



Indicators of Socio-Environmental Equity and Sustainability in Ibero-American Cities: A Variable Weighting Approach

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Abstract

From an equity-centered perspective, urban and environmental processes that negatively impact specific groups while benefiting others are critical determinants of urban sustainability. These complex processes intertwine various analytical dimensions and may differ based on territorial context. Studies primarily conducted in the Global North have aimed to assess environmental equity in cities by developing intricate indices; however, achieving consensus on which variables and indicators to employ or how much weight to assign to each remains elusive. We aimed to identify suitable variables for measuring socio-environmental equity and proposed weighted criteria for evaluation in Ibero-American cities. To accomplish this, we surveyed 41 qualified informants, using a criteria weighting technique to assess the variables and establish their relative importance. We found that inequalities regarding access, quality of green and public spaces, and the impacts of environmental threats were the most recognized issues in the region, with individuals from lower socioeconomic strata being the most affected. Furthermore, we proposed and weighted 14 essential and supplementary variables to evaluate socio-environmental equity, including factors such as access to basic services, housing quality, water and air pollution, the presence of green spaces, extreme weather events, and their effects on public health.

Keywords Environmental justice · Spatial justice · Criteria weighting · Ibero-american cities

Introduction

Environmental issues in cities have become a central focus of the United Nations (UN) Agenda 2030, which emphasizes the need to make cities more inclusive, safe, resilient, and sustainable (Rama et al., 2020).

The world's urban population has continuously grown in recent years, a trend projected to persist (Ibrahim et al., 2018). Rapid urbanization has led to an increase in slums, inadequate infrastructure and services, and environmental degradation, while also putting pressure on natural resources, particularly freshwater, wastewater,

and public health (United Nations, n.d.). Various realities regarding these issues are evident in Ibero-American cities. Latin America is a heterogeneous region, recognized as the most urbanized developing region in the world, with 80% of its total population residing in cities (Montero & García, 2017). International standards label these cities as unequal (ONU-Habitat, 2012). Spain has similarly undergone a rapid urbanization process, rising from 65 to 87% between 1950 and 2018, marking it one of the most significant increases on the European continent (Gutiérrez et al., 2020). Meanwhile, Portugal, one of Europe's smallest and least urbanized countries, has also experienced rising levels of urbanization, characterized by a notably unequal distribution of urban spaces concentrated in specific regions (Balsas, 2006).

The growing concern for an increasingly urbanised world has led to urban spaces being considered key to addressing sustainability. In recent years, sustainable urban development has garnered increasing interest among academics, planners, and policymakers (Larimian et al., 2020). Swyngedouw and Heynen (2003) argue that one cannot categorise a city as inherently unsustainable. Urban and environmental

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processes unfavourably affect certain groups while benefiting others. These processes take the form of the unequal distribution of urban resources, differentiated access to infrastructure, selective exposure to environmental risks, and the instrumentalization of scale to legitimize decisions that harm the most disadvantaged sectors of the population. Even urban environmental planning policies can trigger complex processes that favor certain privileged groups while denying resources and decision-making power to historically marginalized communities (Anguelovski et al., 2016). For instance, in Madrid (Spain), the creation of the Madrid Río Park improved environmental quality. However, it triggered green gentrification, increasing property values and displacing low-income residents while benefiting developers and middle-class groups (Anguelovski et al., 2018). Similarly, in Buenos Aires (Argentina), a notable disparity emerged between residents of affluent neighbourhoods, where essential services such as running water, electricity, and waste collection are readily available, and those residing in informal settlements. The latter population must self-manage to address these fundamental needs, thereby confronting a pronounced manifestation of social and environmental injustice (Besana et al., 2015). Environmental burdens also tend to be concentrated in vulnerable areas. In Santiago de Chile (Chile), low-income populations are disproportionately exposed to air pollution due to their proximity to industrial zones and major traffic arteries (Rose-Pérez, 2015). In Bogotá, it has been found that inequality in air quality distribution exceeds economic and social inequality and that these dimensions overlap in the southwestern area of the city, creating a zone of heightened vulnerability (Bonilla et al., 2023). In the metropolitan region of São Paulo, evidence shows the existence of environmental racism in access to urban green spaces, with significantly worse conditions for Black and Indigenous populations (Bresanne et al., 2024). Finally, the instrumentalization of scale is evident in the case of Rio de Janeiro (Brazil), where thousands of residents were displaced from favelas during preparations for the 2016 Olympic Games under the discourse of national development and urban revitalization, prioritizing global visibility over local needs (Gaffney, 2016). A comprehensive perspective on urban equity analysis should take

these dynamics into account. In this respect, environmental protection and social equity, two fundamental pillars of sustainability, become inseparable, and the focus on environmental equity or justice can provide clarity in this regard (Opp, 2017).

While there are debates about the conceptualisation of the terms “environmental justice” and “equity” (Petrescu-Mag et al., 2016), focusing on the distributive dimension, they refer to how environmental risks and benefits are distributed among the population (Carrier et al., 2014; Fernandez & Wu, 2018; Gandy Jr, 2013). Furthermore, the relationship between these aspects can vary significantly from region to region due to various factors—such as public policies and specific physical and environmental characteristics—that shape diverse territorial realities (World Bank, 2000). For example, urban spatial segregation in Latin America tends to be linked to socioeconomic factors. At the same time, in the United States, ethnic and racial disparities often play a more significant role (Bonilla-Bedoya et al., 2020). Similarly, studies on environmental justice related to technological risks show a higher exposure of lower-income populations in the Global North, but an emerging body of research conducted in developing countries suggests the existence of different patterns (Grineski et al., 2015). This is why selecting a set of indicators capable of measuring the environmental equity of cities presents a challenge. As Rama et al. (2020) proposed, sustainability-related issues involve environmental, economic, political, or social dimensions that determine the need to define appropriate aggregation methods and highlight the importance of adapting them to regional realities, as mentioned earlier. Additionally, indicators can be affected by factors such as data availability or the scale of analysis (Rama et al., 2020).

Several studies, primarily conducted in the Global North, have recently aimed to assess environmental equity by creating complex indices (Table 1). These studies have included environmental variables such as pollution levels, exposure to risks, health impacts, urban habitat conditions, and the availability of green spaces (Sadd et al., 2011; Shrestha et al., 2016; Carrier et al., 2016; Fernández & Wu, 2018; Joseph et al., 2014; and Portelli et al., 2020). Most of these studies focus on measuring air quality rather than water

Table 1 Examples of studies that have proposed using complex indices to measure environmental equity

Reference	Proposed index/method	Area of study	No. of variables included
Sadd et al., 2011	Environmental Justice Screening Method	California	23
Joseph et al., 2014	Environmental Quality Index	Port-au-Prince	24
Shrestha et al., 2016	Index of multiple environmental burdens and benefits, and the index of social vulnerability	Dortmund	12
Carrier et al., 2016	Global environmental equity index	Montreal	11
Bellini et al., 2016	Environmental inequality index	Rio das Ostras	6
Fernández & Wu, 2018	Environmental Improvement Priority Index	Santiago de Chile	5
Portelli et al., 2020	Environmental Justice Index	Malta	8

quality. Additionally, proxy indicators have been utilized, including proximity to industrial areas (Portelli et al., 2020) and waste disposal (Bellini et al., 2016).

Exposure to environmental risks has been included in several indices, particularly focusing on meteorological and climatic risks, including urban heat risk (Carrier et al., 2016; Fernández & Wu., 2018), flood risk and coastal surge (Joseph et al., 2014), and technological risks (Sadd et al., 2011). Similarly, Sadd et al. (2011) and Portelli et al. (2020) have considered health risks associated with environmental conditions.

The availability of green spaces is one of the most frequently used variables in the indices developed by Joseph et al. (2014), Shrestha et al. (2016), Bellini et al. (2016), Fernández & Wu (2018), and Portelli et al. (2020). The concept of urban liveability has been examined through both negative aspects, such as the presence of slums (Joseph et al., 2014) and proximity to degraded sites, as well as positive aspects, including access to parks (Carrier et al., 2016), the safety of drinking water, and the condition of sanitation facilities (Bellini et al., 2016).

Socioeconomic status is among the most frequently used variables related to the social determinants of environmental inequality, appearing in several studies (Carrier et al., 2016; Shrestha et al., 2016; Fernandez & Wu, 2018; Portelli, 2020). Related indicators, such as unemployment status (Portelli, 2020) and housing value (Sadd et al., 2011), have also been considered. Some authors include variables associated with social vulnerability, including age (Sadd et al., 2011; Carrier et al., 2016; Shrestha et al., 2016), ethno-racial origin (Sadd et al., 2011), minority background (Carrier et al., 2016), and educational level (Sadd et al., 2011; Bellini et al., 2016; Portelli, 2020).

Integrating environmental variables, social determinants of environmental justice, and aggregating indices differ across studies. Some authors construct a specific index for each variable and then integrate them into environmental justice indices to identify hotspots (Shrestha et al., 2016; Fernández & Wu, 2018; Portelli, 2020). Others treat social determinants as independent variables and assess their correlation with environmental variables (Carrier et al., 2016).

However, no consensus exists on selecting variables and indicators or the weighting assigned to each when constructing composite indices. This is further evidenced by the findings of a recent scoping review (Camacho Lorenzo et al., 2024), which provides a comprehensive overview of how these issues have been addressed in the literature and highlights key limitations in current methodological approaches. The research revealed a strong predominance of environmental equity studies conducted in North America and Europe, with limited attention given to Ibero-American cities. These studies focused primarily on negative

environmental factors—most notably pollution, especially air pollution—and highlighted socioeconomic status as a key explanatory variable for environmental inequities. They also demonstrated significant heterogeneity in the selection and classification of indicators and a lack of consensus regarding each variable's weight or relative importance. Thus, we identify two main research gaps. Firstly, there is conceptual-methodological fragmentation in measuring urban environmental equity, as the studies reviewed employ multiple indicators, often selected or designed from a Global North perspective. Secondly, a geographical imbalance exists, with cities in Latin America and the Iberian Peninsula significantly underrepresented in the research. This last point was also highlighted by the review conducted by Fernández et al. (2023), specifically for Latin America. The authors found that the study of environmental inequalities is an emerging topic in the region that has gained relevance over the past two decades. However, to date, more than half of the countries in the region have not been analyzed.

The underlying research problem guiding our study is how socio-environmental equity in Ibero-American cities can be effectively measured using a weighted set of contextually relevant indicators. This general problem is further developed through the following specific inquiries: What is the current state of environmental equity in Ibero-American cities? Which variables and indicators are most appropriate for this assessment? What weight should be assigned to each of them, and what are the most significant social determinants that explain it?

The research is theoretically grounded in the distributive dimension of environmental justice, which focuses on the spatial and social distribution of environmental goods and burdens. It acknowledges the need for methodological innovation tailored to the specific socio-spatial configurations of Ibero-American cities.

Therefore, our study aims to develop a more coherent and context-sensitive framework for measuring environmental equity in urban settings. It offers a practical diagnostic tool to support urban policy and planning efforts to advance environmental justice in the region.

Methods

We surveyed knowledgeable informants and employed a criterion weighting technique to achieve the stated objective. The decision to survey knowledgeable informants was based on the assumption that these individuals possess relevant information for contextualising phenomena within their specialisation (Batthyány & Cabrera, 2011). Whereas criterion weighting is one of the fundamental steps in multicriteria evaluation models (Yajure Ramírez, 2016). It is

commonly used to address complex issues by evaluating all variables involved according to their relative importance (Boggia et al., 2018).

Survey of Knowledgeable Informants

The survey consisted of three sections: the first included informed consent procedures and participant profiles; the second contained four questions in which participants rated the importance of each environmental variable (Fig. 1) across four categories: unimportant, limited importance, medium importance, and high importance; and the third section assessed the participants' perceptions of environmental equity in their respective cities. Altogether, we asked nine closed-ended questions to understand the participants' profiles, their opinions on environmental equity indicators and social determinants, recommendations for indicator selection, obstacles identified during data collection, and their experiences in research and key findings. Furthermore, two open-ended questions allowed participants to suggest additional types of indicators and share their experiences regarding data availability for those indicators. Experts were asked to identify which of the eight types of environmental inequity were present in their city and which of the eight population groups were most affected. The variables in the list were selected from a previous scoping review (Camacho Lorenzo et al., 2024). We conducted this online survey in three languages (English, Spanish, and Portuguese).

The survey was sent out in May and June 2023 to 171 recipients, identified according to three criteria:

1. We conducted a literature review from January 2011 to June 2022, consulting three scientific databases (Scopus, Web of Science, and Scielo) to identify research on

urban environmental equity in cities in Latin America and the Iberian Peninsula. We identified 55 researchers involved in these studies.

2. To complement the regional approach, we selected cities with populations over 100,000 within the geographic area and identified 53 professionals and policymakers from public administrative bodies based on their roles in municipal administration in fields related to urban environmental equity, including territorial planning and management, the environment, and social development.
3. Applying the same criteria as in point 2, we selected 63 academics from leading universities in Latin America and the Iberian Peninsula, specializing in fields related to urban environmental equity, including territorial planning and management, geography, environmental studies, and social development.

The experts evaluated each environmental equality variable and determinant used in the study (Fig. 1) on a scale of 0 to 3 (where 0 was 'not important' and 3 was 'very important'). Subsequently, each respondent's scores for every variable were aggregated to establish a cumulative rating, which was then used to rank the variables from the most to the least valued.

Criterion Weighting

Criterion weighting is a technique that assigns weights to different variables in complex analyses. Obtaining these weights through mathematical formulas is more reliable than assigning weights directly to the criteria or variables involved (Roszkowska, 2013). We used a ranking-based weighting technique that converted an ordinal hierarchy of specific criteria into numerical weights. Among these

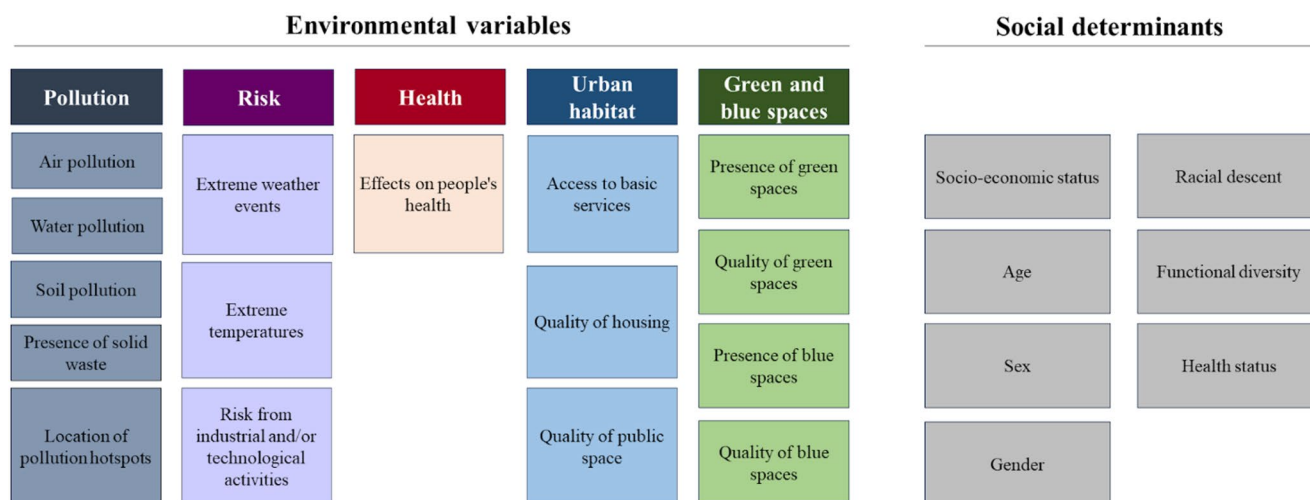


Fig. 1 Environmental variables assessed in the survey by area. Source: the authors.

methods are equal weight (EW), rank sum weight (RS), rank exponent weight (RE), inverse or reciprocal weights (RR), and the rank-order centroid weight method (ROC) (Roszkowska, 2013).

According to Roszkowska (2013), ROC weights have a stronger theoretical foundation and are more accurate in selection than other options. This type of weighting is based on identifying the centroid of all possible weights to estimate the weight of the variable using the following mathematical expression (Yajure Ramírez, 2016):

$$W_j = \frac{1}{n} \cdot \sum_{k=j}^n \frac{1}{r_k}$$

Where,

- W_j is the weight of the variable
- n is the total number of variables considered
- r_k is the position according to the established hierarchical order.

Results

The responses were collected and analyzed, yielding 41 participants, of whom eight belonged to informant group one and 33 to group two. They self-identified as follows: 28 as professors or researchers, nine as directors, coordinators, or managers, two as specialists, and two did not specify any of these categories.

Expert opinions were obtained from 20 Ibero-American cities in their respective work areas. The cities with the highest participation were Bogotá and Buenos Aires, each yielding six responses, followed by Lima, Madrid, and Montevideo, each providing four responses. Brasília and Santiago de Chile also contributed two responses each. For the remaining cities, the opinion of one informant per city was gathered (Fig. 2).

Socio-Environmental Equity in Cities

The results indicate that most experts (40 out of 41 respondents) identified environmental inequities in their study cities. Only one participant from Madrid stated that they did not find such inequities.

Furthermore, more than half of the respondents (60%) reported the presence of inequities in access to basic services such as clean water, electricity, or sanitation (Fig. 3a).

Groups Most Affected by Socio-Environmental Inequity

Regarding the opinion on which groups are most affected, it is important to highlight that while impacts were identified for all consulted groups, the percentages vary among them. On one hand, nearly all experts identified individuals from lower socioeconomic strata as disadvantaged, giving this group a central role in explaining inequities. On the other hand, 65% of respondents identified older individuals as affected groups; approximately half of the experts recognized harm to children and adolescents (53%) and people with disabilities (50%). Furthermore, 43% pointed out impacts on racialized individuals, and to a lesser extent, on women (38%) and the LGBTQ+ community (20%) (Fig. 4a). However, experts noted differences in the affected groups between cities in Latin America and the Iberian Peninsula. In Latin America, 41% of experts consider women to be affected (Fig. 4c), while in the Iberian Peninsula, only 17% share this view (Fig. 4b). Conversely, in the Iberian Peninsula, most experts identify racialized populations as affected; in comparison, this figure is lower in Latin America (Fig. 4b and c).

Assessment of Socio-Environmental Equity Variables

Figure 5 presents the experts' assessment based on the 16 variables proposed by the research team and derived from previous literature reviews. While the experts typically assign high and medium ratings to all variables, the percentages differ for each one.

Both water and air pollution are primarily recognized as significant issues in urban areas. On one hand, 80% of experts agreed that water quality is essential, and none deemed it unimportant. On the other hand, 71% rated the study of air quality as very high, with only 2% considering it low or unimportant. With lower but still substantial percentages, we note the localization of pollution sources and the presence of waste, which were rated very important by 61% and 59% of the experts, respectively. Furthermore, none of them considered the presence of waste to be unimportant. Soil pollution is viewed as the least significant in this context, deemed very important by 54% of respondents and of low importance by 10% of them.

Similarly, all experts concur on assigning a degree of relevance (low, medium, or high) to the variables of extreme weather events and extreme temperatures. 68% of the experts consider extreme weather events to be very important, while only 2% regard them as unimportant. Extreme temperatures, along with the risks associated with technological or industrial activities, receive similar evaluations.

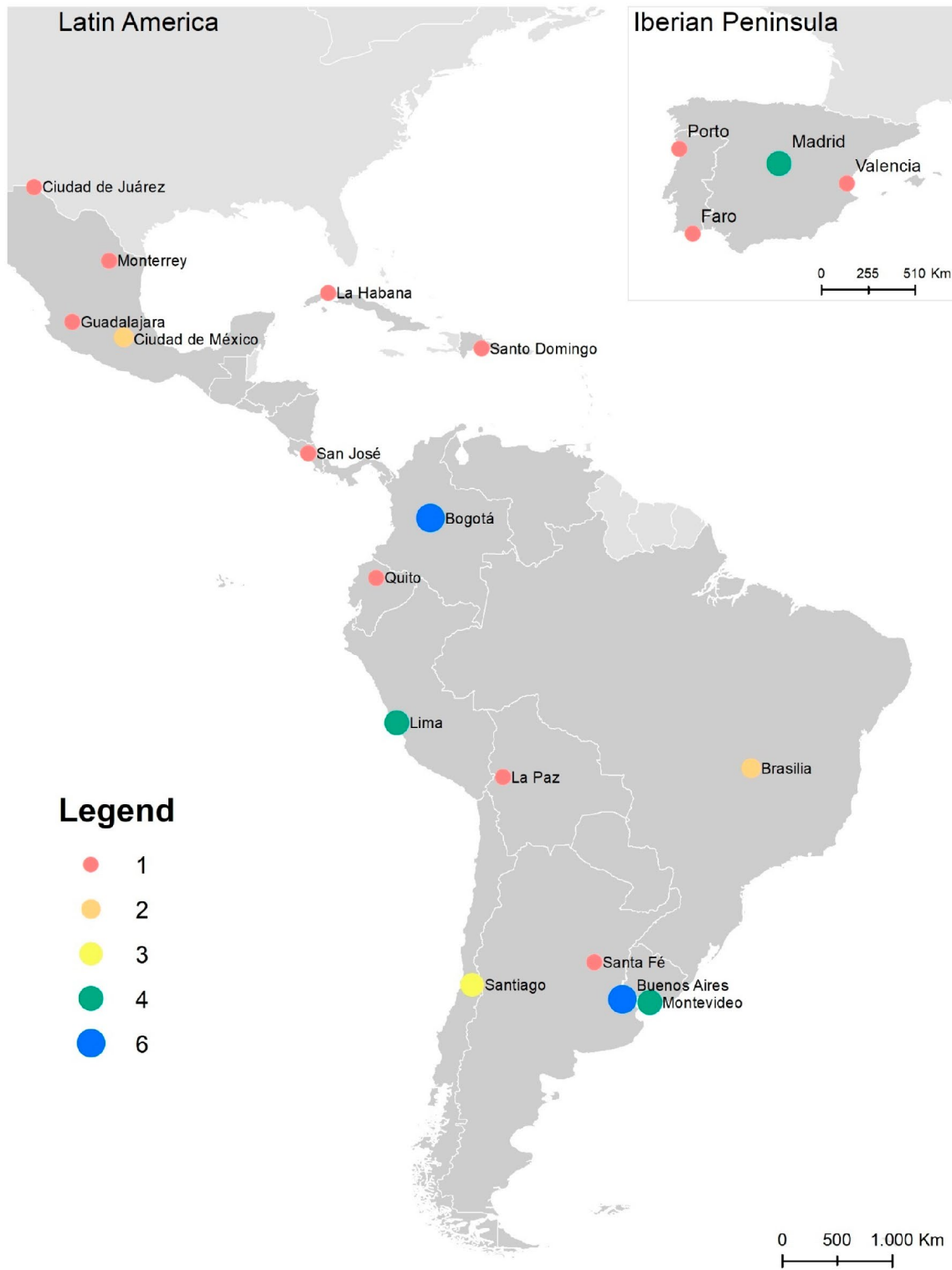


Fig. 2 Number of experts per city, participating in the survey by city. Source: the authors.

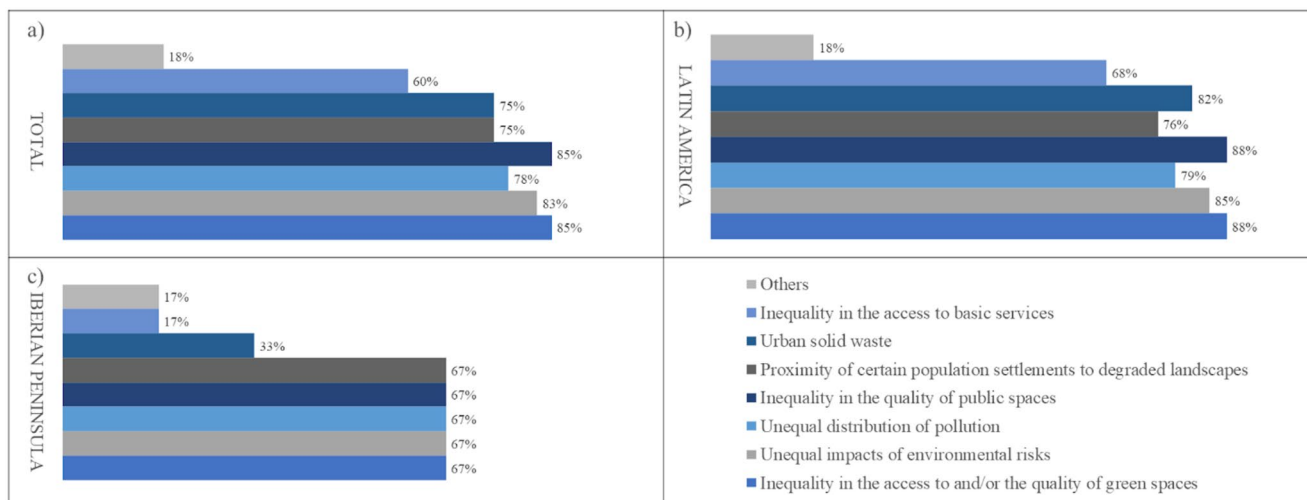


Fig. 3 a) Percentage of experts by type of detected inequities in all cities; b) Percentage of experts by type of detected inequities in Latin American cities; c) Percentage of experts by type of detected inequities in Iberian Peninsula cities. Source: the authors.

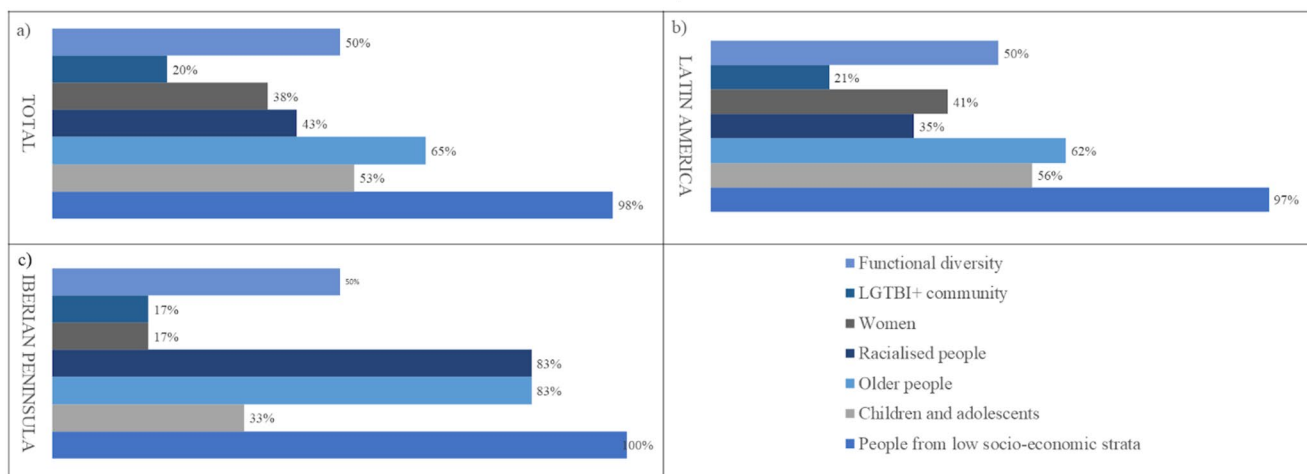


Fig. 4 a) Percentage of experts by type of affected group by detected environmental inequities in all cities analysed; b) Percentage of experts by type of affected group by detected environmental inequities in Latin American cities; c) Percentage of experts by type of affected group by detected environmental inequities in Iberian Peninsula cities. Source: the authors.

They are seen as very important by 49% and 51%, respectively, and as low importance by 15% and 12%, respectively. However, as previously mentioned, no expert has deemed extreme temperatures unimportant.

The group of variables within the habitat category—access to basic services, housing quality, and quality of public spaces—stands out, as all experts agree on assigning some importance to them. Notably, the variable access to basic services is the only one unanimously rated as medium importance (12%) or high importance (88%) and is deemed crucial for measuring inequities.

Disparate estimates are noted regarding the dimensions of green and blue spaces within the variable group. While

the quality and presence of green spaces are generally valued as very important by experts (68% and 73%, respectively), these levels decline for the quality and presence of blue spaces, being regarded as very important by 51% and 37% of experts, respectively.

In addition to the variables considered in the questionnaire, experts recommended including other variables or indicators. For example, four surveys emphasized the importance of considering noise pollution, while others mentioned additional aspects such as light pollution or radiation exposure. Furthermore, three of the respondents highlighted the relevance of indicators related to citizen participation, such as the public’s perception and assessment of

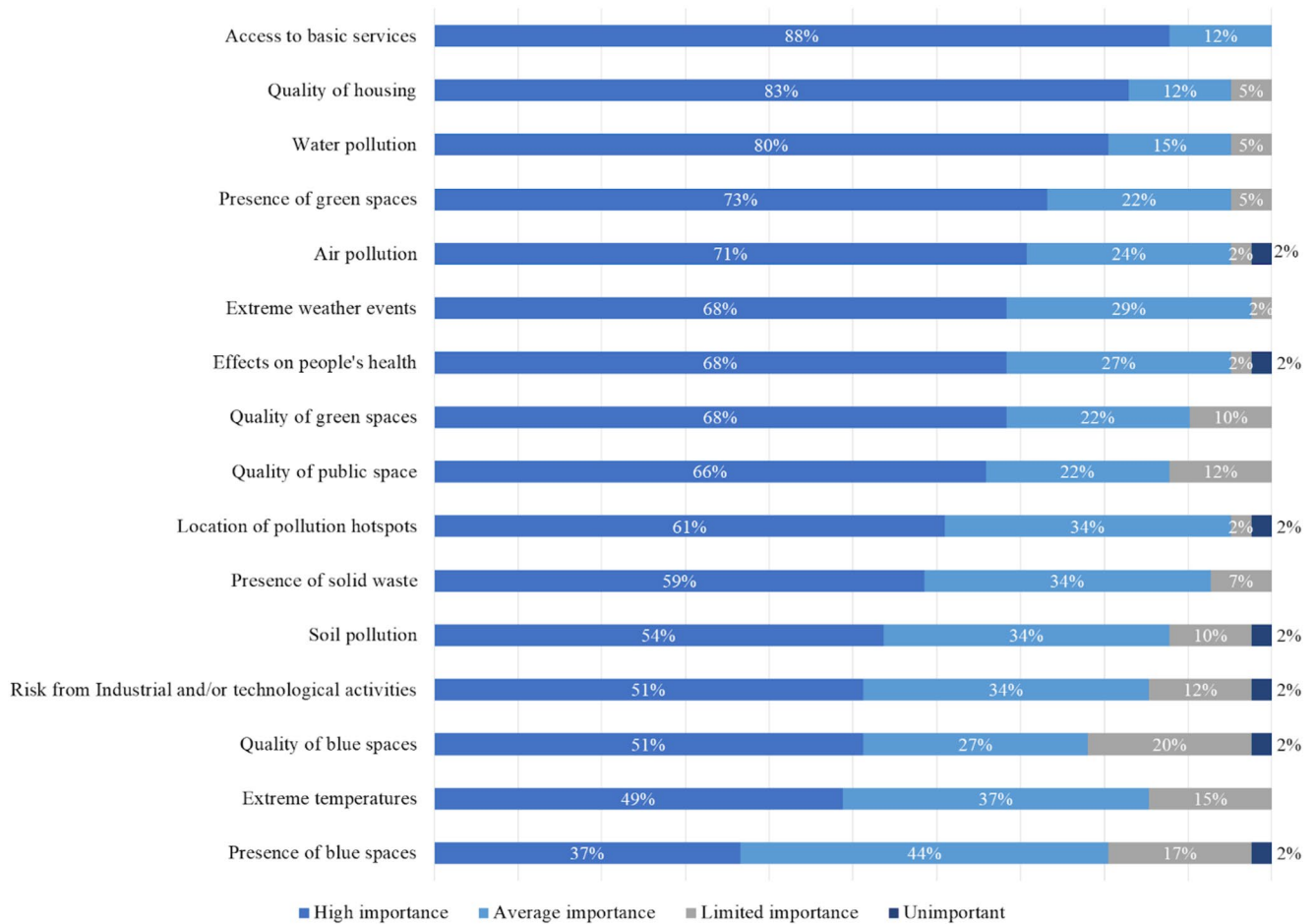


Fig. 5 Percentage of experts based on their assessment of the socio-environmental equity variables surveyed. Source: the authors.

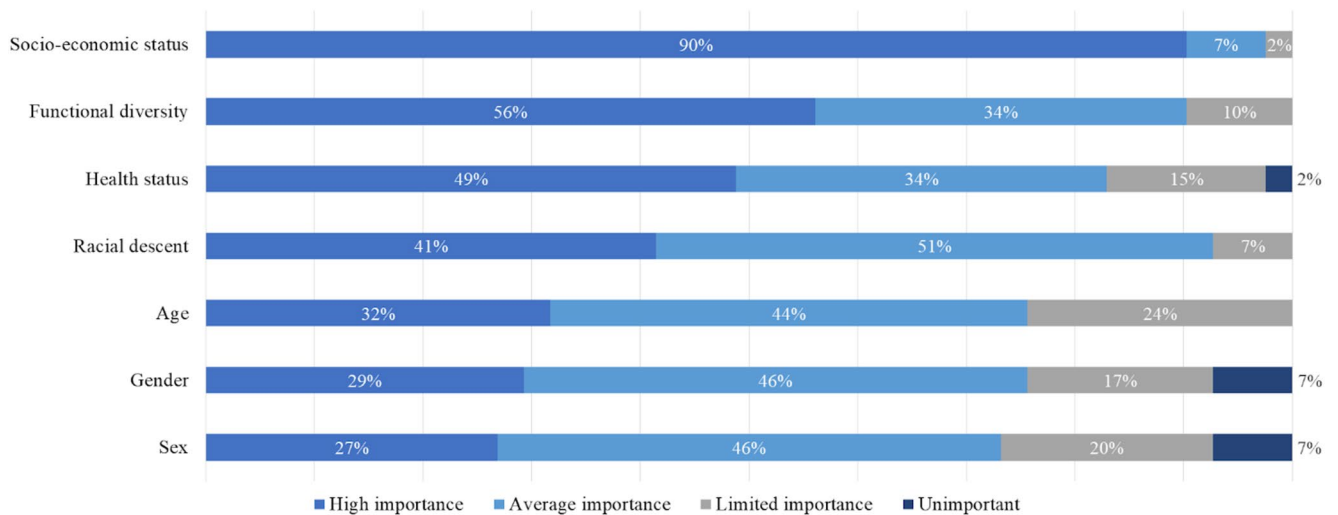


Fig. 6 Percentage of experts based on their assessment of the social determinants of environmental equity. Source: the authors.

environmental quality, the level of community involvement, and the integration of groups. Broader indicators, such as the quality of public institutions, were also mentioned. Other emerged aspects included indicators related to protecting natural and heritage areas and safeguarding indigenous communities. Finally, safety and economic indicators were proposed, including the costs associated with housing change mitigation strategies.

The Social Determinants of Socio-Environmental Equity

Experts hold various opinions regarding the social variables identified as determinants of socio-environmental equity. Socioeconomic status emerges as the most significant factor, with 90% of participants rating it as highly important, 7% as moderately important, 2% as minimally important, and none considering it unimportant. Other variables, such as health status and functional diversity, were also recognized as significant, albeit to a lesser degree, and received similar ratings. Approximately half of the experts (49% and 56%, respectively) rated these as highly important, 34% as moderately important, and 15% and 10% as minimally important. Notably, no experts deemed functional diversity unimportant, while only 2% considered health status unimportant.

On the other hand, ethnic-racial background and age were primarily rated as medium importance (51% and 44%, respectively), though no expert considered them unimportant. Gender and sex were generally assigned lower significance. Approximately half of the respondents (46%) regarded them as medium relevance, while a small percentage (7%) found them unimportant. Only 29% and 27% of the experts believed these variables were significant.

Limitations in the Application of Socio-Environmental Equity Indicators

A total of 21 respondents reported omitting certain variables or indicators in their studies due to insufficient information. However, they often cited variables associated with negative environmental factors, such as pollution, noise exposure, and health effects. Regarding pollution, the respondents noted difficulties accessing data related to air, soil, and water pollution. Furthermore, several experts commented on inconsistent records and the absence of data on specific pollutants like benzene or radon in indoor environments. In the case of noise pollution, participants expressed challenges in obtaining both general data and specific information on noise sources. Four participants reported difficulties acquiring data on health impacts in general terms and concerning specific damages.

Also absent from reports were indicators related to positive environmental factors, such as biodiversity in urban areas (e.g., phytoremediation plants or the presence of trees), accessibility to green spaces, the percentage of vegetative cover, access to shaded areas, the proportion of impermeable surfaces, and the quality and accessibility of blue spaces. To a lesser extent, experts excluded indicators concerning housing quality; some pertained to the internal comfort of households, such as access to air conditioning or building characteristics, while others focused on external conditions like sewage disposal, drainage features, sewer systems, or recycling services.

Lastly, indicators related to citizen participation and perceptions of specific risks or impacts were noted as another category of unavailable data.

Proposal of Socio-Environmental Equity Variables and Weighting

Based on the variable assessment, we determined that the variables associated with the blue spaces should be excluded from the initial 16. This exclusion is justified by their low importance in expert assessments and inconsistent application. Cities lacking sea, river, or lake in their geographical surroundings will have a lower environmental equity value than those with these features. Thus, a hierarchy was established, considering 14 variables grouped into the five proposed categories (Fig. 1).

Table 2 presents the weighting results by considering (1) the overall expert assessment (the sum of individual assessments), (2) the hierarchical ranking of variables based on their assessments, and (3) the relative weight assigned to each using the ROC weighting method. Consequently, the potential value score for a variable is 123 points, calculated from the highest rating (three points) multiplied by the number of participants (41). The resulting percentages range from 23.2% for access to basic services (potable water, electricity, and sanitation) to 0.5% for extreme temperatures. Although this variable received the same assessment as industrial and/or technological activity risk, it ranked last due to receiving fewer 'high importance' ratings.

Finally, a list of indicators (Table 3) facilitates the operationalization of the variables.

Regarding the social determinants used to establish correlations with environmental variables and detect environmental inequities, we developed a hierarchy of importance based on ratings assigned by experts (Table 4). The primary factor to consider is the socioeconomic level of the population, which is complex to operationalize through indicators and has been extensively researched in the social sciences (Sen, 1998; Stiglitz et al., 2008). This factor can be approached from various perspectives, including individual

Table 2 Overall expert assessment of the analysed variables, established ranking and weighting according to the ROC method.

Source: the authors

Variable	Assessment	Ranking	Weighting
Access to basic services	118	1	23,2%
Housing quality	114	2	16,1%
Water pollution	113	3	12,5%
Presence of green spaces	110	4	10,1%
Extreme weather events	109	5	8,3%
Atmospheric pollution	108	6	6,9%
Health impacts on people	107	7	5,7%
Quality of green spaces	106	8	4,7%
Localisation of pollutant sources	104	9	3,8%
Quality of public space	104	10	3,0%
Presence of solid waste	103	11	2,3%
Soil pollution	98	12	1,7%
Risk arising from industrial and/or technological activity	96	13	1,1%
Extreme temperatures	96	14	0,5%

attributes such as education, material living conditions, income, and housing conditions. In the field of environmental justice, measuring attributes such as educational level (Barzyk et al., 2011; Branis & Linhartova, 2012; Sánchez et al., 2014) and particularly material conditions has been a primary focus. Direct indicators like individual and household income (Chakraborty, 2020; Tonne et al., 2018; Verbeek, 2019), the percentage of people living below the poverty line (Su et al., 2012), or per capita GDP (Zhang et al., 2016), among others, have been utilized. Composite indicators such as the Index of Multiple Deprivation (Morrison et al., 2014) or the integration of multiple indicators like education level, the Human Development Index, and housing sales and rental prices have also been applied.

Discussion

As mentioned, research on justice, equity, and inequality in environmental matters plays a central role in urban management policies (Mayorga & Vásquez, 2017). Our research reinforces this statement, as the widespread confirmation of inequities by experts in their respective cities not only supports the idea that environmental risks and benefits are distributed unevenly in urban areas and affect populations differently but also underscores the importance of this issue for Ibero-American cities.

In this context, it is important to emphasise that the consulted experts identified inequities in all the areas analysed. Inequalities related to access, the quality of green and public spaces, and the impacts of environmental threats were the most identified. Likewise, significant concerns were also observed regarding environmental pollution, the presence of solid waste, and proximity to degraded landscapes. Most of these perceptions align with the issues documented in the

available scientific literature in the region (Fernández et al., 2023; Mayorga & Vásquez, 2017). However, these same studies do not reference urban solid waste.

Similarly, while impacts on different groups were identified, consistent with the literature on Latin American and European cities, individuals from lower socioeconomic strata are the most affected by socio-environmental inequities in these cities. This finding emphasizes the need for specific policies to address socioeconomic disparities in access to a healthy urban environment.

Regarding the analyzed variables, it is important to highlight several issues arising from this topic's complexity. It encompasses various areas of study and presents both conceptual and methodological challenges.

Our study presents 14 variables that address phenomena related to the physical environment, human health, and social dynamics. Each variable operates at different spatial and temporal scales, requiring the integration of various methods and data sources. While focusing on individual variables is valid, it is essential to advance toward approaches that address the cumulative impacts on populations. Despite being underexplored (Sadd et al., 2011), this area offers a more comprehensive understanding of environmental effects on the population. Our work contributes to identifying a common framework for studying environmental justice in cities; however, implementing cumulative impact analyses remains challenging for researchers and communities alike (Barzyk et al., 2011). Furthermore, it establishes cross-city comparisons and defines the most effective variables for explaining urban inequities. However, assessments and weights may vary since Ibero-America is a vast and highly diverse region. Therefore, applying this framework requires acknowledging data diversity and conducting context-specific analyses, which may entail

Table 3 Suggested indicators for operationalizing variables by area and type.

Source: the authors.

Area	Variable	Indicators
Environmental pollution	Air pollution	Annual average concentration of NO ₂ (µg/m ³) (Shrestha et al., 2016; Verbeek, 2019; Zhang et al., 2016), Annual average concentration of ozone (Romero-Lankao et al., 2013), Annual average concentration of PM 2.5 (µg/m ³) (Cushing et al., 2015; Cardenas et al., 2020; Petroni et al., 2021), Annual average concentration of PM10 (µg/m ³) (Morrison et al., 2014; Romero-Lankao et al., 2013; Shrestha et al., 2016; Zhang et al., 2016), Annual average concentration of SO ₂ (Branis & Linhartova, 2012; Zhang et al., 2016), Percentage of the area with an annual average NO ₂ concentration greater than or equal to 30 µg/m ³ relative to the total neighbourhood area, Percentage of the area with an annual average PM10 concentration greater than or equal to 25 µg/m ³ relative to the total neighbourhood area (Flacke et al., 2016)
Environmental pollution	Water pollution	Costal pollution (Joseph et al., 2014), Number of pollutants in water bodies (Cushing et al., 2015), Proximity to toxic releases in water bodies (Petroni et al., 2021).
Environmental pollution	Soil pollution	Soil metal index (Morrison et al., 2014), Lead exposure potential (Greenberg, 2021), Peak Ozone (ppb) (Grineski et al., 2012)
Environmental pollution	Presence of solid waste	Waste disposal index (Bellini et al., 2016), Hazardous waste disposal sites (Sadd et al., 2011), Permitted hazardous waste facilities and generators, weighted by waste type and volume (Petroni et al., 2021), Solid waste facilities, operations, and disposal sites, weighted by site type and state (Cushing et al., 2015)
Environmental pollution	Localisation of pollution sources	Number of points releasing pollutants per km ² (Pineda-Pinto et al., 2021), Traffic proximity and density (e.g., annual average vehicle count on major roads within 500 m of the block centroid divided by distance in metres) (Chakraborty, 2020; Cushing et al., 2015)
Environmental risks	Extreme weather events	Households with past storm or flood experiences indicate their high exposure (Hamidi et al., 2020), Risk index due to extreme weather events (Cardona et al., 2020)
Environmental risks	Extreme temperatures	Heat vulnerability index (Petroni et al., 2021), Measuring temperature during heat/cold waves in summer/winter (Carrier et al., 2016), Physiological Equivalent Temperature (PET) (Hoelzl et al., 2021), Land Surface Temperature (Fernandez & Wu, 2018)
Environmental risks	Risk from industrial and/or technological activities	Proximity to designated hazardous sites (Refineries, nuclear power plants, chemical factories, airports, power plants, and electrical substations, etc.). (Sadd et al., 2011)
Health	Effects on people's health	Estimated cancer risk based on modelled concentrations of air pollutants (Sadd et al., 2011), Toxic risk to respiratory health (Petroni et al., 2021; Sadd et al., 2011), Prevalence of respiratory diseases (Morrison et al., 2014), Cardiovascular mortality (Romero-Lankao et al., 2013)
Urban habitat	Access to basic services	Lack of piped water in the home (Rufat & Marcinićzak, 2020), Proportion of households with electricity as the main lighting source (Mitchell et al., 2021)
Urban habitat	Housing quality	Quality of structures/buildings. (Lejeune & Teller, 2016), Average commercial value per square metre for residential use (Cárdenas et al., 2020), Percentage of households with more than 7 members (Romero-Lankao et al., 2013)
Urban habitat	Quality of the public space	Proportion of the area designated to public use, public space per inhabitant (Cárdenas et al., 2020), Urban facilities (Sadd et al., 2011)
Green spaces	Presence of green spaces	Normalised Difference Vegetation Index (NDVI) (Bellini et al., 2016; Bonilla-Bedoya et al., 2020; Fernandez & Wu, 2018; Mitchell et al., 2021; Portelli et al., 2020), Proportion of green space. (Bonilla-Bedoya et al., 2020; Pineda-Pinto et al., 2021a), Access to green spaces within a 5-minute walk (Shrestha et al., 2016)
Green spaces	Quality of the green spaces	Mean size (de la Barrera et al., 2016), Path density, Tree diversity, Sport, Sitting and playground density (Kraemer & Kabisch, 2021), Safety, cleanliness, and area maintenance (Buck et al., 2019).

Table 4 Overall expert assessment and ranking of the analysed conditioning variables.

Source: the authors.

Variables	Assessment	Ranking
Socioeconomic level	112	1
Functional diversity	79	2
State of Health	72	3
Ethnic-racial heritage	60	4
Age	55	5
Gender	49	6
Sex	45	7

modifying weights or including new variables based on local conditions.

Considering the indicators proposed by experts, it is important to emphasize that, as several authors (Cook & Swyngedouw, 2012; Coolsaet, 2020; Menton et al., 2020) have shown, environmental justice encompasses at least four dimensions: distributive, recognition, participation and capabilities. The distributive dimension focuses on the unequal distribution of goods, benefits, and impacts. The other dimensions support this by addressing justice through the full recognition of different groups, the exercise of their rights, and their ability to participate in planning and

decision-making processes. Our work concentrates on the distributive dimension and the methodological and quantitative tools that can be employed to measure it. However, some indicators proposed by experts, such as citizens' perceptions and assessments of quality, the degree of association, and group integration, aim to address other dimensions by recognizing the existence of different communities and analyzing their active involvement in city decision-making and management processes. While this extends beyond the initial study objectives, it is important to note that, as Mayorga and Vásquez (2017) found in the Latin American context and Walker (2009) in the global context, research on environmental justice has primarily focused on the distributive dimension, often analyzing the other dimensions in isolation, with little comprehensive debate. Furthermore, some experts have suggested incorporating indicators related to the distributional dimension, such as those concerning noise pollution and light pollution. In this regard, assessing the relevance of these indicators in each specific context is crucial, as well as evaluating their significance and potential impact on study outcomes.

The results also reveal challenges in data collection, particularly regarding environmental pollution, noise exposure, and health-related data. These limitations could hinder the measurement and addressing of socio-environmental inequities while steering research toward specific topics with more readily available data. Addressing these gaps is imperative for facilitating future evidence-based research and policies that more effectively reflect the complexity of the socio-environmental equity phenomenon.

The initial motivation was not to establish a representative sample, considering that the relevance of these studies lies in detecting key informants rather than their quantity. While also acknowledging the challenges in identifying the study universe, it is nonetheless recognized that more responses would contribute to a better understanding of the problem, especially if they represent more regional cities.

Conclusions

Through expert assessment, this study has successfully identified the fundamental variables for analyzing socio-environmental equity (access to basic services, housing quality, water and atmospheric pollution, presence of green spaces, extreme weather events, and their impact on people's health) in cities across Ibero-America. It has also pinpointed additional variables that complement these, ensuring the aggregated index reflects the accumulation of inequalities in specific populations and urban areas. Socioeconomic status emerged as the most relevant social determinant for capturing population-level disparities. Simultaneously, the

operationalization of each variable through specific indicators enhances the feasibility of implementing the framework in applied contexts.

Beyond its empirical contributions, the study offers an intellectual advancement in environmental justice and equity by proposing a context-sensitive and theoretically grounded approach tailored to the specifics of Ibero-American urban contexts. Rooted in the distributive dimension of environmental justice and informed by expert judgment, this research addresses key methodological gaps in the literature, particularly the predominance of frameworks developed in the Global North. Consequently, it contributes both a practical diagnostic tool for policymakers and urban planners and a conceptual innovation for scholars seeking to advance the study of environmental equity in underrepresented regions. This dual contribution aims to support more just and sustainable urban futures within the Ibero-American region and beyond.

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Data Availability The data supporting these findings are available in the OSF repository, https://osf.io/v29a8/view_only=7c7ac932cb284b9b5bb57027b2b3028.

Declarations

Ethical Approval This study has been approved by the Research Ethics Committee on People, Society and Environment of the Universitat Rovira i Virgili (CEIPSA-2021-PR-0026). The authors have no relevant interests to disclose.

Research Data The data supporting these findings are available in the OSF repository, accessible at: https://osf.io/v29a8/?view_only=7c7ac932cb284db9b5bb57027b2b3028.

Competing Interests The authors declare no competing interests.

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