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Indicators for measuring urban environmental equity: a scoping review

Aplicación de indicadores para medir la equidad ambiental urbana: una revisión de alcance

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Abstract

Reducing urban environmental inequity is one of the main objectives in advancing towards more sustainable cities. This situation implies developing tools that allow for an integrated assessment environmental and social impacts, to reveal inequalities in the distribution of resources and environmental risks. Applying indicators by using Geographic Information Systems (GIS) and statistical tools can be a valid option for fulfilling this aim, since it allows for territorial patterns in disparities to be exposed. The aim of this work is to identify and classify the environmental equity indicators applied to date in studies that use statistical methods and GIS for processing and analysing them. Thus, a scoping review was conducted using the SALSA Framework and PRISMA extension for scoping reviews protocol based on the Scopus, Web of Science and Scielo

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databases. A total of 31 articles were identified that fulfilled the search criteria and which were developed mainly by countries in North American and Europe. They involved 167 different indicators that demonstrate the complexity and heterogeneity in addressing this topic. Negative aspects of the environment such as pollution, and social factors such as the socioeconomic status, were the most used.

Key words: environmental justice; GIS; spatial analysis; environmental indicators.

Resumen

Reducir la inequidad ambiental urbana es uno de los objetivos principales para avanzar hacia ciudades más sostenibles. Esta situación implica desarrollar herramientas que permitan evaluar los impactos ambientales y sociales de forma integrada y así evidenciar las desigualdades en la distribución de los recursos y riesgos ambientales. La aplicación de indicadores a través del uso de Sistemas de Información Geográfica (SIG) y herramientas estadísticas puede ser una opción válida para cumplir este propósito, dado que permite mostrar los patrones territoriales en las disparidades. El objetivo de este trabajo es identificar y clasificar los indicadores de equidad ambiental aplicados hasta el momento en estudios que utilicen métodos estadísticos y SIG para su procesamiento y análisis. Así, se realizó una *scoping review* utilizando el *Framework* SALSA y el protocolo PRISMA *extension for scoping reviews* a partir de las bases de datos Scopus, Web of Science y Scielo. Se identificaron un total de 31 artículos que cumplieron los criterios de búsqueda y que fueron desarrollados en su mayoría por países de Norteamérica y Europa. Implicaron a 167 indicadores diferentes que evidencian la complejidad y heterogeneidad en el abordaje del tema. Aspectos negativos del ambiente como la contaminación, y factores sociales como el estatus socioeconómico, fueron los más utilizados.

Palabras clave: justicia ambiental; SIG; análisis espacial; indicadores ambientales.

1 Introduction

Since the beginning of the Industrial Revolution, the accelerated urbanisation process has entailed social and environmental consequences. While cities have turned in centres of growth and economic development, they have also turned into places with serious environmental problems (Wu, 2014). In the Bruntland Report by the UN (United Nations) in 1987, the focus of sustainability associated with the carrying capacity of the global system (Pérez-Rincón, 2018), has been the dominating paradigm (Machado, 2017); however, alongside this, other approaches have emerged emphasising justice, and promoting the assessment of processes that can generate inequalities inside the system (Bowen, 2002 as cited in Moreno Jiménez, 2013).

While among those who mobilise for environmental sustainability the emphasis is frequently on intergenerational equity (preserving the environment for future generations), activists for environmental justice focus their concern on how environmental damage can disproportionally affect certain populations, who are already suffering from a range of disadvantages associated with social issues like gender or racial discrimination (Gandy, 2013). Reducing urban environmental inequity is a major aim in advancing towards more sustainable cities (UN-Habitat, 2014). This means developing tools that allow an integrated assessment of social and environmental impacts and, this framework, environmental justice and, consequently, environmental equity (as defined below), have become essential concepts for assessing social disparities from an environmental perspective (Bosisio & Moreno Jimenez, 2019).

There are various perceptions of justice and environmental equity, which are related terms, but not identical. The concept of environmental equity concentrates on assessing the inequalities in the distribution of resources and environmental risks (Carrier et al., 2014; Fernández & Wu, 2018; Gandy Jr., 2013) from the perspective of social equity, whereas environmental justice goes further, and includes issues like power relations, politics and social movements (Fernández & Wu, 2018). In other words, environmental equity puts the emphasis on the distributive dimension of environmental justice, closely linked to territorial justice. Thus, it aims to ascertain whether there are situations in which certain population groups experience a disproportionate negative environmental burden, or if there is territorial segregation linked to environmental conditions that are understood to be inadequate (Bosisio & Moreno Jimenez, 2019; Cárdenas et al., 2020). The study on environmental equity or inequity plays an essential role in safeguarding environmental inequalities within the broader concept of environmental justice (Fernández & Wu, 2018).

In this respect, since the origin of the concepts of environmental justice and equity coined by social movements in the 70s (Merlinsky, 2017), several works have tried to develop tools to measure it, and it is a complex issue as it involves transverse research, is developed on multiple scales and requires genuine understanding of the interactions between human beings and the rest of nature (Fernández & Wu, 2018; Wandersee et al., 2012). Studying these interactions, the processes and dynamics of which occur in space, requires tools and methods capable of modelling spatial phenomena. In this case, both Geographic Information Systems (GIS) and statistical techniques can be a valid option since they allow for territorial patterns in inequalities to be exposed and, also, they are useful in the territory management and planning processes (Török, 2018; Qiang, 2019; as cited in Bosisio & Moreno Jiménez, 2019).

Citing some examples of the application of these tools, the contributions by Robert Bullard (1993 y 1999) were decisive, as through statistical analyses, he endeavoured to evidence the link between environmental risk and social inequality (Merlinsky, 2017). More recently, Moreno Jiménez (2013) conducted an analysis of environmental justice combining the use of a GIS and statistical techniques to measure the extent to which different population groups in Madrid are potentially exposed to air pollution. Prieto-Flores et al. (2017) analyse the relations between spatial patterns of vulnerable sociodemographic groups, atmospheric particle pollution and the mortality rate due to cardiovascular disease, also in the city of Madrid. Flacke et al. (2016) use census data and a GIS to generate health and spatial and urban equity indicators, by considering a range of environmental and social dimensions. Pineda-Pinto et al. (2021) adopt the view of environmental justice and its application to urban planning in order to devise a new methodology for mapping socio-ecological injustices in urban landscapes. Other recent studies focus on analysing the distribution of positive aspects of the environment, such as the analyses of tree cover and urban vegetation (Baró et al., 2019; Greene et al., 2018; Kolosna & Spurlock, 2019; Nesbitt, Meitner et al., 2019) or in studying the role of ecosystem services and environmental equity (Mullin et al., 2018).

Nevertheless, many of these works focus on using indicators to analyse how a certain dimension of the environment, for example, air pollution, access to parks or locating waste deposit sites, etc., affect certain populations. At the same time, there is no common theoretical-methodological framework providing a basic selection of indicators and categories, and that enables better comparison between different territories. This study focuses on compiling this framework by assessing how various the environmental dimensions are integrated. Therefore, the question guiding this research is: Which indicators do studies integrating different dimensions of the environment use to measure environmental inequity? Therefore, the aim is to identify and classify the environmental equity indicators applied to date in studies that use statistical methods and GIS for processing and analysing them.

2 Methods

For this scoping review, the SALSA Framework (Grant & Both 2009) was used as a reference, applying the following work stages: (1) Search, (2) Assessment, (3) Analysis and (4) Synthesis. Also, the systematic approach used to compile the evidence, used the PRISMA extension for scoping reviews protocol (Tricco et al., 2018).

In the search stage, the online Scopus, Web of Science and Scielo databases were used. The search was conducted by title, keywork and summary, taking into account the areas of (1) environmental equity (2) the use of indicators and (3) that they were applied to urban areas. The search parameters are detailed in Table 1.

Table 1. Search parameters

<table>
<tr><th colspan="2">Keywords[1]</th><th colspan="2">Applied filters</th></tr>
<tr><td rowspan="4">OR</td><td>Environmental justice</td><td rowspan="4">Include</td><td>Written in English, Spanish or Portuguese</td></tr>
<tr><td>Spatial justice</td><td>Published between 2011 and 2021</td></tr>
<tr><td>Environmental equity</td><td>Document types: article</td></tr>
<tr><td>Social sustainability</td><td>Subject areas: environmental sciences, geography, urban studies, social sciences, earth sciences, multidisciplinary studies and health sciences.</td></tr>
<tr><td colspan="2">AND</td><td rowspan="3">Exclude</td><td rowspan="3">Subject area: Physical-mathematical Sciences, engineering, chemistry, biochemistry, genetics, health sciences not directly related to the topic (dermatology, paediatrics, psychology, psychiatry, odontology and radiology), economy and business, veterinary sciences, mining and fishing, social work, international relations and public administration.</td></tr>
<tr><td rowspan="2">OR</td><td>City</td></tr>
<tr><td>Urban</td></tr>
</table>

[1] The same terms were used in the Scielo database, but translated into Spanish.

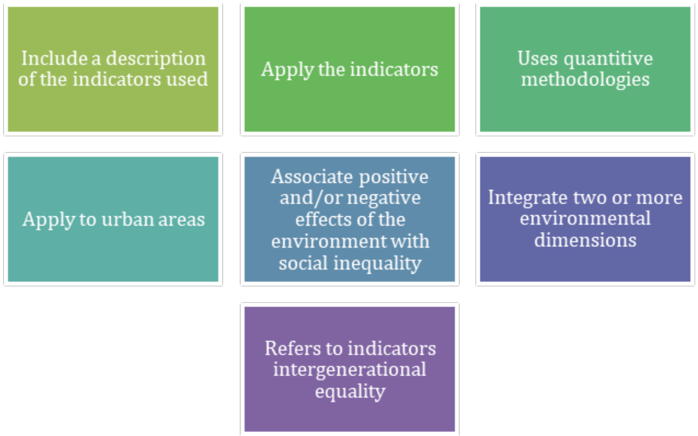
Note: The concepts of "environmental justice", "environmental equity", "spatial justice" and "social sustainability" were considered synonyms for procedural purposes, however, as mentioned, they are not homologous concepts.

Source: authors' own production

Once the searches had been conducted, inclusion and exclusion criteria were defined. The period between the year 2011 and 2021 was considered, articles written in languages known to the work team (English, Spanish and Portuguese) and areas associated with the topic. Those areas not considered part of the study subject were excluded (Table 1).

Overall, 727 results were obtained, and they were downloaded to the Mendeley reference manager to identify and delete duplicated cases. To assess the search results, a reading was made of the title and abstract of the 646 results, and the articles related to the objectives of the review were selected (Figure 1).

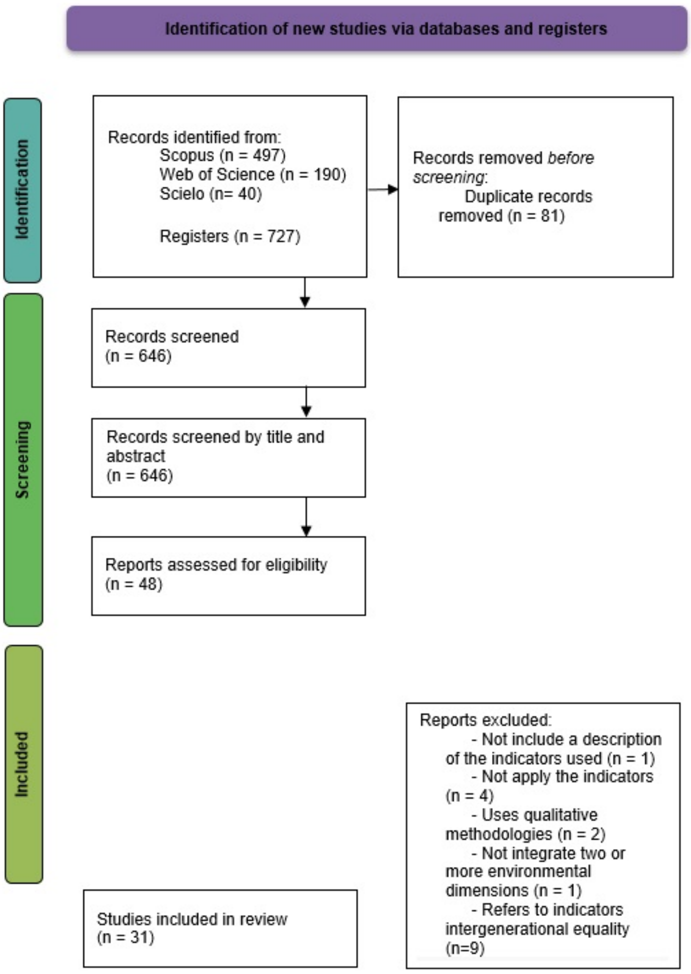
Figure 1. Elegibility criteria



Source: authors' own production

Overall, 48 registers were obtained for a complete reading, again applying the above-mentioned selection criteria (Figure 1). The end result was a total of 31 articles included in the review (Figure 2).

Figure 2. Diagram flow



Source: own production based on Page et al. (2020)

For the analysis stage, each article was assigned a code (Id) for identifying it; a complete reading was made and the relevant information was collected using Microsoft Excel software in 3 databases: (1) Metadata, (2) Methods, (3) Indicators (hereinafter known as BD1, BD2 and BD3 respectively). The first database collects information regarding the basic data on each article, such as the unique identifier, the year of publication, the title or the authors. The second, is focused on storing data on the study of environmental equity, considering the study area, the scales of analysis and the main methods and software used. Finally, the third database includes the data on each of the identified indicators (Table 2).

Table 2. Databases used to collect information

Database 1: Metadata	Database 2: Methods	Database 3: Indicators
Article ID	Article ID	Article ID
Year of publication	Country of study	Environmental Justice Factor
Authors	Study area	Variable
Title	Scale of analysis	Dimension
Journal	Software used	Indicator
Country of origin		Indicator code
Abstract		Data source

Source: authors' own production

Finally, a synthesis of the results was carried out for the purpose of organising the data obtained in the previous stage. For the third database, a priori analysis categories were defined and organized into three levels:

1. Environmental justice factor referenced.
2. Analysis variable.
3. Study dimension within the variable.

At the first level, the environmental and social factors which, in their interaction, define the concept of environmental equity (Anguelovsky, 2020) were considered. Within the environmental factors, a distinction was made between those considered to be negative (1), i.e., the environmental effects that generate or which, potentially, could damage the health of the population or the ecosystems; and the positive ones (2), locating the environmental effects that generate benefits for the population; also considered were the social factors (3) that interact with the former. For the grouping into variables and dimensions (second and third level), the variable operationalising process (Arias, 2006) was reversed, beginning with specific indicators to establish which dimensions and variables are measured via them.

Also, each category and indicator were assigned a code where synonymous indicators are considered to be unique (reclassification process for their simplification). Subsequently, a statistical analysis was carried out using the IBM SPSS Statistics 26 software.

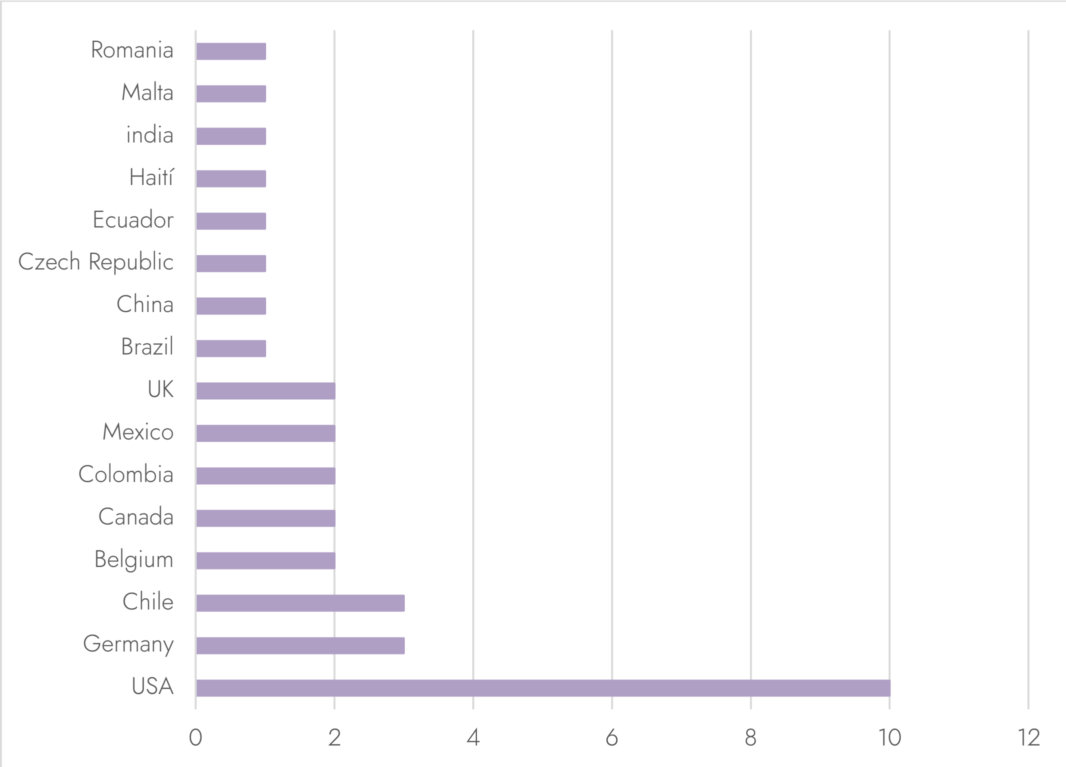
3 Results

3.1 General analysis of the studies on environmental equity

The review resulted in a total of 31 articles (Appendix 1). It is worth mentioning that 193 articles were discarded because they included a single environmental dimension in their analysis. Out of these discarded articles, 44% analysed the urban green infrastructure, 32% air pollution and 10% environmental risks. To a lesser degree, studies on solid pollution (5%), the industrial presence (5%), noise pollution (2%), water pollution (1%) and urban solid waste (0.5%) were identified.

When considering the country where the studies have been developed, it is significant that 10 of the 31 have been in USA (Barzyk et al., 2011; Sadd et al., 2011; Grineski et al., 2012; Su et al., 2012; Sanchez et al., 2013; Cushing et al., 2015; Chakraborty, 2020; Greenberg, 2021; Petroni et al., 2021; Pineda-Pinto et al., 2021). The USA is followed by Germany and Chile, with three studies (Flacke et al., 2016; Shrestha et al., 2016; Hoelzl et al., 2021; Romero-Lankao et al., 2013; Fernández & Wu, 2016, 2018) and Canada, Belgium, United Kingdom, Colombia and Mexico with two each (Romero-Lankao et al., 2013; Morrison et al., 2014; Carrier et al., 2016, 2019; Lejeune & Teller, 2016; Tonne et al., 2018; Verbeek, 2019). The rest are distributed among the Czech Republic, Malta, Romania, Brazil, Ecuador, Haiti, China and India, with one in each case (Branis & Linhartova, 2012; Grineski et al., 2012; Joseph et al., 2014; Bellini et al., 2016; Zhang et al., 2016; Bonilla-Bedoya et al., 2020; Cárdenas et al. 2020; Portelli et al. 2020; Rufat & Marcinczak, 2020; Mitchell et al., 2021).

Figure 3. Articles according to the country of the case study



Source: authors' own production

Different scales of analysis have been chosen, related to the specific characteristics of the case studies, most use some kind of census area or unit, with smaller scales such as districts, communities or towns also being used. In a minority of cases, large scales are used, with high resolution pixels (30 x 30 m) (Joseph et al., 2014; Mitchell et al., 2021) or individual or household level analysis (Lejeune & Teller, 2016; Tonne et al., 2018) (Table 3).

Table 3. Articles according to country, study area and scale of analysis.

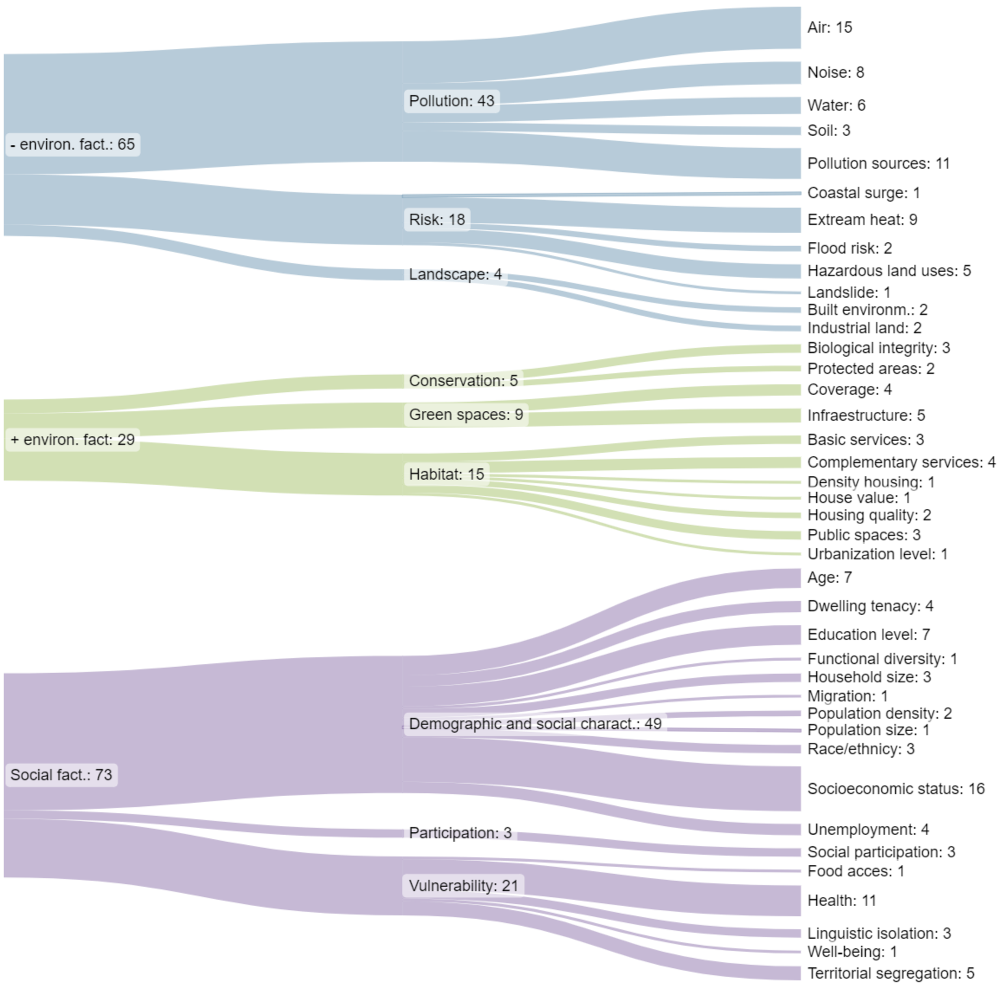
Country of study	Area and scale of study	Unit of analysis
Belgium	Region (Wallonia)	Individual
Belgium	City (Ghent)	Census block, statistical or similar
Brazil	Town (Rio das Ostras-RJ)	Census block, statistical or similar
Canada	City (Montreal)	City block
Canada	City (Montreal)	Multiscale
Chile	City (Santiago de Chile)	Multiscale
Chile	City (Santiago de Chile)	Multiscale
China	City and Municipalities (26 provincial capital cities and four municipalities)	Multiscale
Colombia	City (Medellin)	Neighbourhood
Colombia, Mexico y Chile	City (Bogotá, Ciudad de Mexico and Santiago de Chile)	Local administrative units (Municipality)
Czech Republic	Country (39 cities with more than 20 thousand inhabitants)	City
Ecuador	City (Quito)	Local administrative units (parish)
Germany	City (Dortmund)	Neighbourhood
Germany	City (Dortmund)	Pixel
Germany	City (Berlin)	Neighbourhood
Haiti	City (Puerto Príncipe)	Pixel
India	City (Delhi)	Multiscale
Malta	Country (Malta)	Locality
Romania	City (Bucharest)	Multiscale
UK	City (Glasgow)	Census block, statistical or similar
UK	City (London)	Individual
USA	City (Milwaukee, Chicago and Port Arthur)	Multiscale
USA	State (California)	Census block, statistical or similar
USA	State (California)	Census block, statistical or similar
USA	State (Michigan)	Census block, statistical or similar
USA	State (California)	Census block, statistical or similar
USA	County (Harris)	Census block, statistical or similar
USA	City (New York, Chicago, Philadelphia, Detroit, Los Angeles)	Circles with a1-mile radius
USA	City (New York)	Multiscale
USA	City (New York)	Local administrative units (community districts)
USA-Mexico	Ciudad (El Paso and Ciudad Juárez)	Census block, statistical or similar

Source: authors' own production

3.2 Analysis of the indicators

A total of 322 indicators were identified, 16 of which were discarded because they were not defined sufficiently or did not refer directly to the objectives of this review. When unifying the duplicated ones, 167 different ones remained. The studies use an average of 6 indicators, with cases including a maximum of 26 (Sadd et al., 2011) and a minimum of 3 (Carrier et al., 2019).

Figure 4. Number of indicators according to factor, variable and analysis dimension.



Source: own production based on SankeyMATIC

Negative environmental factors. In the studies revised, three main variables were identified related to the factor of negative environmental impacts: environmental pollution, environmental risks and landscape degradation (Table 4).

Table 4. Synthesis of indicators according to factor, variable, dimension

N1[1]	N2[1]	N3[1]	Description of the indicators used	Article Id[2]	No. of studies
1	Pollution	Air pollution	Pollution of particulate and gas pollution in the atmosphere and indicators of risk of associated diseases.	1-3, 5, 7, 8, 9, 10, 12-21, 24, 25, 27, 28, 30.	22
		Noise pollution	Maximum and minimum detected noise levels.	8, 14, 16, 18, 20, 21, 25, 26.	8
		Pollution sources	Presence and proximity to potential pollution sources: certain industrial activities, solid urban waste deposit sites and hazardous waste, vehicular traffic, use of pesticides, among others.	2, 10, 11, 15, 23, 27, 30, 31.	8
		Soil pollution	Presence of pollution in the soil (ozone and heavy metals).	4, 9, 27.	3
		water pollution	Presence and exposure to pollutants in extensions of water.	8, 10, 27, 30.	4
	Risk	Coastal surge	Indicators of coastal storm surge.	8.	1
		Extreme temperatures	Maximum and minimum registered temperatures, vulnerability to heat and complementary indicators of wind direction and humidity.	4, 5, 7, 12, 13, 19, 28-30.	8
		Flood risk	Frequency and exposure of homes to flooding.	4, 8, 30.	3
		Hazardous Land Uses	Indicators of land use for activities considered to be hazardous (refineries, port facilities, railways, etc.).	2.	1
		Landslide	Includes an indicator of the risk of landslides.	8.	1
	Landscape	Built environment	Indicators of built sites that deteriorate the landscape (e.g. Impoverished settlements)	8.	1
		Industrial land	Surface area and proportion of industrial areas.	1, 25, 26.	3
2	Conservation	Biological Integrity	Indices of biological integrity and biodiversity indicators.	7.	1
		Protected areas	Number and proportion of protected areas with respect to the total study area.	31.	1
	Green spaces	Green coverage	Indices of vegetation and proportion of green areas with respect to the total study area.	8, 11-14, 19, 22, 25, 26, 29, 31.	10
		Green infrastructure	Availability and accessibility to public green areas.	16, 17, 28.	3
	Habitat	Basic services	Supplies of drinking water, health and electric energy services.	11, 26, 29.	3
		Complementary services	Presence of complementary services (education centres, health centres, children's facilities, public markets, etc.).	2, 7, 8.	3
		Housing Density	Includes an indicator of housing density.	15.	1
		House value	Average house values.	2, 24.	2
		Housing quality	Indicators of quality and age of housing.	15, 26.	2
		Urbanization level	Includes an indicator of proportion of urban population.	17	1
		Public space	Presence and proportion of public spaces and public spaces per inhabitant.	2, 24.	2

Table 4. Continuation

N1[1]	N2[1]	N3[1]	Description of the indicators used	Article Id[2]	No. of studies
3	Demographic and social characteristics	Age	Distribution and proportion of the population according to age.	1, 2, 4, 6, 7, 10, 12, 16, 20, 26, 27, 29, 30.	13
		Home ownership	Proportion of households according to home ownership and the proportion of people renting.	1, 2, 6, 7, 15, 21, 23, 26, 29.	9
		Educational level	Proportion of the population according to education level reached, literacy rate and average education.	1-4, 6, 10, 11, 25, 27, 29, 30.	11
		Functional diversity	Proportion of the population that has some kind of functional diversity.	1, 23, 30.	3
		House moves	Includes an indicator of the number of home moves per inhabitant.	21.	1
		Household size	Indicators related to the size of the household and the number of single-parent households.	1, 4, 6, 7, 28, 29.	6
		Migration	Includes an indicator of the percentage of the population with a migratory background.	14, 16, 21, 28.	4
		Population density	Population density.	4, 13, 19, 23, 25, 29.	5
		Population Size	Total population.	3, 17.	2
		Race/ethnicity	Percentage of the population according to race, non-white population and minority populations.	1, 2, 5, 6, 12, 20, 27, 30.	8
		Socioeconomic status	Indicators relating to: income level, percentage of people below the poverty line, perceived economic situation, deprivation indices, people who receive state benefits, ownership of comfort elements, among others.	1-3, 5, 6, 7, 9-17, 19-21, 23, 27-30.	22
		Unemployment	Employment rate and the proportion of people unemployed	1, 3, 14, 21, 25, 30.	6
	Social participation	Social participation	Indicators that measure the participation based on the percentage of people who participate in general elections or do volunteering	2, 15, 31.	3
	Social vulnerability	Health	Proportion of premature births, infant mortality, prevalence and mortality of respiratory and cardiac diseases.	1, 2, 4, 7, 9, 10, 25, 30.	8
		Linguistic isolation	Percentage of the population with linguistic isolation and English language learning.	2, 10, 27, 30.	4
		Subjective well-being	Includes an indicator of subjective well-being.	22	1
		Territorial segregation	Specific indices to measure territorial segregation (local isolation, isolation, dissimilarity, etc.)	22, 26.	2
		Food access	Includes an indicator of the low-income population without close access to food.	30.	1

[1] According to the aforementioned methodology, the indicators are organized into 3 levels: Level 1 factor (N1), where 1 is negative environmental impacts and 2 is positive environmental impacts. Level 2 (N2) refers to the analyzed variables and Level 3 (N3) to the dimension within the variable.

[2] In Appendix 1 it is possible to consult the id of each article.

Source: authors' own production

Environmental pollution: in this variable there are 43 different indicators that refer to 5 dimensions of environmental pollution: pollutants in the atmosphere (15 indicators), the water (6), the soil (3), environmental noise (8) and pollutant hotspots (11). Within these dimensions, air pollution is the most widely-addressed, being present in 22 of the 31 studies analysed, followed by the presence of pollution hotspots or sources (8 studies) and environmental noise (8), water pollution (4) and, finally, soil pollution (3). The most widely used indicators for measuring environmental pollution are the average annual concentration of NO2 (µg/m3), which was used in 11 of the 31 studies, the concentration of PM 2.5 (µg/m3), present in 9 studies, and the proximity to hazardous waste deposit sites, used in 5 of the 31 studies analysed.

Environmental risks: in this case, 18 indicators were identified and grouped into 5 dimensions: the risk of coastal surge (1 indicator), flooding (2), landslides (1), extreme temperatures (9) and hazardous land use (5). In this case, extreme temperatures is the most widely addressed dimension, being present in 8 of the 31 studies, followed by the risk of flooding, present in 3 studies. The most used indicator is the surface temperature, which is mentioned in 3 of the 31 studies.

Landscape degradation: here, 4 indicators and two dimensions were found: the built environment (2 indicators) and industrial land (2). In this case, industrial land is considered in three of the studies, and the built environment only in one. The most widely used indicator is the proportion of industrial land.

Positive environmental factors

Regarding the environmental factors that are considered to be positive, three analysis variables were identified: the habitat, the green areas, and conservation (Table 4).

Habitat: to measure the quality of the habitat, 15 indicators were used, grouped into 8 dimensions: access to basic (3) and complementary (4) services, the density (1), value (1) and quality of housing (2), the access and quality of the public spaces (3) and the level of urbanisation (1). In this case, access to basic services is the most widely addressed dimension, being present in three studies, whereas the complementary services dimension is used in 3 studies, and the value and quality of the housing and public spaces are both studied in two articles. Both the proportion of the urban population and the density of housing are dimensions with indicators in just one article each.

In this dimension, the most used indicators are access to drinking water in the home and the average value of the home, both present in 2 studies.

Green area: regarding the green areas variable, 9 indicators and two dimensions were identified: vegetation cover (4 indicators) and green infrastructure (5). In the first case, remote detection tools are used to calculate the surface area of vegetation in the city; in the second case, the quality and accessibility to green infrastructure are measured. Most of the studies measured the surface area covered by vegetation, a dimension present in 10 out of the 31 studies, while 3 of them specifically address the accessibility and quality of green infrastructure. The most widely used indicators are the standardized difference vegetation index and the percentage of green area, both present in 4 of the studies. Accessibility indicators, such as the green areas within walking distance or the amount of public green areas per capita were also used.

Conservation: this variable was the least used for the studies integrating the positive environmental aspects. In this case, 5 indicators were found that took into account two dimensions: biological integrity (3 indicators) and protected areas (2). Each of these dimensions was considered in a single, different study, using biological integrity indices (for example, IBI or Family IBI) and indicators of the percentage of protected spaces or areas.

Social factors

To analyse social factors in these studies, three different variables are analysed: the demographic and social characteristics of the population, social vulnerability, and participation (Table 4).

Social and demographic characteristics of the population: 49 indicators were identified. Due to the complexity of analysing the demographic and social characteristics of a population, 11 dimensions were identified for integrating the indicators used. These included those focused on general characteristics such as the volume (1 indicator), density (2) of the population and households (3), and those that consider the specific characteristics of individuals, such as age (7), level of education (7), race (3), migratory background (1), functional diversity (1), unemployment (4), home ownership (4) and the socioeconomic status (16). Out of this set of dimensions, the socioeconomic status is the most widely studied, with several indicators being used to measure it (16) in 22 of the 31 studies. It is followed by age (in 13 studies) and the level of education (in 11 studies). For its part, home ownership (in 9 studies) and ethnic-racial background (present in 8) are also commonly analysed dimensions.

The most used indicators include the percentage of ageing population and the percentage of people below the poverty line (used in 8 studies), followed by the percentage of households according to home ownership (6 studies), the percentage of people under 5 years' old and the percentage of the population who have completed secondary education, all of them being used in 5 of the 31 studies.

Social vulnerability: 21 indicators were identified and measured from 5 different dimensions: access to food (1 indicator), health (11), linguistic isolation (3), subjective well-being (1) and territorial segregation (5). In this case, health is the most analysed dimension, present in 8 of the studies. Linguistic isolation is the other dimension of interest, present in 4 of the research works. Indicators such as the asthma rate (2 studies), low birth weight (2) or the proportion of premature births (2) are mainly used in relation to health. Also, indicators such as the percentage of the population with linguistic isolation and the local spatial dissimilarity index are often used, being identified in two studies each.

Social participation: the only variable that has just one dimension. It was the least addressed in the set with a total of 3 indicators identified in 3 studies. The indicators are: percentage of votes cast in general elections, participation in the voluntary sector, or the number of environmental stewardship groups.

4 Discussion

In 2011, Sadd et al. stated that the development of tools for measuring the damages cumulative impacts can generate was in its early stages. The review presents 31 investigations that, in the last decade, have made progress along these lines, by applying indicators for an integrated measurement of inequities.

Most of the studies found, in line with Ju et al. (2021) and Romero-Lankao et al. (2013), are carried out in countries in the global north. Although there is an incipient development in South America and Chinese participation with several institutions involved in the development of research, studies of this type applied to southern cases continue to be less frequent. Furthermore, the USA is the main country both in terms of the selection of the case studies and the origin of the research centres promoting them. This is not surprising considering its tradition regarding the analysis of environmental justice and equity.

Based on this review, it is obvious that there are at least 9 variables involved in the study of environmental equity. The environmental variables include negative impacts such as pollution, environmental risks, and landscape degradation, as well as positive impacts such as conservation, habitat, and green spaces. The social variables address dimensions related to population characteristics, vulnerability, and participation.

Similarly, by identifying these indicators, environmental equity is verified as a concept that originated by focusing on environmental racism (disproportionate negative environmental burden on some racialised minorities), but which later expands and incorporates other aspects (Pérez-Rincón, 2018). In this case, although the negative environmental burden, particularly pollution, continues to be the most used variable to assess environmental factors (Branis & Linhartova, 2012), positive aspects are also included, where dimensions of interest comprise the coverage of green areas and the availability of basic services. Likewise, although the population's ethnic-racial component continues to be an important dimension, other characteristics such as socioeconomic status (the most used variable) are included and used to explain inequalities. Others, such as age, level of education, or home ownership, are also used, but to a lesser extent.

Limitations of the study are identified in relation to aspects associated with the characteristics of the review and its scope. As for the characteristics, this review includes works from scientific journals included in three databases that represent standard, multidisciplinary and geographically broad sources. It includes peer-reviewed articles to guarantee the quality of the research. However, it is possible other similar studies are not included in the above-mentioned databases. Expanding the analysed databases and including technical documents could lead to including new indicators.

Regarding the scope of this work, it has been observed that the information available in the analysed articles does not contain some relevant aspects for assessing the use of environmental justice indicators. Among these deficiencies, the impossibility of identifying how the availability of data and the scale or size of the analysis units influences the selection of applied indicators, stands out.

5 Conclusions

The applied methodology was adequate to fulfil the proposed objectives. It was possible to access a significant number of studies published in recent years in order to understand how of environmental equity indicators have been used, integrating various dimensions.

The heterogeneity presented by the identified indicators demonstrates the complexity of addressing environmental inequities. The city is the most frequent analysis scale, and census units are typically used for data analysis. Indicators that measure environmental burdens such as pollution, particularly air pollution, are the most widely used. Furthermore, indicators referring to socioeconomic status are the most common when explaining environmental inequities.

The importance of this type of study should be highlighted for assessing the heterogeneity of cities and how environmentally equitable they are. The use of indicators of this type allows guiding policies and urban planning to achieve intra and intergenerational urban sustainability.

In future research, it is crucial to expand the geographic scope to more meaningfully include countries in the global south, where there are currently fewer studies. This expansion will allow for a better understanding of environmental inequities in diverse socio-economic and cultural contexts. In addition, in terms of indicators, it is recommended that progress be made in determining the relative weight of each variable for the construction of synthetic indices of environmental equity, considering that these may vary by region. Finally, although a complete set of indicators has been achieved at a general level, not all studies integrate the complexity of variables that define environmental quality, and it is therefore essential to promote research in this direction.

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Appendix 1. Articles included in the review

Id	Year	Authors	Title	Journal
1	2011	Barzyk et al., 2011	Linking socio-economic status, adverse health outcome, and environmental pollution information to develop a set of environmental justice indicators with three case study applications	*Environmental Justice*
2	2011	Sadd et al., 2011	Playing it safe: Assessing cumulative impact and social vulnerability through an environmental justice screening method in the South Coast Air Basin, California	*International Journal of Environmental Research and Public Health*
3	2012	Branis and Linhartova, 2012	Association between unemployment, income, education level, population size and air pollution in Czech cities: Evidence for environmental inequality? A national scale pilot analysis	*Health and Place*
4	2012	Grineski et al., 2012	Climate change and environmental injustice in a bi-national context	*Applied Geography*
5	2012	Su et al., 2012	Inequalities in cumulative environmental burdens among three urbanized counties in California	*Environment International*
6	2013	Sanchez et al., 2013	Development of a socio-ecological environmental justice model for watershed-based management	*Journal of Hydrology*
7	2013	Romero-Lankao et al. 2013	Exploration of health risks related to air pollution and temperature in three Latin American cities.	*Social Science & Medicine*
8	2014	Joseph et al., 2014	GIS-based assessment of urban environmental quality in Port-au-Prince, Haiti	*Habitat International*
9	2014	Morrison et al., 2014	An initial assessment of spatial relationships between respiratory cases, soil metal content, air quality and deprivation indicators in Glasgow, Scotland, UK: Relevance to the environmental justice agenda	*Environmental Geochemistry and Health*
10	2015	Cushing et al., 2015	Racial/ethnic disparities in cumulative environmental health impacts in California: Evidence from a statewide environmental justice screening tool (CalEnviroScreen 1.1)	*American Journal of Public Health*
11	2016	Bellini et al., 2016	The environmental inequality analysis in Rio das Ostras-Rj, Brazil, using AHP (analytic hierarchy process) technique	*RA'E GA - O Espaco Geografico em Analise*
12	2016	Carrier et al., 2016	Application of a Global Environmental Equity Index in Montreal: Diagnostic and Further Implications	*Annals of The American Association of Geographers*
13	2016	Fernández and Wu, 2016	Assessing environmental inequalities in the city of Santiago (Chile) with a hierarchical multiscale approach	*Applied Geography*

14	2016	Flacke et al., 2016	Mapping Environmental Inequalities Relevant for Health for Informing Urban Planning Interventions-A Case Study in the City of Dortmund, Germany	*International Journal of Environmental Research and Public Health*
15	2016	Lejeunea & Teller, 2016	Incentives and barriers to environmental inequality mobilization: A case-study analysis in Wallonia, Belgium	*Environmental Science and Policy*
16	2016	Shrestha et al., 2016	Environmental health related socio-spatial inequalities: Identifying "hotspots" of environmental burdens and social vulnerability	*International Journal of Environmental Research and Public Health*
17	2016	Zhang et al., 2016	Empirical Evidence and Determinants of Region-Based Environmental Injustice in China: Does Environmental Public Service Level Make a Difference? *	*Social Science Quarterly*
18	2017	Carrier et al., 2017	School locations and road transportation nuisances in Montreal: An environmental equity diagnosis	*Transport Policy*
19	2018	Fernández & Wu, 2018	A GIS-based framework to identify priority areas for urban environmental inequity mitigation and its application in Santiago de Chile	*Applied Geography*
20	2018	Tonne et al.,2018	Socioeconomic and ethnic inequalities in exposure to air and noise pollution in London	*Environment International*
21	2019	Verbeek, 2019	Unequal residential exposure to air pollution and noise: A geospatial environmental justice analysis for Ghent, Belgium	*SSM - Population Health*
22	2020	Bonilla-Bedoya et al., 2020	Forests and urban green areas as tools to address the challenges of sustainability in Latin American urban socio-ecological systems	*Applied Geography*
23	2020	Chakraborty, 2020	Unequal Proximity to Environmental Pollution: An Intersectional Analysis of People with Disabilities in Harris County, Texas	*Professional Geographer*
24	2020	Cárdenas et al., 2020	Territorial equity in Medellin: public space, natural hazards and air quality	*Estudios Socioterritoriales*
25	2020	Portelli et al., 2020	Developing an environmental justice index for small island states: The case of Malta	*Sustainability (Switzerland)*
26	2020	Rufat and Marcinczak, 2020	The equalising mirage? Socioeconomic segregation and environmental justice in post-socialist Bucharest	*Journal of Housing and the Built Environment*
27	2021	Greenberg, 2021	Environmental and Social Justice on the Border of Five Major U.S. Cities	*Environmental Justice*

28	2021	Hoelzl et al., 2021	Vulnerable socioeconomic groups are disproportionately exposed to multiple environmental burden in Berlin - implications— for planning	*International Journal of Urban Sustainable Development*
29	2021	Mitchell et al., 2021	Social inequities in urban heat and greenspace: analyzing climate justice in Delhi, India	*International Journal of Environmental Research and Public Health*
30	2021	Petroni et al., 2021	NYenviroScreen: An open-source data driven method for identifying potential environmental justice communities in New York State	*Environmental Science and Policy*
31	2021	Pineda-Pinto et al., 2021	Examining ecological justice within the social-ecological-technological system of New York City, USA	*Landscape and Urban Planning*

Source: authors' own production