Landscape and Urban Planning 208 (2021) 104019

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

School greening: Right or privilege? Examining urban nature within and around primary schools through an equity lens

Francesc Baró [a,b,c,d,e,*], David A. Camacho [a,c], Carmen Pérez Del Pulgar [a,b,c], Margarita Triguero-Mas [a,b,c], Isabelle Anguelovski [a,b,c,f]

[a] *Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Edifici Z (ICTA-ICP), Carrer de les Columnes s/n, Campus de la UAB, 08193 Cerdanyola del Vallès, Spain*
[b] *Hospital del Mar Medical Research Institute (IMIM), Carrer Doctor Aiguader 88, 08003 Barcelona, Spain*
[c] *Barcelona Lab for Urban Environmental Justice and Sustainability (BCNUEJ), Carrer Doctor Aiguader 88, 08003 Barcelona, Spain*
[d] *Department of Geography, Vrije Universiteit Brussel (VUB), Pleinlaan 2, B-1050 Brussels, Belgium*
[e] *Department of Sociology, Vrije Universiteit Brussel (VUB), Pleinlaan 2, B-1050 Brussels, Belgium*
[f] *Institució Catalana de Recerca i Estudis Avançats (ICREA), Passeig de Lluís Companys, 23, 08010 Barcelona, Spain*

HIGHLIGHTS

- School-based exposure to urban nature is markedly uneven across Barcelona.
- A substantial share of greener schools are located in the wealthiest neighborhoods.
- No relevant green inequalities are found between public and charter schools.
- Children in greener schools also enjoy frequent outdoor activities in nature.
- School greening and outdoor educational programs should be driven by equity criteria.

ARTICLE INFO

Keywords:
Children's geographies
Ecosystem services
Geospatial analysis
Urban environmental justice
Urban green space

ABSTRACT

A mounting body of research shows strong positive associations between urban nature and child well-being, including benefits related to mental and physical health. However, there is also evidence that children are spending less time in natural environments than previous generations, especially those living in deprived neighborhoods. To date, most studies analyzing children's (unequal) exposure or access to urban green and blue spaces focus on residential metrics while a school-based perspective, also an essential part of children's daily experience, is still understudied. The overall goal of this research is to assess spatially the amount and main components of green infrastructure within and around a sample of primary schools ($n = 324$) in the city of Barcelona, Spain, and to examine the equity implications of its distributional patterns. A multi-method approach based on GIS, correlation and cluster analyses, and an online survey, is used to identify these patterns of inequity according to three main dimensions: socio-demographic disparities across neighborhoods; school type (public, charter and private); and the frequency of outdoor educational activities organized by schools. Results show that schools located in the wealthiest neighborhoods are generally greener, but inequities are not observed for school surrounding green infrastructure indicators such as access to public green spaces or between public and charter schools. Survey results also indicate that greener schools generally organize more nature-based outdoor activities than those with less exposure to urban nature. In the light of these findings, we contend that multiple indicators of green infrastructure and different dimensions of equity should be considered to improve justice in the implementation of school-based re-naturing and outdoor educational programs.

* Corresponding author at: Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Edifici Z (ICTA-ICP), Carrer de les Columnes s/n, Campus de la UAB, 08193 Cerdanyola del Vallès, Spain.
E-mail address: francesc.baro@uab.cat (F. Baró).

https://doi.org/10.1016/j.landurbplan.2020.104019
Received 3 August 2020; Received in revised form 4 December 2020; Accepted 5 December 2020
Available online 26 December 2020

1. Introduction

In our rapidly urbanizing planet, making cities inclusive, safe, resilient and sustainable (UN Sustainable Development Goal 11) includes “providing universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, older persons and persons with disabilities”. The focus on children is supported by a mounting body of research showing a strong positive relationship between urban nature and child overall well-being (Chawla, 2015). For example, access to, exposure to, or engagement with urban green and blue spaces has been associated with improved physical and mental health of children (Kabisch et al., 2017; McCormick, 2017; Tillmann et al., 2018; Vanaken and Danckaerts, 2018), including moderation of stress (Akpinar, 2016) and improvement of attention-deficit/hyperactivity disorder’s (ADHD) symptoms (Faber Taylor and Kuo, 2011; Markevych et al., 2014). There is also epidemiological evidence on the positive impact of urban greenness on child behavioral and cognitive development (Amoly et al., 2014; Dadvand et al., 2015). Further, urban green spaces provide social environments for children to play with their peers, establish supportive social groups and multicultural relationships, and strengthen their overall emotional and relational well-being (Chawla et al., 2014; Ward et al., 2016; Seeland et al., 2008; Pérez del Pulgar, Anguelovski, & Connolly, 2020). Several studies have even examined if green space exposure can foster child academic performance and intelligence, generally showing mixed results (Browning and Rigolon, 2019; Bijnens et al., 2020). Additionally, contact with natural environments at an early age allows children to develop a positive view or affinity towards nature that can make them local stewards in their adulthood (Kals et al., 1999; Broom, 2017).

Despite this wide range of benefits, there is also evidence that children are spending less time in natural environments than previous generations (Clements, 2004; Karsten, 2005), especially those living in deprived neighborhoods, belonging to low-income households and/or to racial and ethnic minorities (Strife and Downey, 2009; Gidlow and Ellis, 2011). This declining and unequal trend has been explained by different factors. First, several studies show a growing prevalence of indoor sedentary behaviors (e.g. TV viewing or computer use) during children’s free time (Arundell et al., 2016). This prevalence seems more prominent for children living far from green spaces (generally coming from lower socioeconomic group households) than those having to walk shorter distances (Aggio et al., 2015). Children in disadvantaged or gentrifying neighborhoods also face more frequent parental restrictions on outdoor play due to safety concerns (Clements, 2004; Oscilowicz et al., 2020). Perceived unsafety by adults has been associated indeed with lower outdoor physical activity and green space use (Weimann et al., 2017; Hong et al., 2018). More generally, environmental justice literature has shown that low socioeconomic and ethnic minority groups have access to smaller urban parks, with lower quality, maintenance, and safety than more privileged residents (Rigolon, 2016; Rigolon et al., 2018; Nesbitt et al., 2019). For all the above-mentioned reasons, children are a particularly relevant age group to pay attention to in terms of understanding their access and exposure to urban nature and the inequities they might face in reaping the benefits from urban green spaces (Anguelovski et al., 2020).

In this research, we start with the hypothesis that schools and their environments might play a relevant role in the reduction of such residential disparities in the access to urban nature, given the substantial amount of time that children spend in school settings on a daily basis. According to some studies (Slater et al., 2012; García-Serrano et al., 2017), children spend from 4 to 10 h a week in school playgrounds, considering both recess and educational time (mainly physical education). Although schoolyards tend to still be generally dominated by (paved) sport fields, nature-oriented designs are increasingly valued due to their positive effect on children. Greener school grounds can enhance a broad range of health-promoting behaviors such as physical activity, diversify play options and improve children’s behavioral and learning attitudes, as well as their social interaction (Chawla et al., 2014; van Dijk-Wesselius et al., 2018). Green schoolyards are also increasingly recognized as outdoor learning environments (Anguelovski, 2014; van Dijk-Wesselius et al., 2020) and as *shelters* against climate change impacts (see Barcelona’s “Climate Shelters” and Paris’ “Oasis” projects in www.uia-initiative.eu). School surroundings, including public squares, streets, and nearby green spaces can also provide important opportunities for children to have contact with natural environments before, during or after school hours. For instance, children can appreciate urban greenery such as street trees along their daily home-school routes, especially if they commute to school by foot (Łaszkiewicz and Sikorska, 2020). Observational studies also show that the use of public green space (especially urban parks) around schools substantially increases after school hours (Pérez del Pulgar et al., 2020). In addition, higher levels of biodiversity around schools have been recently associated with better children respiratory health (Cavaleiro Rufo et al., 2020). School-related access to nature can also be realized beyond school settings and their surroundings. School curriculum-based outdoor educational programs or activities, generally described as teaching and/or learning and/or experiencing in an outdoor natural environment, have shown to provide multiple beneficial effects on child well-being (Becker et al., 2017).

Yet, to date, the majority of studies analyzing (unequal) exposure or access to urban green and blue spaces by children focus on residential metrics (Feng and Astell-Burt, 2017; Vanaken and Danckaerts, 2018) while the school-based perspective is still understudied; it is also mostly focused on the relationship with academic performance and clearly dominated by US case studies (Browning & Rigolon, 2019). To our knowledge, no previous studies have specifically looked at the equity dimensions related to school-based exposure or access to nature, including spatial distribution, school type (public vs charter or private) and the frequency of curriculum-based outdoor activities. Moreover, the structure and components of urban nature within school compounds and their surroundings are generally overlooked. Studies focusing on exposure to green space in school settings generally use single and coarse indicators of *greenness,* mainly based on Normalized Difference Vegetation Index (NDVI) data (Dadvand et al., 2015, Browning & Rigolon, 2019).

In response to this shortcoming, this paper approaches school greening as part of a wider urban green infrastructure (GI), i.e., a “strategically planned network of green and blue spaces, designed and managed to deliver a wide range of ecosystem services and other benefits at various spatial scales” (Hansen et al., 2017). We consider indeed that both the amount and main components of GI in and around school environments can provide relevant indications of the type of benefits that schoolchildren have possibly access to (Kabisch et al., 2017). For instance, tree cover in schoolyards or the number of street trees around schools are directly related to urban cooling benefits (Baró et al., 2019), and thus to children’s comfort, while access to nearby green spaces and playgrounds is associated with recreational opportunities and social interaction among children (Pérez del Pulgar et al., 2020).

Thus, our overall goal is to assess spatially the amount and main components of school GI within and around a sample of primary schools ($n = 324$) in the city of Barcelona, Spain, and to examine the equity implications of its distributional patterns. We thus contribute novel research at the intersection of urban green equity, environmental justice, and children’s wellbeing and development. More specifically, the research objectives include: 1) to determine the distributional patterns (spatially across the city and according to school type) of GI within and around schools compounds using six different indicators (see Table 1); 2) to detect potential associations between school GI indicators and three social vulnerability variables (low household income, low educational attainment, and high share of Global South residents) at the neighborhood level; and 3) to assess the relationship between school GI indicators and the frequency of outdoor activities included in the schools’ curriculum, examining whether such activities somewhat

Table 1
Green infrastructure indicators quantified at the school level ($n = 324$).

Indicator	Unit	Relevance	Data sources
Inner canopy (total plant canopy cover within school compound)	% of school compound area	Exposure/access to GI during recess time and other school-based activities	Plant canopy cover vector layer based on NDVI 40 cm resolution raster (Barcelona Open Data, 2019; Barcelona Regional, 2015). Aerial orthophoto 25 cm resolution image (Catalan Cartographic Institute, 2018).
Inner tree canopy (tree canopy cover within school compound)	% of school compound area	Exposure/access to GI during recess time and other school-based activities	Plant canopy cover vector layer based on NDVI 40 cm resolution raster (Barcelona Open Data, 2019; Barcelona Regional, 2015). Aerial orthophoto 25 cm resolution image (Catalan Cartographic Institute, 2018).
Outer canopy (total plant canopy cover around school compound - buffer 300 m)	% of buffer area	Exposure to GI before/after school hours (especially relevant for environmental benefits)	Plant canopy cover vector layer based on NDVI 40 cm resolution raster (Barcelona Open Data, 2019; Barcelona Regional, 2015). Aerial orthophoto 25 cm resolution image (Catalan Cartographic Institute, 2018).
Street trees around school main entrance (service area 300 m)	Num. of street trees within service area	Exposure to GI before/after school hours (especially relevant for environmental benefits)	Street tree inventory (Barcelona Open Data, 2019). Street/road graph (Barcelona Open Data, 2019).
Public playgrounds around school main entrance (service area 300 m)	Num. of public playgrounds within service area	Exposure/access to GI before/after school hours (especially relevant for recreational benefits)	Playgrounds inventory (Barcelona Open Data, 2019). Street/road graph (Barcelona Open Data, 2019).
Public green spaces around school main entrance (service area 300 m)	Num. of green spaces intersecting service area	Exposure to GI before/after school hours (especially relevant for recreational benefits)	Public green space vector dataset (own elaboration based on different sources). Street/road graph (Barcelona Open Data, 2019).

compensate or exacerbate potential inequities related to nature's exposure or access within or around schools.

2. Data and methods

2.1. Description of the case study

The municipality of Barcelona, with an area of 101 km^2 and a total population of 1.62 million inhabitants (Barcelona City Council Statistical Yearbook, 2019), is characterized by its compact urban form and high population density (over 400 inhabitants per ha. in several neighborhoods). These traits make open public space (including green spaces) a scarce land cover in many parts of the urban fabric, and thus a critical case study city for the analysis of distributional access to green amenities. A recent study (Barcelona Regional, 2015) estimated that Barcelona has a total plant canopy cover (or vegetation cover) area of 3,463 ha (including private land), unevenly distributed across the 10 districts of the municipality (see Fig. 1). This represents 34% of the municipality, but almost 50% of this share (1,699 ha.) corresponds to the mountain range of Collserola, currently protected as a periurban natural park (see Fig. 1). Barcelona's urban green space availability is thus low when compared to other European cities (especially from Northern countries), but similar to other Mediterranean urban areas (Kabisch et al., 2016). Availability of public green space (including the mountain range of Collserola) among children from 3 to 12 years old (the main study group of this research, see its population distribution per district and neighborhood in Table A1 – Appendix A) is very unequal, ranging from 27 m^2 of green space per child in the middle-income central district Eixample to 718 m^2 per child in the upper-income district of Sarrià-Sant Gervasi (own calculation based on Barcelona City Council Statistical Yearbook, 2019).

The relevance of Barcelona as case study area is further supported by an ambitious urban greening agenda (e.g. the Barcelona Green infrastructure and Biodiversity Plan 2020, the Master Plan for Barcelona's Trees 2017–2037 and the Barcelona Climate Action Plan 2018–2030). One key target that the City Council has outlined is to increase urban green space by 1.6 km^2 (or 1 m^2 per resident) until 2030, with likely greening effects on school environments. The City has also recently adopted the Barcelona Plan for Play in Public Spaces Horizon 2030 (Barcelona City Council, 2019), which aims, among other goals, to enhance the suitability of schoolyards and public green spaces as playful and socially inclusive areas for children. Finally, it is also worth mentioning here the "Climate Shelters in Schools" pilot project (implemented in 2020 thanks to EU funds) which fosters the enhancement of GI in primary schools for climate change adaptation.

2.2. Definition of school sample and green infrastructure indicators

This research focuses on 324 schools of primary education in Barcelona corresponding to schoolchildren between 6 and 12 years old (school data retrieved from the Catalan Directory of Educational Centers: http://ensenyament.gencat.cat). This sample represents almost 93% of the total number of primary schools in Barcelona ($n = 349$) opened during the school year 2018/2019. The vast majority of the selected schools ($n = 319$) also give pre-primary education for children from 3 to 5 years old, hence the sample encompasses most of schoolchildren in Barcelona between the ages of 3 and 12 years old. Slightly more than half of the sample ($n = 163$) are public schools (public management and funded completely by public funds), 152 are charter schools (private management, but partially funded by public funds) and only 9 are private schools (private management without public funds). In general, schools are evenly distributed across the entire municipality (except in Collserola and the industrial and port area located in the south, see Fig. 1), although charter/private schools are especially clustered in two districts: Sarrià-Sant Gervasi ($n = 35$) and Eixample ($n = 28$).

Our first analytical step to assess GI within school compounds involved identifying school boundaries (all geoprocessing operations described hereafter were carried out using ArcGIS 10.7). To this end, we used the UTM coordinates indicating the schools' main entrance included in the school directory, the city cadaster map indicating urban plot boundaries (Barcelona City Council, 2018), and 2018 high resolution aerial orthophotos (25 cm resolution image; Catalan Cartographic Institute, 2018) to support/confirm school boundaries identification. During this process we had to discard 25 schools (from the original directory of 349) due to the following reasons: 1) Unclear school boundaries (usually related to cadaster errors) ($n = 12$); 2) Schools located in temporary locations ($n = 8$); and 3) special schools located in healthcare facilities for hospitalized children ($n = 5$). Total plant canopy cover (i.e., tree, shrub and herbaceous cover) within each school compound (*inner canopy cover*) was estimated using a simple intersect between the school boundaries and the municipal high-resolution plant

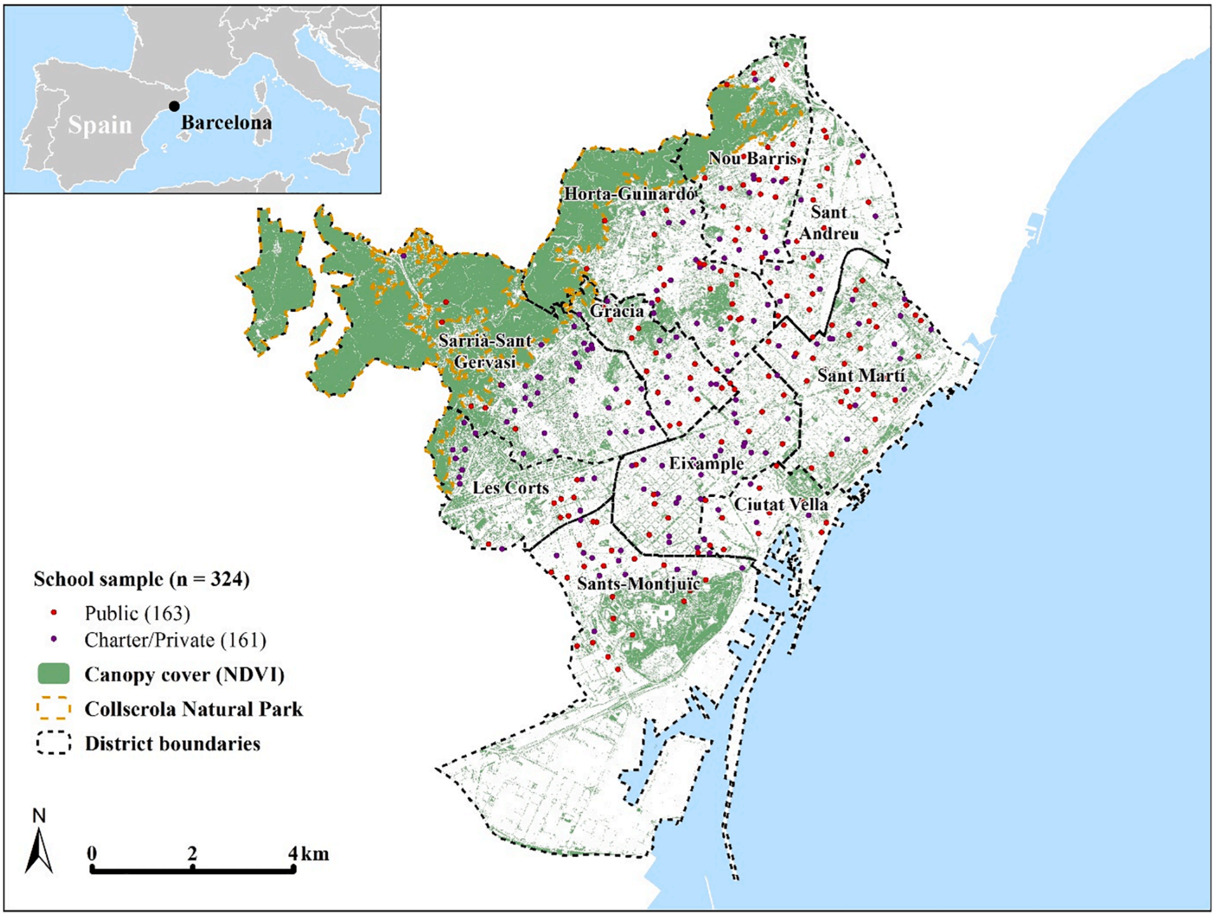

Fig. 1. Barcelona municipality displaying the distribution of the sampled primary schools and the plant canopy cover based on a Normalized Difference Vegetation Index (NDVI) map. Source: own elaboration based on Barcelona City Council datasets.

canopy cover vector layer based on NDVI imagery (see Table 1). Tree canopy cover within school compounds (*inner tree cover*) was estimated via the removal of shrub and herbaceous cover areas from the previous school canopy cover layer using a manual photointerpretation of the above-mentioned high resolution aerial orthophotos. This process also allowed for the correction of errors in the original total canopy cover layer (i.e., artificial covers incorrectly identified as green areas).

The assessment of GI around schools involved the quantification of four indicators (see Table 1 for units and data sources). First, total plant canopy cover around school compounds (*outer canopy cover*) indicates the availability of greenery within a 300 m Euclidean buffer around the school boundaries. Therefore, it estimates the general exposure of schools to nearby green space environmental benefits, even if those spaces are not publicly accessible, such as air filtering, temperature regulation or even aesthetic appreciation (Gómez-Baggethun and Barton, 2013). Second, the number of *street trees* was quantified considering a service area (i.e., considering the street network) of 300 m around schools' main entrance. The 300 m distance threshold corresponds to the mean value of the walking independent mobility standard for children between 6 and 12 years old defined between 200 and 400 m by UNICEF (UNICEF, 2018). This analytical step recognizes that street trees are an important source of regulating ecosystem services in Barcelona (Baró et al., 2019) and can improve children's aesthetic appreciation of home-school routes (Łaszkiewicz and Sikorska, 2020), especially since most primary schoolchildren in Barcelona tend to commute on foot. Finally, the number of *public playgrounds* and *public green spaces* around each school (also considering the service area of 300 m from the main entrance) indicates mainly the outdoor recreational opportunities for children after school hours (Pérez del Pulgar et al., 2020; Oscilowicz et al., 2020). Public playgrounds are generally located within green spaces (or tree-covered public spaces such as squares) in Barcelona and hence play a key role in enabling children's contact with urban nature. Fig. 2 illustrates the spatial representation of the six school GI indicators (including school boundaries, buffer and service areas) using a sampled school as example. The distributional patterns of school GI indicators were analyzed spatially, aggregating the school median values at the district ($n = 10$) and neighborhood ($n = 73$) levels, and also according to school type (public, charter and private). The total population, children's population and area of each district and neighborhood is available in Table A1 (Appendix A).

2.3. Definition of socio-demographic variables and equity analyses

In order to assess the distribution of school GI through a social equity lens we selected three available socio-demographic variables for Barcelona, (see Table 2) which indicate neighborhood social vulnerability in terms of socioeconomic status (income and level of educational attainment) and risk of social exclusion (immigrants from the Global South). These or similar variables have been used in previous environmental justice assessments in Barcelona and other cities (e.g., Moreno-Jiménez et al., 2016; Anguelovski et al., 2018; Baró et al., 2019). Although parents or children's legal guardians in Barcelona can choose, during the enrollment process, any primary school located in the municipality, the final allocation is based on a score system in which the proximity criterion usually has a decisive weight. To this end, each public and charter school is assigned to a catchment area where children living inside receive the maximum score for the proximity criterion. School catchment areas are generally aligned with neighborhood

Fig. 2. Spatial representation of the school green infrastructure indicators in one sampled school. Source: own elaboration based on different sources (see Table 1). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Neighborhood socio-demographic indicators of social vulnerability considered in the assessment.

Indicator	Unit	Data sources
Income (gross household disposable income index). Low values indicate higher vulnerability.	Index value where 100 is the city average	Statistical Yearbook (Barcelona City Council Statistical Yearbook, 2018)
Low educational attainment (residents with primary education or no studies). High values indicate higher vulnerability.	% of population over 16 years old	Statistical Yearbook (Barcelona City Council, 2018)
Immigrants from the **Global South** (residents whose nationality is from the Global South). High values indicate higher vulnerability.	% of total population	Statistical Yearbook (Barcelona City Council, 2018)

boundaries, and it can therefore be assumed that a substantial part of the children enrolled in a certain school reside in the same neighborhood. This circumstance enabled us to use neighborhoods (n = 73) as a consistent spatial unit for school equity analyses and assign the neighborhood vulnerability values to the corresponding schools. The spatial distribution of the three socio-demographic variables related to vulnerability at the neighborhood level is shown in Fig. A1 (Appendix A), together with the number of schools located therein.

Following the approach of other studies examining the distributional equity of urban green amenities (Schwarz et al., 2015; Baró et al., 2019), the potential associations between school GI and socio-demographic variables were analyzed using bivariate and cluster techniques. As our study variables had a non-normal distribution, we employed non-parametric Spearman correlations between socio-demographic characteristics and school GI indicators (Duncan et al., 2014). Secondly, we classified schools into clusters based on similar combinations of school GI and socio-demographic normalized variables using a k-means clustering algorithm contained in QGIS 3.4 software (Attribute based clustering plugin). The appropriate number of clusters was determined by interpreting the meaning of different clustering outputs. To stabilize the clusters, the number of iterations in the k-means procedure was set at 1,000 to ensure a global minimum of variance. Each cluster was illustrated with the median and IQR (i.e. interquartile range) and their spatial distribution was mapped using ArcGIS v.10.7. Spatial autocorrelation of the obtained clusters was also measured using the Global Moran's I statistic.

2.4. Online survey

In order to complement previous analyses and assess the actual children's use or interaction with school GI elements and the frequency of outdoor nature contact activities during school hours (research objective 3), we developed an online survey. The questionnaire included eight questions, but only the following three are relevant for this research: 1) Do children directly interact with school GI elements (e.g., during leisure time or environmental education lessons)? (binary question: yes/no); 2) Does the school organize curriculum-based outdoor activities (outside school compound) in which children have a direct contact with natural environments (e.g., urban parks, natural protected areas, etc.)? (binary question: yes/no); 3) How often do these outdoor activities take place generally? (possible answers: weekly; monthly; quarterly; half-yearly; yearly; other or don't know). The survey was created using Google Forms and circulated to schools via email. The request to answer the survey (together with brief information about the study) was addressed to school directors, headmasters or other personnel with a good overall knowledge about the school facilities and curriculum. The survey was open between March 28th and April 19th, 2019 and several reminders were sent to encourage participation.

3. Results

3.1. School green infrastructure distributional patterns

The distribution of each GI indicator across the school city-wide sample is represented in the histograms of Fig. A2 (Appendix A). Their distributional patterns are shown geographically, aggregating the school GI values at the district ($n = 10$, see Table 3) and neighborhood (n = 73, see Fig. A3 in Appendix A) levels, and also based on school type (public, charter and private, see Table 3). Since these results show right-skewed distributions for all indicators (except street trees), we mainly report medians and IQR (i.e. interquartile range) rather than means and SD following recent calls in regard to the assessment of spatial equity of urban green spaces (Tan and Samsudin, 2017).

First, the school inner canopy cover distribution shows that 141 schools (43.5% of the sample) have less than 5% of canopy cover within their compounds while only 14 schools (4.3% of the sample) have more than 40%. Spatially, this indicator ranges from a median of 0.8% of the school compound in the central district of Eixample to 14.7% in the district of Sarrià-Sant Gervasi located in the northwest of the municipality (see district boundaries and names in Fig. 1). Interestingly, public schools contain almost four times higher the share of inner canopy cover compared to charter schools (medians 11.3% and 3.1% respectively), while the nine private schools show the highest median value (22.3%). In general, the values of inner tree canopy cover are slightly lower than total canopy and show similar distributional patterns, indicating that trees are the most frequent GI component within school settings. Results also show that larger schools in terms of compound area usually have a higher share of inner total canopy (and tree) cover (see also Table 4).

Indicators of GI around schools show contrasting distributional patterns. On the one hand, total canopy cover around school compounds displays a similar right-skewed distribution to inner GI indicators, with most schools (72.2%) situated in the lower ranges (below 25% of the buffer area is covered by canopy) and only a few (4.0%) showing very high values (above 60%). Geographically, schools located in Les Corts and Sarrià-Sant Gervasi enjoy the greenest surroundings while schools located in Ciutat Vella or Sant Andreu suffer the greyest environs. Private schools display again the highest median value (38.4%) of outer canopy cover compared to public and charter schools, both showing similar median values this time (around 16.5%). On the other hand, access to street trees, public playgrounds and green spaces clearly displays different distributional patterns, somewhat spatially inverse. Schools located in the districts of Sant Martí, Nou Barris and Sant Andreu show the highest median values while those located in Sarrià-Sant Gervasi, Les Corts and Gràcia display generally the lowest. Similarly, the highest median values of these indicators correspond to public schools, followed closely by charter schools, and far above private school median values.

3.2. Associations with social vulnerability indicators

The bivariate analysis results are shown in Table 4. Inner total canopy cover is very strongly (i.e., $r > 0.90$) positively correlated with inner tree canopy and both are, to a lesser extent, also positively correlated with outer canopy cover ($r > 0.40$). Positive and moderately ($r = [0.40–0.69]$) significant associations are also found between the other school GI variables (street trees, playgrounds and green spaces). In contrast, the relationships between the latter school GI variables and the former (inner and outer canopy cover indicators) are always negative and weakly ($r = [0.10–0.39]$) statistically significant.

The correlation results between school GI and socio-demographic variables also show several statistically significant associations. Low education attainment and Global South variables are positively weakly correlated with street trees, playgrounds and parks, but negatively weakly correlated with outer canopy cover. In contrast, income shows inverse (weak) associations with these school GI variables, indicating that schools located in wealthier neighborhoods have greener surroundings, but not due to a higher number of parks or street trees. Interestingly, only the variable of Global South residents shows a statistically significant and negative (weak) correlation with the two indicators of inner GI.

The cluster analysis (*k*-means) reveals four meaningful groups of schools based on the distributional patterns of the six school GI variables and the three socio-demographic variables considered in the study (see Fig. 3 and Table 5). All groups are also highly spatially clustered (Moran's Index = 0.07 and z-score = 12.54). Cluster 1 (16.4% of the total sample), so-called "*Greenest schools*", encompasses schools mostly situated in the districts of Gràcia, Sants-Montjuïc and Horta-Guinardó, and generally close to or within large green spaces such as the parks of Montjuïc and Tres Turons (see Fig. 3). The socio-demographic median values suggest that schools in this cluster are generally located in middle or low-income neighborhoods with a share of Global South residents and population with low education attainment similar to the city average. The cluster stands out by the highest median values of inner GI indicators: more than 25% of the schools' compound area is covered by

Table 3
Median and IQR (interquartile range, in parentheses) of school compound area and green infrastructure indicators in the whole sample, at the district level and according to school type (n = number of schools).

District / school type	Compound area(m^2)	Inner canopy(%)	Inner tree(%)	Outer canopy(%)	Street trees(#)	Playgrounds(#)	Green spaces(#)
Barcelona ($n = 324$)	3331.43 (3657.14)	7.40 (18.34)	6.73 (16.14)	16.84 (14.81)	459.50 (30.50)	2.00 (2.00)	4.00 (3.00)
Ciutat Vella ($n = 17$)	2475.19 (1791.12)	3.03 (14.74)	3.03 (12.77)	8.62 (5.73)	338.00 (271.00)	2.00 (3.00)	5.00 (3.00)
Eixample ($n = 41$)	2812.61 (2431.19)	0.82 (6.81)	0.31 (4.96)	15.10 (3.72)	563.00 (107.00)	2.00 (2.00)	3.00 (2.00)
Gràcia ($n = 26$)	2563.64 (2550.22)	5.18 (18.77)	5.18 (18.76)	13.95 (22.73)	292.00 (256.25)	1.00 (2.75)	3.00 (2.00)
Horta-Guinardó ($n = 36$)	3629.34 (5495.67)	13.72 (22.17)	13.72 (20.04)	21.19 (16.42)	364.00 (194.00)	1.00 (3.00)	3.00 (3.00)
Les Corts ($n = 18$)	4491.37 (2172.16)	13.08 (25.41)	10.91 (17.04)	23.14 (33.95)	467.50 (415.50)	1.50 (1.75)	3.00 (2.75)
Nou Barris ($n = 35$)	3040.94 (2673.58)	7.78 (10.77)	7.12 (10.78)	11.12 (13.15)	653.00 (357.00)	3.00 (2.00)	4.00 (3.50)
Sant Andreu ($n = 29$)	3462.20 (4568.08)	6.71 (14.57)	6.71 (14.57)	11.81 (6.26)	591.00 (111.00)	3.00 (3.00)	5.00 (2.00)
Sant Martí ($n = 46$)	3831.31 (3587.62)	7.07 (12.21)	6.85 (12.18)	20.43 (9.58)	612.50 (320.50)	4.00 (3.00)	4.00 (4.00)
Sants-Montjuïc ($n = 34$)	3276.98 (3418.02)	6.26 (19.73)	5.92 (18.72)	13.39 (15.47)	391.50 (152.50)	1.00 (1.75)	4.00 (2.00)
Sarrià-Sant Gervasi ($n = 42$)	4106.51 (7229.71)	14.74 (15.29)	12.61 (14.02)	34.21 (22.93)	275.00 (222.75)	1.00 (1.75)	2.00 (2.00)
Public ($n = 163$)	3633.12 (2846.34)	11.30 (17.08)	11.14 (16.43)	16.84 (14.56)	467.00 (320.50)	2.00 (3.00)	4.00 (2.00)
Charter ($n = 152$)	2516.16 (4285.27)	3.07 (13.10)	2.59 (10.40)	16.40 (14.81)	458.50 (286.75)	2.00 (3.00)	3.00 (3.00)
Private ($n = 9$)	1284.37 (2147.07)	22.33 (20.15)	15.47 (12.34)	38.44 (28.88)	299.00 (185.00)	0.00 (2.00)	1.00 (1.00)

Table 4
Spearman's correlation coefficients (r_s) between school green infrastructure and socio-demographic variables at the school level ($n = 324$). Note: In bold statistically significant correlations (*p-value* less than 0.01).

	Inner canopy	Inner tree	Outer canopy	Street trees	Play-grounds	Green spaces	Income	Low educat.	Global South
Inner Tree	**0.98**								
Outer canopy	**0.46**	**0.44**							
Street trees	**−0.33**	**−0.33**	**−0.29**						
Playgrounds	**−0.17**	**−0.17**	**−0.16**	**0.53**					
Green spaces	**−0.15**	**−0.16**	**−0.16**	**0.40**	**0.47**				
Income	0.09	0.06	**0.27**	**−0.33**	**−0.37**	**−0.31**			
Low education	−0.08	−0.05	**−0.24**	**0.30**	**0.34**	**0.33**	**−0.95**		
Global South	**−0.23**	**−0.22**	**−0.38**	**0.22**	**0.25**	**0.30**	**−0.58**	**0.67**	
Compound area	**0.56**	**0.55**	**0.30**	−0.12	−0.09	−0.08	0.08	−0.04	**−0.20**

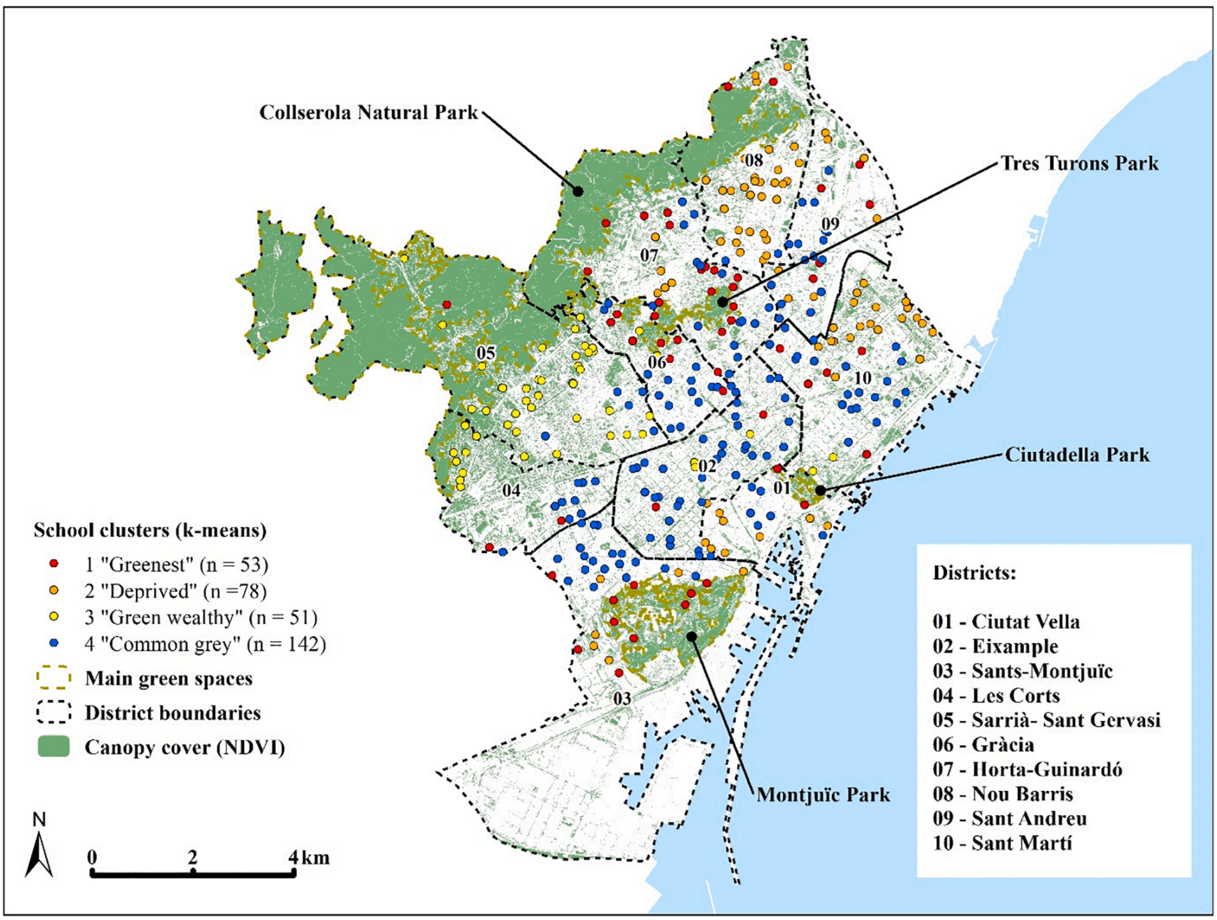

Fig. 3. Spatial distribution of school clusters. The number of schools per cluster is indicated with *n*. Source: own elaboration based on Barcelona City Council data (see Table 1 and Table 2).

Table 5
Median and IQR (interquartile range, in parentheses) of green infrastructure and socio-demographic variables within each school cluster (n = number of schools).

	Inner canopy	Inner tree	Outer canopy	Street trees	Playgrounds	Green spaces	Income	Low educat.	Global South
Cluster 1 "Greenest"($n = 53$)	26.45 (14.76)	25.55 (13.95)	26.66 (25.42)	342.00 (305.00)	1.00 (3.00)	3.00 (3.00)	83.60 (20.80)	19.56 (9.84)	9.28 (4.90)
Cluster 2 "Deprived"($n = 78$)	8.05 (12.40)	7.08 (12.27)	17.77 (13.61)	655.50 (353.50)	3.00 (2.00)	5.00 (3.00)	60.40 (15.40)	31.37 (7.47)	13.43 (10.76)
Cluster 3 "Green wealthy"($n = 51$)	19.44 (15.37)	14.80 (11.39)	39.36 (26.42)	275.00 (213.00)	0.00 (2.00)	2.00 (3.00)	192.10 (9.00)	6.38 (1.98)	5.18 (1.78)
Cluster 4 "Common grey"($n = 142$)	1.78 (5.05)	1.42 (4.69)	13.67 (6.31)	488.00 (205.75)	2.00 (2.00)	3.00 (2.00)	101.80 (30.68)	17.59 (7.60)	8.62 (3.64)

Table 6
Frequency of outdoor activities in green spaces reported by the schools that responded the online survey disaggregated by school clusters.

	Weekly	Monthly	Quarterly	Semi-annually	Annually
Cluster 1 "Greenest"($n = 13$)	5 (38.5%)	0 (0.0%)	3 (23.1%)	3 (23.1%)	2 (15.4%)
Cluster 2 "Deprived"($n = 17$)	0 (0.0%)	3 (17.6%)	12 (70.6%)	1 (5.9%)	1 (5.9%)
Cluster 3 "Green wealthy"($n = 11$)	3 (27.3%)	4 (36.4%)	2 (18.2%)	1 (9.1%)	1 (9.1%)
Cluster 4 "Common grey"($n = 41$)	2 (4.9%)	7 (17.1%)	23 (56.1%)	5 (12.2%)	4 (9.76%)

(tree) canopy, more than triple of the city median. Schools from this cluster also enjoy green surroundings in terms of outer canopy cover, but not in relation to street trees or public green spaces as these indicators show values below the city medians. Cluster 2 ("*Deprived schools*") includes 24.1% of the school sample, mainly located in the most disadvantaged areas of Barcelona, such as the district of Nou Barris and some neighborhoods of Sant Martí and Ciutat Vella, all below city average household income. These areas are characterized by low-income residents and a high share of Global South inhabitants and residents with low educational attainment compared to the city average. Regarding the school GI indicators, the cluster shows the highest median values of number of street trees, playgrounds and public green spaces, but relatively low levels of inner and outer canopy cover, making more prominent the apparent incongruity mentioned above. In sharp contrast to the previous group, schools included in Cluster 3 (15.7% of the sample), named "*Green wealthy schools*", are mostly located in the most affluent districts of Barcelona, i.e., Sarrià-Sant Gervasi and Les Corts. This cluster also stands out by its median outer canopy cover value (39.4%), doubling the city median, but also by the lowest median values of the other surrounding school GI indicators. Finally, Cluster 4 ("*Common grey schools*") contains, by far, the highest number of schools (43.8% of the sample), distributed across different districts, especially Eixample, Sant Martí, Sants-Montjuïc or Gràcia, generally characterized by sociodemographic values close to the city averages (i.e., not particularly deprived or wealthy). Schools show the lowest median levels of inner and surrounding canopy cover (less than 2% and 15% respectively) and middle values for the rest of school GI indicators.

3.3. Frequency of outdoor activities in nature

Last, in terms of the survey analysis, the online questionnaire was answered by 87 schools, mostly by school directors or headmasters (80%). Despite the relatively low response rate (26.9%), all school clusters were represented by between 20 and 30% of their schools, and always at least by 10 schools (see Table 6). Most schools ($n = 80$) reported that children use or have direct contact with school GI elements during leisure time or environmental education lessons. Similarly, almost all respondents ($n = 84$) answered that their schools organize outdoor activities to green spaces (urban parks, protected natural areas, etc.) where children can have direct contact with nature. However, the majority of the schools (66.7%) organize these activities quarterly ($n = 40$), semi-annually ($n = 10$) or annually ($n = 8$), while only 27.6% stated weekly ($n = 10$) or monthly ($n = 14$). Interestingly, half of this latter group correspond to schools in clusters 1 (*Greenest*) and 3 (*Green wealthy*), i.e., the schools enjoying a higher share of inner and outer canopy cover. Moreover, the percent of schools in these clusters that organize outdoor activities in green spaces weekly or monthly is substantially higher than in clusters 2 (*Deprived*) and 4 (*Common grey*) (see Table 6). These results suggest that children in greener schools also enjoy more frequent outdoor activities in natural environments than those in greyer schools, further compounding inequities in nature contact.

4. Discussion

4.1. School-related access to nature: Right or privilege?

Previous literature examining school green space has mainly focused on its potential impact on academic performance (Browning and Rigolon, 2019) or mental well-being, including behavioral and cognitive benefits (Amoly et al., 2014; Chawla, et al., 2014; Dadvand et al., 2015; Akpinar, 2016). In general, these studies do not explicitly examine the distributional patterns and components of school green space nor the related (in)equity implications at the city level or other spatial scales. The main goal of this research was to bridge this knowledge gap and examine school greening through an environmental justice lens and a GI approach, and thus to contribute to novel research at the intersection of equitable green space planning and access, environmental justice, and children's wellbeing and health.

Our results show that school-based exposure and access to GI is markedly uneven across the urban and social fabric of Barcelona. The majority of schools analyzed display very low levels of both inner and outer canopy cover while only 30 schools (9.3%) are able to offer a substantial amount of inner GI (more than 30% of total plant canopy cover) to their students. Greenest schools are generally characterized by high inner tree canopy cover, which has been shown to be an important trait for the provision of a variety of benefits such as air temperature (heat) regulation, directly related to positive children health effects (Kabisch et al., 2017). Our findings suggest that schools with a higher amount of inner and outer GI (Clusters "Greenest" and "Green wealthy") are usually located in low density neighborhoods and/or nearby (even within) large green areas of the city. These schools might have taken advantage of more available land and pre-existing urban nature (due to low-density zoning regulations) to design greener and larger schoolyards. Interestingly, a substantial share of these schools (mostly grouped in Cluster 3) are located in the wealthiest districts of Barcelona in terms of household income (Les Corts and Sarrià-Sant Gervasi), also characterized by a low percentage of Global South immigrants and residents with low educational attainment. Similar associations have been also observed in previous research mainly carried out in US. For instance, Kuo et al. (2018) found that public schools in Chicago serving more white, well-off pupils have greener schoolyards and surroundings, especially in relation to tree cover. Likewise, schools in Washington D.C. attended by more Hispanic students had fewer trees than those attended predominantly by white students (Kweon et al., 2017).

Another equity dimension analyzed in regard to school greening relates to school public, private, or mixed (charter) status. To our knowledge, this aspect has been overlooked in previous studies, as the majority of them have only analyzed public school samples (Browning & Rigolon, 2019). Our hypothesis anticipated that charter and private schools might have more resources to provide better facilities to their students, including greener schoolyards and settings. However, only private centers have proved to be greener than public (22.3% and 11.3% of median inner canopy cover respectively) while charter schools are surprisingly the least green (median 3.1%). These low median values of inner green space in charter schools might be explained by their widespread distribution and heterogeneity in terms of compound size, indicating that a substantial share of charter schools are small and located in compact neighborhoods. Besides, many charter schools in Barcelona offer reduced tuition fees and attract diverse families from a socioeconomic standpoint. In contrast, private schools in Barcelona tend to have very high monthly tuition thus concentrating the relatively few and high-income families able to afford them. Still, given the small sample of private schools analyzed ($n = 9$) compared to charter and public ($n = 315$), any association of school greening as a privilege of a small elite of private schools should be taken with caution.

An additional objective of this research pointed at the relationship between school GI indicators and the frequency of outdoor activities in natural environments included in the schools' curriculum. We hypothesized that schools in greyer environments might compensate the lack of green schoolyards and surrounding GI with more frequent outdoor activities in distant urban green spaces or natural areas. Again, this dimension of (un)equal school-related access to nature has not been explicitly assessed in previous research. The sub-sample results suggest that children enrolled in greener schools also enjoy more frequent outdoor activities in natural environments than those in greyer schools, indicating a potential exacerbation of green inequalities and unequal green access and benefits of nature contact among schoolchildren. Schools with a higher amount of inner and outer GI might organize outdoor activities more frequently thanks to their closeness to green areas (such as the park of Collserola) and a higher recognition of or ability to value nature's benefits for children.

Methodologically, our novel use of a multiple indicator approach to school greening has also shown interesting patterns of outer GI typology across the city that traditional approaches based on indicators of urban *greenness* would have overlooked. Although the proportion of overall canopy cover around schools located in disadvantaged neighborhoods (Cluster 2- "Deprived") and, more generally, in middle-income neighborhoods (Cluster 4- "Common grey") is substantially lower than for the schools grouped in the other clusters, the access to nearby street trees, public green spaces and playgrounds displays inverse patterns. This apparent incongruity could be explained by the importance of Collserola Natural Park, and to a lesser extent of private green space, in terms of total canopy cover in the northwest of the municipality, where high-income neighborhoods are mostly located. In contrast, the distribution of streets trees, public green spaces and playgrounds is determined by other underlying drivers such as urban form (see Baró et al., 2019). The compactness and density of many low and middle-income neighborhoods in Sant Martí, Sant Andreu or Nou Barris districts makes them less green in terms of total canopy cover, but with a higher number of street trees and smaller green patches (e.g., pocket parks) usually including playgrounds and other public amenities. These results suggest a compensatory equity benefit of small-scale public and community green interventions in front of the clearly uneven distribution of private green space and large (pre-existing) urban forests. Such findings also reflect the recent history of Barcelona, with targeted efforts to build children green and play facilities in many dense and neglected neighborhoods (Pérez del Pulgar et al., 2020), and highlight the importance of assessing urban GI components beyond general indicators of *greenness*.

4.2. Limitations and future research

Our equity analyses assume that the socio-demographic characteristics of schools (i.e., of children attending each school) are directly related to those of the neighborhood in which each school is located. While this assumption is supported by the prominent weight of the proximity criterion during the school enrollment process, the real distribution of schoolchildren in the different centers is also determined by school segregation-related factors. The magnitude of school segregation by socioeconomic level in Barcelona, and more generally in Spain, as expressed by its unevenness dimension (Gorard index) or its exposure dimension (Isolation index), is one of the highest in Europe (Murillo and Martínez-Garrido, 2018). The analysis of the multiple drivers of school segregation, such as the economic, cultural and religious entry barriers usually imposed by charter and private schools, and its effects on schoolchildren distribution goes beyond the scope of this research. However, we acknowledge that this phenomenon likely exacerbates socio-demographic differences between educational centers in Barcelona. A potential solution to this limitation, unfortunately not available for Barcelona due to data access restrictions, would imply directly collecting the socio-demographic data of children at the school level.

Our research goes beyond the use of a sole NDVI-derived indicator of greenness to analyze green inequities by considering different GI components within and around schools. This novel approach can be a first step towards a more functional/quality-based approach on urban (school) greening based on the quantification of the ecosystem services provided by GI components (Ekkel and de Vries, 2017). Available tools such as i-Tree Eco (Nowak et al., 2008) can estimate the amount of regulating ecosystem services such as urban cooling, air purification or runoff control provided by urban trees and shrubs. In a context of increasing urban climate change-related impacts, these benefits are especially important in school settings to ensure safer and healthier play environments for children.

Future research on school-related green space exposure and access should also expand on the multiple spatial and temporal scales through which children might have contact with nature. While GI within school settings is particularly relevant during recess time and GI around schools during children's daily commutes, more distant GI might also play an important role depending on the frequency of outdoor educational activities included in the schools' curricula. From a distributional justice perspective, all these aspects can reflect potential inequities in the access to nature's benefits when socio-demographic differences (in terms of household income, race or ethnicity) among schools are considered. Given the heterogeneity of urban green space coverage (Fuller and Gaston, 2009) and outdoor education programs (Becker et al., 2017) across European cities, the patterns observed in Barcelona can be the basis for future cross-city and even cross-country comparative studies. Also, the consideration of larger school samples can allow a more consistent analysis of inequities according to school type (public versus charter or private) and frequency of outdoor educational activities. Finally, future studies could explore if other variables (e.g., area population density) play a confounding role in explaining the relationship between school GI and area socioeconomic characteristics using different analytical approaches (e.g., multivariate analyses).

5. Conclusions: Towards greener school environments for all children

The positive impacts of school-related green space on children's overall well-being is increasingly acknowledged in the literature. While evidence on these benefits expands, cities worldwide promote the implementation of re-naturing projects in school settings and their surroundings supported by international networks such as the International School Grounds Alliance (ISGA, see http://www.internationalschoolgrounds.org/) and/or national movements like Green Schoolyards America (https://www.greenschoolyards.org/) in the US. In Europe, recent EU-funded initiatives to transform school settings into greener spaces, such as the projects "Oasis" in Paris and "Climate Shelters" in Barcelona, are aimed at mitigating the harmful impacts of climate change on children.

Building upon the findings of this research based on the case study of Barcelona, we argue that school greening programs should be driven by equity criteria to avoid perpetuating and even exacerbating existing residential and school-based disparities in the access to urban green and blue spaces by children. Planning green cities for children from an environmental justice lens requires considering diverse types of inequities in exposure and access to GI and assessing the diversity of environments that children enter in contact with on a daily basis. To this end, we formulate more specific recommendations targeting municipal policymakers, urban planners, landscape architects and the educational community more generally. First, pilot school greening initiatives should prioritize those centers with least exposure to natural environments (both within and around school settings), but also consider aspects related to the socioeconomic status of schoolchildren. In Barcelona, for instance, the "Climate Shelters" project selected 11 schools based on equality criteria (at least one "grey school" per district) rather than equity. Second, municipal and education authorities should foster (via public funding schemes) more outdoor education activities, especially for schools located in greyer environments, as a compensatory mechanism to ensure access to green space benefits for all children. More generally, the use of green spaces as classrooms (Bentsen et al., 2013), within or outside school settings, should be further explored as a strategy to increase children's direct contact with nature beyond recess time or physical education lessons, to explore different teaching and learning methodologies, and to address environmental justice needs (Anguelovski, 2014). In current times of COVID-19 pandemic and more frequent heatwaves, outdoor natural spaces can indeed provide safer and more innovative learning environments for children than traditional classrooms. Finally, school greening policies, programs or projects must be shaped by a fair participatory process where all the voices of the school community can be expressed, and above all of them, those of children.

CRediT authorship contribution statement

Francesc Baró: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **David A. Camacho:** Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Carmen Pérez Del Pulgar:** Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Margarita Triguero-Mas:** Formal analysis, Writing - original draft, Writing - review & editing. **Isabelle Anguelovski:** Writing - review & editing, Funding acquisition.

Acknowledgements

We thank our colleagues from BCNUEJ, James Connolly, Helen Cole, Melissa García-Lamarca and Galia Shokry for their valuable comments on an early version of the manuscript. We are also grateful to all the schools who answered the online survey. Authors acknowledge financial support from: the LASEG research group through the AGAUR grant 2017SGR0775; the Spanish Ministry of Science, Innovation and Universities through the 2015-2016 BiodivERsA COFUND (project ENABLE, code PCIN-2016-002); the European Research Council (project GREENLULUs; grant agreement ID: 678034); and the EU's Horizon 2020 framework program for research and innovation (project NATURVATION, grant agreement ID: 730243). MTM is funded by Juan de la Cierva fellowships [FJCI-2017-33842] awarded by the Spanish Ministry of Science, Innovation and Universities. This work also contributes to the "María de Maeztu" Programme for Units of Excellence of the Spanish Ministry of Science and Innovation (CEX2019-000940-M). Finally, we also appreciate the work of three anonymous reviewers for their valuable comments and suggestions to the original version of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2020.104019.

References

Aggio, D., Smith, L., Fisher, A., & Hamer, M. (2015). Mothers' perceived proximity to green space is associated with TV viewing time in children: The Growing Up in Scotland study. *Preventive Medicine (Baltim), 70*, 46–49.
Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., … Sunyer, J. (2014). Green and Blue Spaces and Behavioral Development in Barcelona Schoolchildren: The BREATHE Project. *Environmental Health Perspectives, 122*, 1351–1358.
Akpinar, A. (2016). How is high school greenness related to students' restoration and health? *Urban Forest Urban Green, 16*, 1–8.
Anguelovski, I. (2014). *Neighborhood as refuge: Environmental justice, community reconstruction, and place-remaking in the City*. Cambridge: MIT Press.
Anguelovski, I., Connolly, J. J. T., Masip, L., & Pearsall, H. (2018). Assessing green gentrification in historically disenfranchised neighborhoods: A longitudinal and spatial analysis of Barcelona. *Urban Geography, 39*, 458–491.
Anguelovski, I., Brand, A. L., Connolly, J. J. T., Corbera, E., Kotsila, P., Steil, J., … Ramos, L. A. (2020). Expanding the Boundaries of Justice in Urban Greening Scholarship: Toward an Emancipatory, Antisubordination, Intersectional, and Relational Approach. *American Association of Geographers Annals*, 1–27.
Arundell, L., Fletcher, E., Salmon, J., Veitch, J., & Hinkley, T. (2016). A systematic review of the prevalence of sedentary behavior during the after-school period among children aged 5–18 years. *Int. J. Behav. Nutr. Phys. Act., 13*, 93.
Barcelona Open Data (2019). Barcelona City Council, Spain. Retrieved from: http://opendata-ajuntament.barcelona.cat/.
Barcelona City Council (2018). Cadastre map of Barcelona (Plots and blocks). Retrieved from: https://w20.bcn.cat/cartobcn/default.aspx?lang=en.
Barcelona City Council (2019). Barcelona Plan for Play in Public Spaces Horizon 2030. Retrieved from: http://hdl.handle.net/11703/113764.
Barcelona City Council Statistical Yearbook (2018). Department of Statistics, Barcelona City Council, Barcelona, Spain. Retrieved from: http://www.bcn.cat/estadistica.
Barcelona City Council Statistical Yearbook (2019). Department of Statistics, Barcelona City Council, Barcelona, Spain. Retrieved from: http://www.bcn.cat/estadistica.
Barcelona Regional (2015). First Identification of Green Infrastructure in Barcelona Based on NDVI Index. Report Commissioned by the Barcelona City Council. Retrieved from: http://hdl.handle.net/11703/106076.
Baró, F., Calderón-Argelich, A., Langemeyer, J., & Connolly, J. J. T. (2019). Under one canopy? Assessing the distributional environmental justice implications of street tree benefits in Barcelona. *Environmental Science & Policy, 102*, 54–64.
Becker, C., Lauterbach, G., Spengler, S., Dettweiler, U., & Mess, F. (2017). Effects of Regular Classes in Outdoor Education Settings: A Systematic Review on Students' Learning, Social and Health Dimensions. *International Journal of Environmental Research and Public Health, 14*.
Bentsen, P., Schipperijn, J., & Jensen, F. S. (2013). Green Space as Classroom: Outdoor School Teachers' Use, Preferences and Ecostrategies. *Landscape Research, 38*, 561–575.
Bijnens, E. M., Derom, C., Thiery, E., Weyers, S., & Nawrot, T. S. (2020). Residential green space and child intelligence and behavior across urban, suburban, and rural areas in Belgium: A longitudinal birth cohort study of twins. *PLoS Medicine, 17*, 1–20.
Broom, C. (2017). Exploring the Relations Between Childhood Experiences in Nature and Young Adults' Environmental Attitudes and Behaviours. *Australian Journal of Environmental Education, 33*(1), 34–47.
Browning, M. H. E. M., & Rigolon, A. (2019). School Green Space and Its Impact on Academic Performance: A Systematic Literature Review. *International Journal of Environmental Research and Public Health, 16*.
Catalan Cartographic Institute (2018). Aerial orthophoto 25 cm resolution imagery. Retrieved from: http://www.icc.cat/appdownloads/.
Cavaleiro Rufo, J., Ribeiro, A. I., Paciência, I., Delgado, L., & Moreira, A. (2020). The influence of species richness in primary school surroundings on children lung function and allergic disease development. *Pediatric Allergy and Immunology, 31*, 358–363.
Chawla, L., Keena, K., Pevec, I., & Stanley, E. (2014). Green schoolyards as havens from stress and resources for resilience in childhood and adolescence. *Health Place, 28*, 1–13.
Chawla, L. (2015). Benefits of Nature Contact for Children. *Journal of Planning Literature, 30*(4), 433–452.
Clements, R. (2004). An investigation of the status of outdoor play. *Contemp. Issues Early Child., 5*, 68–80.
Dadvand, P., Nieuwenhuijsen, M., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences, 112*(26), 7937–7942.
Duncan, D. T., Kawachi, I., Kum, S., Aldstadt, J., Piras, G., Matthews, S. A., … Williams, D. R. (2014). A Spatially Explicit Approach to the Study of Socio-Demographic Inequality in the Spatial Distribution of Trees across Boston Neighborhoods. *Spatial Demography, 2*, 1–29.
Ekkel, E. D., & de Vries, S. (2017). Nearby green space and human health: Evaluating accessibility metrics. *Landscape and Urban Planning, 157*, 214–220.
Faber Taylor, A., Kuo, F. E., & (Ming),. (2011). Could Exposure to Everyday Green Spaces Help Treat ADHD? Evidence from Children's Play Settings. *Applied Psychology: Health and Well-Being, 3*, 281–303.
Feng, X., & Astell-Burt, T. (2017). Residential Green Space Quantity and Quality and Child Well-being: A Longitudinal Study. *American Journal of Preventive Medicine, 53*, 616–624.
Fuller, R. A., & Gaston, K. J. (2009). The scaling of green space coverage in European cities. *Biology Letters, 5*, 352–355.
García-Serrano, P., Urda, L., Leal, P., Blas, M. (2017). Estudio MICOS: entornos escolares saludables. Bases para una estrategia de intervención de patios, accesos y entornos escolares. Conference paper presented at Jornadas de Innovación Educativa "i&EDU", Madrid, Spain.
Gidlow, C. J., & Ellis, N. J. (2011). Neighbourhood green space in deprived urban communities: Issues and barriers to use. *Local Environment, 16*, 989–1002.
Gómez-Baggethun, E., & Barton, D. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics, 86*, 235–245.
Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (2017). Urban Green Infrastructure Planning: A Guide for Practitioners. GREEN SURGE. Retrieved from: http://greensurge.eu/working-packages/wp5/.
Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., … Frank, L. D. (2018). Linking green space to neighborhood social capital in older adults: The role of perceived safety. *Social Science and Medicine, 207*, 38–45.
Kabisch, N., Strohbach, M., Haase, D., & Kronenberg, J. (2016). Urban green space availability in European cities. *Ecological Indicators, 70*, 586–596.

Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review. *Environmental Research, 159*, 362–373.

Kals, E., Schumacher, D., & Montada, L. (1999). Emotional Affinity toward Nature as a Motivational Basis to Protect Nature. *Environment and Behavior, 31*(2), 178–202.

Karsten, L. (2005). It all used to be better? Different generations on continuity and change in urban children's daily use of space. *Children's Geographies, 3*, 275–290.

Kuo, M., Browning, M. H. E. M., Sachdeva, S., Lee, K., & Westphal, L. (2018). Might School Performance Grow on Trees? Examining the Link Between "Greenness" and Academic Achievement in Urban, High-Poverty Schools. *Frontiers in Psychology, 9*, 1669.

Kweon, B.-S., Ellis, C. D., Lee, J., & Jacobs, K. (2017). The link between school environments and student academic performance. *Urban For. Urban Green., 23*, 35–43.

Łaszkiewicz, E., & Sikorska, D. (2020). Children's green walk to school: An evaluation of welfare-related disparities in the visibility of greenery among children. *Environmental Science & Policy, 110*, 1–13. https://doi.org/10.1016/j.envsci.2020.05.009.

Markevych, I., Tiesler, C. M. T., Fuertes, E., Romanos, M., Dadvand, P., Nieuwenhuijsen, M. J., … Heinrich, J. (2014). Access to urban green spaces and behavioural problems in children: Results from the GINIplus and LISAplus studies. *Environment International, 71*, 29–35.

McCormick, R. (2017). Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. *Journal of Pediatric Nursing, 37*, 3–7.

Moreno-Jiménez, A., Cañada-Torrecilla, R., Jesús Vidal-Domínguez, M., Palacios-García, A., & Martínez-Suárez, P. (2016). Assessing environmental justice through potential exposure to air pollution: A socio-spatial analysis in Madrid and Barcelona, Spain. *Geoforum, 69*, 117–131.

Murillo, F. J., & Martínez-Garrido, C. (2018). Magnitude of school segregation by socioeconomic level in Spain and its Autonomous Communities and comparison with the countries of the European Union. *Rev. Sociol. la Educ., 11*, 37–58.

Nesbitt, L., Meitner, M. J., Girling, C., Sheppard, S. R. J., & Lu, Y. (2019). Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities. *Landscape and Urban Planning, 181*, 51–79.

Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E., & Walton, J. T. (2008). A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services. *Arboric. Urban Forest, 34*, 347–358.

Oscilowicz, E., Honey-Rosés, J., Anguelovski, I., Triguero-Mas, M., & Cole, H. (2020). Young families and children in gentrifying neighbourhoods: How gentrification reshapes use and perception of green play spaces. *Local Environment, 25*, 765–786.

Pérez del Pulgar, C., Anguelovski, I., & Connolly, J. (2020). Toward a green and playful city: Understanding the social and political production of children's relational wellbeing in Barcelona. *Cities, 96*, 102438. https://doi.org/10.1016/j.cities.2019.102438.

Rigolon, A. (2016). A complex landscape of inequity in access to urban parks: A literature review. *Landscape and Urban Planning, 153*, 160–169.

Rigolon, A., Browning, M., & Jennings, V. (2018). Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States. *Landscape and Urban Planning, 178*, 156–169.

Schwarz, K., Fragkias, M., Boone, C. G., Zhou, W., McHale, M., Grove, J. M., … Cadenasso, M. L. (2015). Trees Grow on Money: Urban Tree Canopy Cover and Environmental Justice. *PLoS ONE, 10*, 1–17.

Seeland, K., Dübendorfer, S., & Hansmann, R. (2008). Making friends in Zurich's urban forests and parks: The role of public green space for social inclusion of youths from different cultures. *Forest Policy and Economics, 11*, 10–17.

Slater, S. J., Nicholson, L., Chriqui, J., Turner, L., & Chaloupka, F. (2012). The Impact of State Laws and District Policies on Physical Education and Recess Practices in a Nationally Representative Sample of US Public Elementary Schools. *Archives of Pediatrics and Adolescent Medicine, 166*, 311–316.

Strife, S., & Downey, L. (2009). Childhood Development and Access to Nature: A New Direction for Environmental Inequality Research. *Organ. Environment, 22*, 99–122.

Tan, P. Y., & Samsudin, R. (2017). Effects of spatial scale on assessment of spatial equity of urban park provision. *Landscape and Urban Planning, 158*, 139–154.

Tillmann, S., Tobin, D., Avison, W., & Gilliland, J. (2018). Mental health benefits of interactions with nature in children and teenagers: A systematic review. *Journal of Epidemiology and Community Health, 72*, 958–966.

UNICEF (2018). Shaping urbanization for children. A handbook on child-responsive urban planning. Retrieved from: https://www.unicef.org/publications/files/UNICEF_Shaping_urbanization_for_children_handbook_2018.pdf.

Vanaken, G.-J., & Danckaerts, M. (2018). Impact of Green Space Exposure on Children's and Adolescents' Mental Health: A Systematic Review. *International Journal of Environmental Research and Public Health, 15*. https://doi.org/10.3390/ijerph15122668.

van Dijk-Wesselius, J. E., Maas, J., Hovinga, D., van Vugt, M., & van den Berg, A. E. (2018). The impact of greening schoolyards on the appreciation, and physical, cognitive and social-emotional well-being of schoolchildren: A prospective intervention study. *Landscape and Urban Planning, 180*, 15–26.

van Dijk-Wesselius, J. E., van den Berg, A. E., Maas, J., & Hovinga, D. (2020). Green Schoolyards as Outdoor Learning Environments: Barriers and Solutions as Experienced by Primary School Teachers. *Frontiers in Psychology, 10*, 2919.

Ward, J., Scott Duncan, J., Jarden, A., & Stewart, T. (2016). The impact of children's exposure to greenspace on physical activity, cognitive development, emotional well-being, and ability to appraise risk. *Health & Place, 40*, 44–50.

Weimann, H., Rylander, L., van den Bosch, M. A., Albin, M., Skärbäck, E., Grahn, P., & Björk, J. (2017). Perception of safety is a prerequisite for the association between neighbourhood green qualities and physical activity: Results from a cross-sectional study in Sweden. *Health Place, 45*, 124–130.