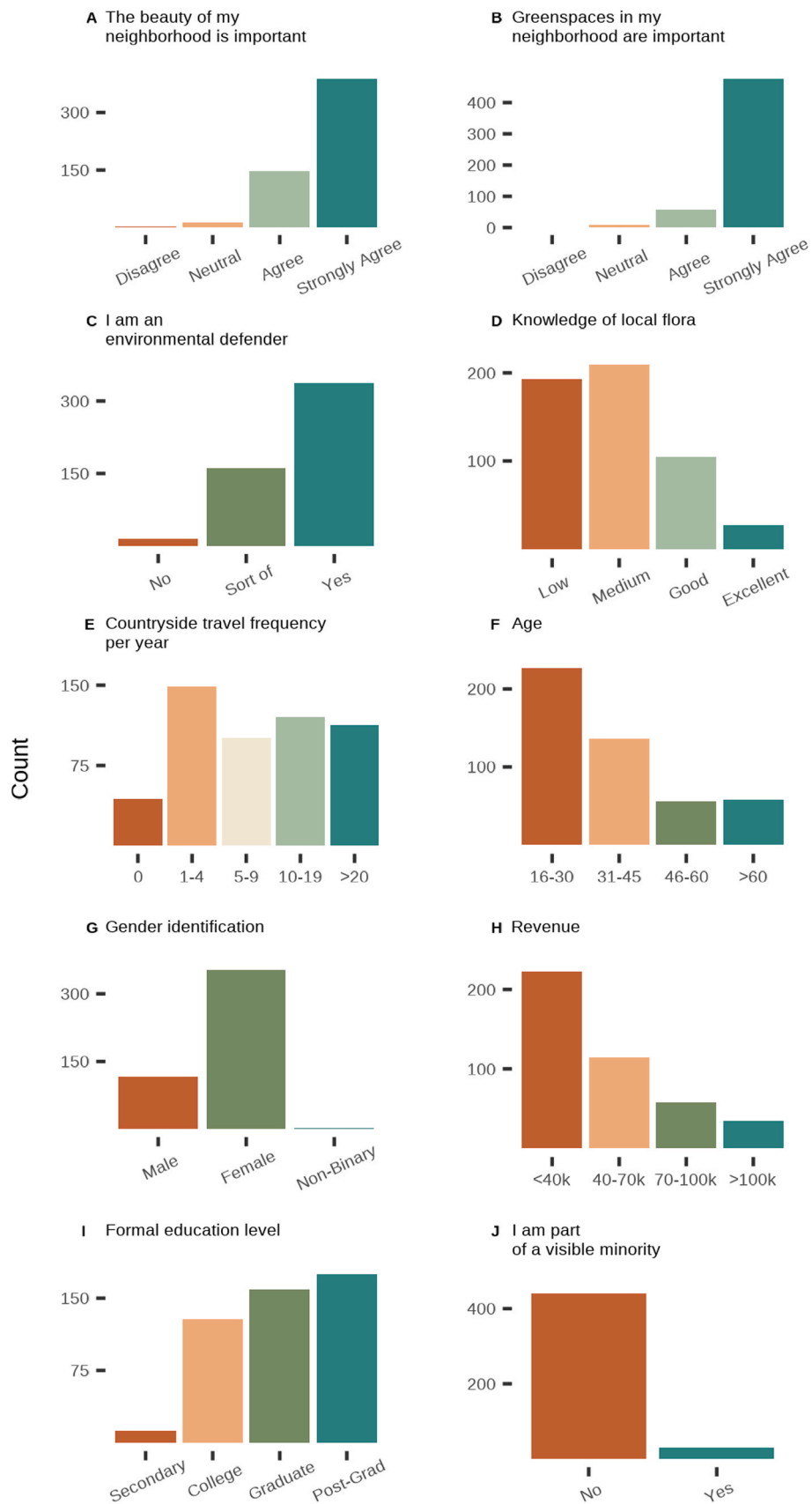


Fig. 4. Number of responses to 10 questions related to pro-environment attitudes, ecological knowledge, nature-related travel habits (including farms, natural parks, campsites, and cottages), and socio-demographic factors.

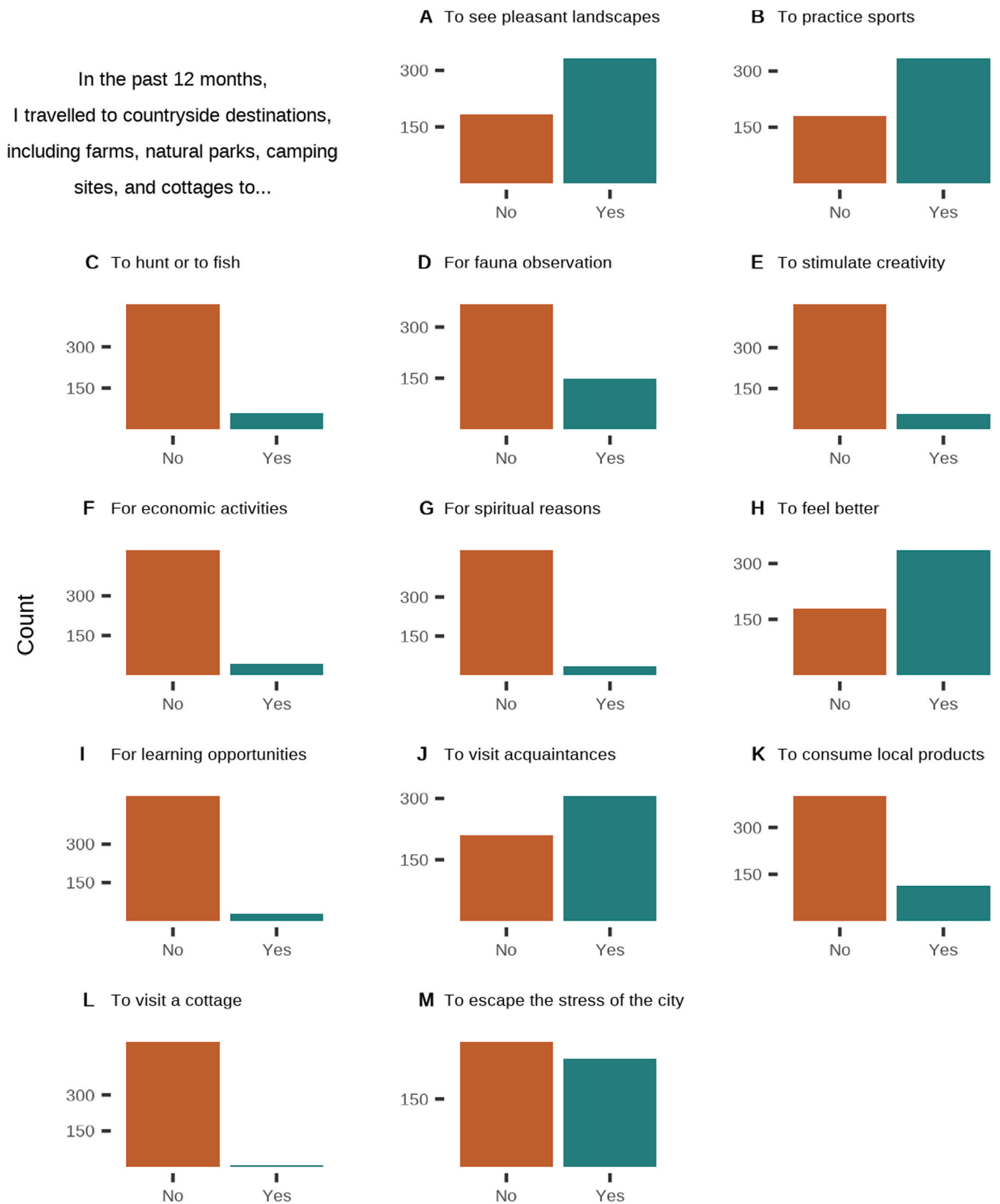


Fig. 5. Number of responses to the multiple-choice question: *What were your reasons for travelling to the countryside, including farms, natural parks, campsites, and cottages within the last 12 months?*

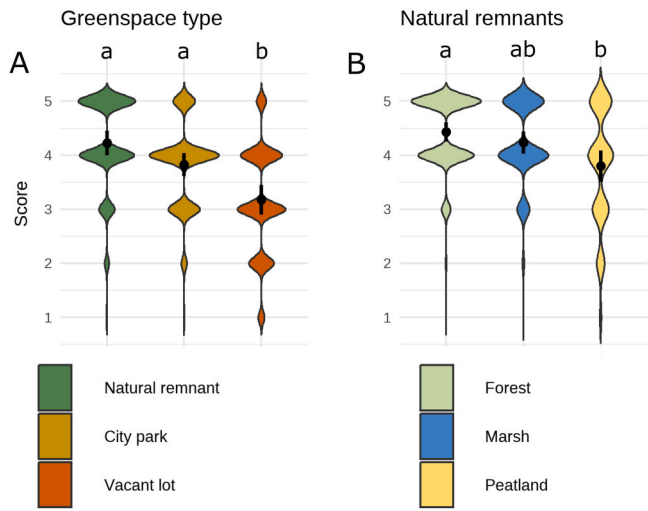


Fig. 6. Violin plots illustrating the appreciation scores given to each type of greenspace (A) and type of natural vegetation remnant (B). Appreciation scores: 5- very beautiful/magnificent, 4- beautiful, 3-Neither beautiful nor ugly, 2- ugly and 1- very ugly. Wider areas of the violin plot represent values more commonly observed. Black dots are estimated marginal means, and hinges are 95 % confidence intervals. Lowercase letters represent significantly different groups obtained from Tukey post-hoc tests.

vegetation features play a more crucial role in aesthetic perception. In vacant lots, however, the presence of buildings in the background was observed to negatively impact their aesthetic value, potentially due to a perceived reduction in naturalness (Kerebel et al., 2019), reflecting a dislike for vacant lots that appear to be altered by human intervention. Among vacant lots without artificial structures, those with higher green pixel coverage were preferred, indicating a preference for more natural-looking vacant lots. However, in the presence of artificial structures, higher green pixel coverage reduced preference, which could be explained by a lower acceptance of vegetation in sites perceived as less natural.

Tall vegetation, such as trees and shrubs, plays an important role in the aesthetic quality of urban environments (Camacho-Cervantes et al., 2014). Preferences for both natural remnants and city parks were highest for images displaying a canopy cover of more than 45–50 % (Fig. 7), highlighting the extent to which trees are valued in urban settings. In city parks with low visual complexity, those with a higher canopy cover were preferred. This finding may be associated with a preference for well-maintained grassy areas interspersed with trees, which would have a high canopy cover accompanied by low vegetation structural complexity (Hägerhäll et al., 2018). City parks, as centers of social interaction, provide venues for various forms of involvement in the community, leisure, and recreation, and a balance between shaded canopy cover and open areas (Bertram et al., 2017; Stewart et al., 2019).

4.2. Observer characteristics and aesthetic value

Individuals who possess greater botanical knowledge, engage in

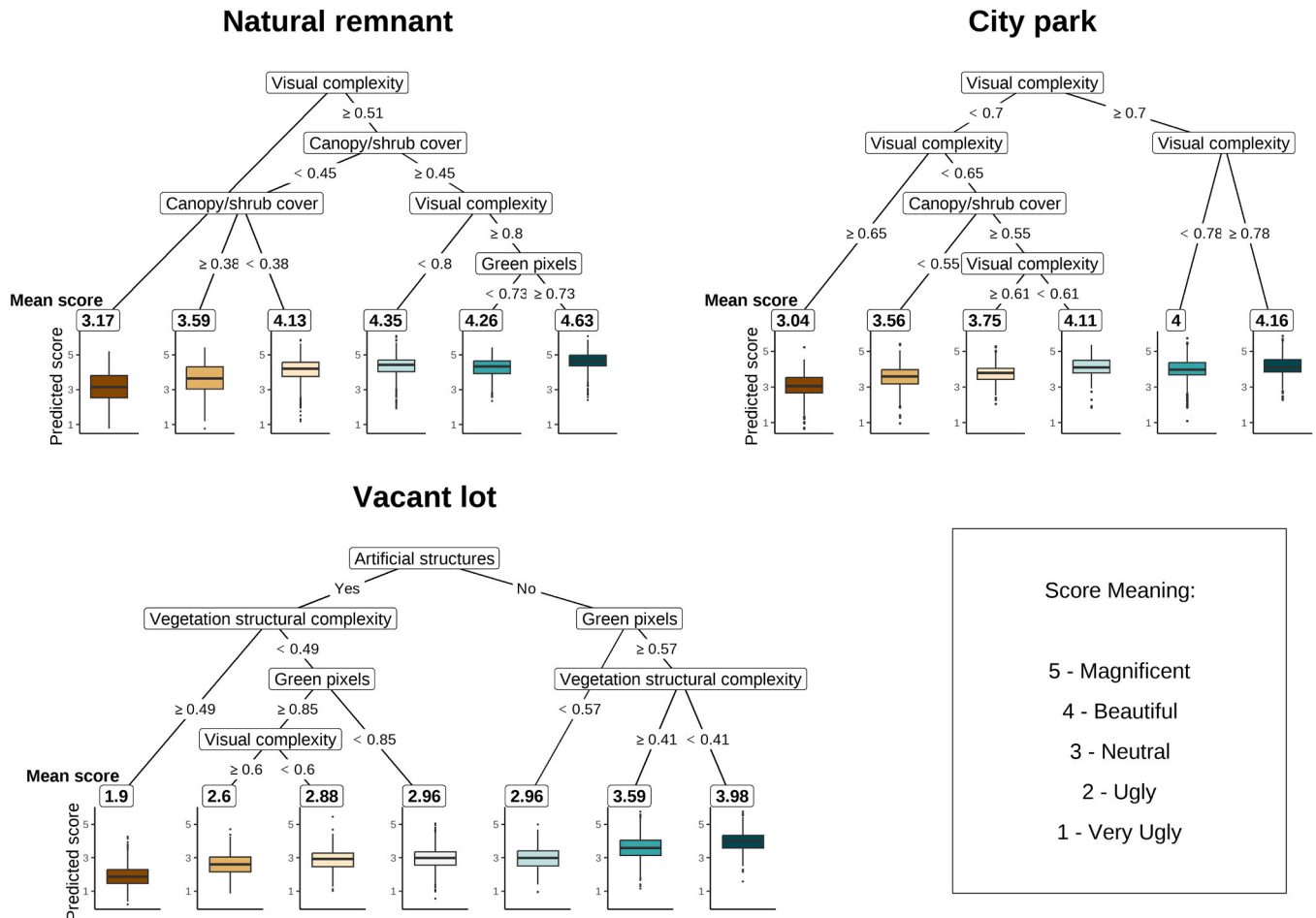


Fig. 7. Regression trees showing the mean appreciation scores given to images at each tree leaf. Boxplots show the variation of predicted scores by the model. The gradient from brown to blue indicates lower to higher predicted appreciation scores.

Table 2

Results of an analysis of variance for the redundancy analysis where the response matrix represented the ecosystem features weighted by appreciation scores, and the explanatory matrix represented the respondents' characteristics. Variables in bold indicate statistical significance.

| Question type | Respondents' characteristics | F | p |
|---------------------------------------|--|--------|--------------|
| Pro-environmental attitudes | The beauty of their neighborhood is important | 0.446 | 0.664 |
| | Greenspaces in their neighborhood are important | 1.246 | 0.247 |
| Ecological Knowledge | Identification as environmental defenders | 11.016 | 0.001 |
| | Knowledge of flora | 9.543 | 0.001 |
| Socio-demographic factors | Education level | 1.470 | 0.236 |
| | Age | 12.348 | 0.001 |
| | Gender Identification | 1.369 | 0.250 |
| | Income | 3.738 | 0.015 |
| | Self-declared minorities | 3.754 | 0.022 |
| | Group (Specialists, U. Laval community, general) | 2.173 | 0.071 |
| Nature-related travel | Nature-related travel frequency | 9.386 | 0.001 |
| Reasons for nature-related travelling | Scenic reasons | 3.219 | 0.035 |
| | Sports | 2.300 | 0.087 |
| | Hunt/Fish | 0.856 | 0.454 |
| | Fauna observation | 5.461 | 0.005 |
| | Foster creativity | 0.989 | 0.395 |
| | Economic-related travel | 0.278 | 0.803 |
| | Spiritual reasons | 1.024 | 0.334 |
| | Improve mental and physical health | 0.213 | 0.876 |
| | Learning travel | 4.128 | 0.019 |
| | Visit acquaintances | 0.581 | 0.578 |
| | Escape city stress | 0.892 | 0.426 |
| | Enjoy local products | 2.323 | 0.079 |
| Place of residence | Visit a cottage | 1.260 | 0.268 |
| | Latitude | 0.839 | 0.452 |
| | Longitude | 2.551 | 0.065 |

fauna-observation, and strongly identify as environmental defenders attributed higher aesthetic value to vacant lots compared to the other participants. These characteristics correlate with greater interest in environmental issues and knowledge of local ecology. This knowledge and interest may be associated with a heightened awareness of the benefits of vacant lots as habitats for urban wildlife and providers of ecosystem services, considering that the literature often describes associations between ecological knowledge and ecosystem services valuation (Cebrián-Piqueras et al., 2020). The notion that nature appreciation is shaped by values and by traditional and non-traditional ecological knowledge assumes that cognitive processes influence how observers value ecosystems aesthetically (Brady and Prior, 2020; Gobster et al., 2007). In this context, less appealing ecosystems, such as vacant lots, may be appreciated more as the observer learns about their benefits to humans and urban wildlife. Interestingly, respondents who have engaged in nature-related travel for learning opportunities attributed higher appreciation scores to natural vegetation remnants, perhaps due to the greater ecological knowledge they acquired during that experience.

Respondents who participated in nature-related travel more frequently gave higher scores to natural remnants, while older respondents and those who self-declared as part of a visible minority attributed higher scores to greenspaces with artificial structures (including trails, bridges, benches, statues, light poles, etc.). In the first case, the exposure to natural landscapes promoted by frequent travels could have positively influenced the appreciation of the native vegetation (Arsénio et al., 2019). Meanwhile, the artificial structures considered in this study are related to greenspace accessibility and recreation prospects. It has been shown that older residents often tend to prefer to participate in more accessible nature-related activities, such as nearby city parks (Sang et al., 2016; Schipperijn et al., 2013). Regarding the

respondents who self-declared as part of visible minorities, we did not ask their immigration status, if any, however; the previous Census showed that 82 % of the racialized population of Quebec are immigrants (Statistics Canada, 2021). Prior research in Canada's two largest urban areas (Toronto and Montreal) indicates that greenspace accessibility plays a vital role in the wellbeing of immigrants to Canada (Edge et al., 2023). This is especially true during the years immediately following immigration, when accessing distant natural parks represent a greater challenge (Edge et al., 2023; Hordyk et al., 2015). These results in combination support that previous contact with native vegetation, the prospect of recreation considering variations in greenspace accessibility for different groups of residents, and nature appreciation are interconnected factors (Alcock et al., 2020). The positive relationship between income and scores given to city parks cannot be easily explained. It contradicts earlier findings that lower-income residents prefer city parks, whereas high-income individuals favor parks that require admission fees (Mäntymaa et al., 2022; Roberts et al., 2022).

4.3. Limitations of the study

The first limitation of this study is that photos are not equivalent to firsthand aesthetic experiences (Pálsdóttir et al., 2021). In the same way, land-use context variables obtained from images might not adequately represent the scale at which observers perceive their surroundings in real life (Gobster et al., 2007; Tribot et al., 2018). Important variables could be perceivable in a dimension that is not captured in our images; for example, smells and sounds could be important drivers of landscape preferences, but would not be represented in an image (Pálsdóttir et al., 2021). In addition, despite efforts to recruit a demographically representative sample from Quebec City and nearby cities, our respondents were predominantly young, female, and highly educated, which does not mirror the local population, where seven out of ten people aged 25–64 lack a university degree (Statistics Canada, 2016) and differ in other respects as well. Furthermore, most participants identified themselves as environmental defenders, potentially meaning that people with less interest in environmental issues are less likely to complete a questionnaire like the one we proposed. Although all images portrayed ecosystems during summer and in clear daylight, variations were evident in the sky's tone and the extent of sky visible in each image. For instance, in forested regions, the canopy obscured much of the sky. Finally, because we only used summer images, the study lacks a cross-seasonal perspective on the aesthetic value of greenspaces in the study region. Therefore, our conclusions are only applicable to summer landscapes.

4.4. Implications for management of greenspaces, and conclusions

The results of this research have the potential to inform management practices for greenspaces. For example, high visual complexity, associated with high richness of natural components, such as water, trees, shrubs, herbs, and flowerbeds can enhance city parks appreciation. However, when visual complexity is lower, high canopy cover enhances city parks appreciation. This indicates two possible strategies to enhance the appreciation of city parks: increasing visual complexity or canopy cover. For vacant lots, those with visible buildings in the background and with higher vegetation structural complexity, which indicates the presence of many layers of vegetation, were disliked by respondents. Strategies like planting trees to obscure buildings can enhance the aesthetic value of these lots (Hofmann et al., 2012). This could be done in combination with mowing to prevent the growth of herbaceous and shrub species, which could increase the vertical complexity of the vegetation. This preference for low vegetation complexity in vacant lots presents a challenge for their ecological restoration, which often involves the presence of "messy-looking" vegetation during its intermediate phases (Prior and Brady, 2017). Despite that, in the long-term, a positive impact of ecological restoration on vacant lots' appreciation is

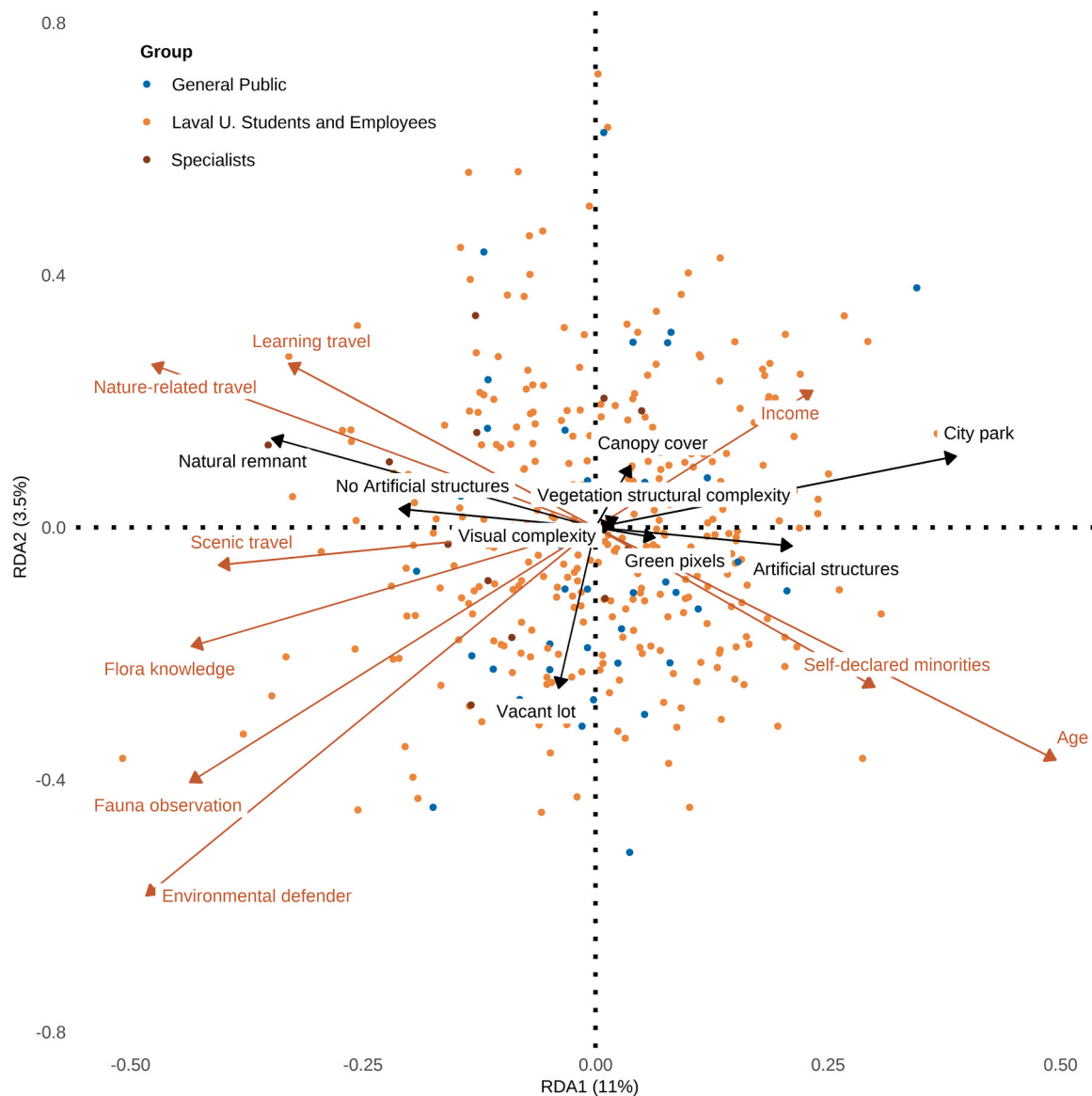


Fig. 8. Redundancy analysis (RDA) where the response matrix represented the ecosystem features weighted by appreciation scores, and the explanatory matrix represented the respondents' characteristics. Black arrows are the RDA scores for each ecosystem feature. Red arrows are the scores of the constraining variables, in this case, the respondents' characteristics. Only significant constraining variables are shown. Circles represent 95 % confidence ellipses for each group of respondents.

expected, as natural vegetation remnants were significantly more appreciated than vacant lots (Fig. 6). Given the relationship between tolerance for vacant lots and both ecological knowledge and pro-environmental values, programs to manage vacant lots should incorporate an educational component to inform residents about their ecological benefits (Kim et al., 2020). Educational initiatives highlighting the benefits of ecological restoration can help mitigate the negative perceptions associated with the initial stages of the restoration process.

Unlike ecological restoration, which aims to return a vacant lot to its pre-disturbance state, ecosystem rehabilitation focuses on making the lot usable and beneficial for residents. This approach could prioritize transforming vacant lots to resemble city parks, which are typically maintained with a look of care. City parks were preferred when they had higher visual complexity; therefore, vegetation complexity could be more accepted in park-like vacant lots. Additionally, it is important to consider that residents with higher ecological knowledge gave lower scores to city parks. This suggests that overly managed parks may not

appeal to those who are more environmentally informed. Therefore, incorporating natural elements that align with ecological principles could better meet the preferences of this demographic. Furthermore, incorporating community input and involvement in the design of restored or rehabilitated vacant lots can foster a sense of ownership and responsibility, potentially improving overall satisfaction (Stewart et al., 2019). The integration of multi-functional greenspaces that serve ecological, recreational, and aesthetic purposes could provide comprehensive benefits, balancing immediate community needs with long-term environmental goals.

This study provides comprehensive insights into the aesthetic preferences associated with different types of greenspaces—natural vegetation remnants, city parks, and vacant lots—using a substantial sample of over 500 respondents. It highlights the nuanced preferences of different demographic groups, emphasizing the importance of considering variables such as age, income, nature-related travel habits, pro-environmental attitudes, and ecological knowledge in greenspace management. The findings contribute to a better understanding of the

relationship between ecological knowledge and public perception, offering valuable guidance for enhancing both the aesthetic and ecological value of urban greenspaces.

Author contributions

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CRedit authorship contribution statement

Monique Poulin: Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Stéphanie Pellerin:** Writing – review & editing, Conceptualization. **Jérôme Cimon-Morin:** Writing – review & editing, Conceptualization. **Marylise Cottet:** Writing – review & editing, Conceptualization. **Jean-Olivier Goyette:** Writing – review & editing, Conceptualization. **Poliana Mendes:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, 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.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128388.

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