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Papers

Sustainable Drainage Technologies Under the Sustainability Tripod Perspective

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Abstract
The management of drainage and urban rainwater management in Brazil and in the world faces numerous challenges in order to be sustainable. When dealing with sustainability, it is important to relate the aspects: of social, environmental and economic, known as the sustainability tripod. Compensatory urban drainage techniques, through infiltration or detention and increasing the evapotranspiration rate, have the potential to reduce: the amount of rainwater runoff; flow peaks; vulnerability of urban areas to flooding; contamination of water courses. It is important that, even with all these benefits, such technologies are associated with such aspects. In this context, this systematic review article (SR) was developed, which aimed to identify trends in the use of sustainable drainage technologies adopted in Brazil and in the world, relating them to aspects of sustainability. For that, a systematic review (SR) was carried out in which the following were identified: trends in the adoption of technologies for sustainable drainage in the world and in Brazil; and the terms used and related to technologies for sustainable drainage. It was also observed, both in Brazil and in the world, that the approach to the theme begins with the technological aspect involving the implementation, life cycle and maintenance of sustainable technologies and, in sequence, the environmental, economic and social aspects unfold in this order, but which are not done in an integral way. It was possible to characterize an important knowledge gap.

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INTRODUCTION

In the process of urbanization, the environment and the natural cycles are altered, generating impacts that bring forth several issues for humankind, as floods resulted from the increased surface runoff caused by the high degree of compaction and waterproofing of the surfaces and by the channeling of runoff in storm drain systems (GUERRA; CUNHA, 2022; FARIAS; MENDONÇA, 2022). Due to these environmental impacts, humankind sees the need to develop solutions that mime the natural cycles.

The urban drainage system allows rainwater to flow out until it reaches watercourses, but a more efficient look at this system is needed so that the flow does not negatively impact the downstream areas, balancing the responsibilities of system users, what is possible with sustainable drainage technologies in which flow reduction and delay are valued.

Compensatory urban drainage techniques, through infiltration or detention and the increase in the rate of evapotranspiration, have the potential to: the amount of rainwater runoff; flow peaks; vulnerability of urban areas to flooding; contamination of water courses (ALAMY FILHO *et al.*, 2016; GONÇALVES et al., 2018; FLETCHER *et al.*, 2015). Even if they allow an association with environmental, economic, and social aspects, compensatory drainage techniques are not always considered.

The United Nations (UN), in its work for the concept of sustainable development, addresses the tripod of sustainability that involves social (socially fair), environmental (environmentally correct), and economic (economically efficient) aspects, which in turn must interact in balance to define the concept. Therefore, these aspects must be considered in the context of sustainable drainage.

There is little uniformity in subjects and definitions of terms within the theme of sustainability with regard to urban drainage. Among the approaches ranging from the technical to the political scope, the growing concern to understand how to operationalize socio-technical solutions capable of guaranteeing significant levels of success based on sustainable development principles become even more relevant (ROSA *et al.*, 2019).

Billing initiatives for drainage services are shyly identified in the international scenario in Brazil, South Africa, Germany, Australia, Canada, Denmark, Equator, the United States, France, England, Poland, Wales, Sweden, and Switzerland (TASCA, 2016; TASCA et al., 2018). In Brazil, this service is funded with municipal resources and there are a minority of municipalities that use an urban drainage fee, as is the case of Santo André, Porto Alegre and Montenegro (SNIS, 2019). This lack of economic and financial autonomy negatively affects the sustainable management of drainage systems and for the discussion of this issue, it is important that sustainability aspects are considered and that technological alternatives are available for its adequate management.

(5)

Brazil faces numerous challenges in relation to basic sanitation and in particular with regard to urban drainage. Actions have been developed to update its National Basic Sanitation Policy (BRASIL, 2020) and issue related norms that consider the universalization of services, their costing in a socially fair manner, and environmental preservation and conservation. Having tools and technologies that collaborate with this is very important.

Thus, the questions are then asked: “What are the sustainable drainage technologies adopted in Brazil and in the world? Do they consider the sustainability tripod?”. In response, an analysis of trends of technological alternatives is envisaged that, based on the ideas of sustainability, considers the adoption of individual retention devices, detention, and/or infiltration that minimize the flow to public roads. Examples of these devices are wells, gutters, infiltration basins, green roofs, floors, and other permeable areas.

Given the above, this work had as a general objective to identify trends in the use of sustainable drainage technologies adopted in Brazil and in the world, relating them to sustainability tripod. Therefore, a systematic review (SR) was developed: the search strategy was defined; the data presented in the report from the Web of Science (WoS) of the validated terms were analyzed and extracted.

MATERIALS AND METHODS

Conducting this SR followed four main phases listed below and review based on the PRISMA framework (PAGE *et al.*, 2021),

(1) Definition of search strategy;
(2) Reading abstracts and extracting data;
(3) Reading complete papers and extracting data;
(4) Data interpretation.

Search strategy

The base adopted in this SR was the WoS, which has a collection of scientific documents with a relevant impact factor at the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (Coordination for the Improvement of Higher Education Personnel in English) in Brazil.

Several searches were performed with different terms that generated reports in WoS. Each report was validated in the VOSviewer system, version 1.6.13, which presented graphic records that verified a more robust relationship between the keywords and the research's question.

For the search, the maximum period provided by the WoS platform was considered, that is, from 1945 to the date of the consultation, 07/15/2020. The platform generated a report, in the form of a spreadsheet, where the abstracts were read, and data extracted that guided the complete reading of articles that were more related to the research question. The graphics generated by WoS were also evaluated regarding the location and date of the publications.

Reading abstracts and extracting data

For a structured reading of the abstracts and complete works that would allow data extraction, eleven questions were considered (Table 1).

Question 1 allowed an interpretation of the academic engagement when doing reviews on the researched theme.

Questions 2, 3, 4, and 5 moved toward the importance of dealing with sustainable solutions for urban drainage from environmental, social, and economic biases.

Table 1 - List of guiding questions for data collection.

#	Question description
1	Is it a systematic review or a literature one?
2	Is an economic-financial approach carried out?
3	Is the country where the work was done developed or developing and least developed countries?
4	Is there a social approach taken?
5	Is a qualitative approach carried out and which pollutants were surveyed?
6	Which compensatory technique is adopted?
7	Is the performance and/or lifecycle of the compensating technology evaluated?
8	Is an individual and particular perspective adopted on the lots?
9	In which tropical zone was the work developed?

Source: The authors (2023).

When the work indicated reference to fees, tariffs and costs of implementing compensatory drainage techniques, a positive answer to question 2 was indicated.

Learning about the development of countries, as proposed by question 3, made it possible to know their commitment to sustainable drainage considering their socioeconomic condition. For these records, the country where the research was developed was considered when presented in the body of the WoS report summary. When it was not possible to identify such location, the country in the researchers' address was considered.

According to question 4, the social aspect was considered when the following were identified: attention to the social conditions of those involved in sustainable drainage; assessment of availability to pay or receive for drainage services; conducting opinion polls; development of educational actions involving the research's theme.

The environmental approach, in response to question 5, considers the assessment of possible impacts of drainage systems or what their absence may have on the environment. It was possible to identify pollutants related to the characterization of urban rainwater effluent (Table 2). This characterization is important both for monitoring receiving bodies and for monitoring devices adopted in these systems.

Table 2 - Types of pollutants found

Type	Pollutants found
Organics	Hydrocarbons, oils and greases, phthalates, total petroleum hydrocarbons, phenol, bisphenol-A, alkyphenols, pyrene, phenanthrene, naphthalene, octylphene, nonylphenol, benzotriazole and pesticides.
Inorganics	zinc, copper, lead, cadmium, sodium, cobalt, nickel, calcium, chromium, iron, manganese, magnesium and potassium.
Biologicals	*Escherichia coli*, *Enterococci*, total coliforms, *Pseudomonas aeruginosa*, *Aromonas hydropila*, coliphage, ecotoxicity, *Daphnia sp*., juvenile coho salmon, zebrafish, algae biomass and chlorophyll.
Nutrients	Nitrogen and phosphorus.
Physicochemical and other compounds	Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Sediments, turbidity, color, pH, temperature, conductivity, chlorine, chlorides, magnesium oxide, nitrate, nitrite, ammonia, ammonium, ammonium nitrate, sulfuric acid, phosphoric acid, carbonic acid, potassium hydroxide, particle charge, particle distribution.

Source: The authors (2023).

For the presentation and discussion of diagnosed technologies, five groups were created (Table 3).

Individual and private initiatives are potential mechanisms for optimizing public drainage systems, so it is crucial to evaluate alternatives for retention, detention, and/or infiltration along with properties to provide urban environmental services. Therefore, questions 6, 7, and 8 were proposed.

Table 3 - Group of technologies found

Group	Technologies	Description
1	Bio-retention and vegetation systems	Technologies that rely on vegetation or derivatives of this or other natural and/or sustainable resources for the retention and treatment of rainwater were considered, namely: green roof; rain garden; infiltration ditch with vegetation; biofilters or infiltrating cells; green areas in general; other filters and bioretention systems in general
2	Permeable Surfaces	Devices used to cover surfaces that facilitate the percolation process and minimize the flow of rainwater, which are: permeable pavements, roads and parking lots
3	Infiltration and water recharge systems	Devices that facilitate the infiltration of rainwater: wells, trenches, ditches, and infiltration systems in general.
4	Flooded or humid areas	Structures that operate with a considerable depth of water that allow: temporary storage, cushioning the impact of large volumes of rainwater runoff; the treatment of this effluent; infiltration when structures that allow it are adopted; the maintenance of artificial aquatic environments imitating natural ones: pond or retention tank; retention basin; riparian plugs; retention channel or ditch; diverse wetlands.
5	Other technologies and accessories	Drainage technologies that did not fit into the groups defined above, identified accessories and other technologies not clearly identified: Rainwater Harvesting (RWH); drains and perforated pipes; geotextile blankets; Source Water Protection (SWP); not identified.
6	Terms of sustainable urban drainage management	Different terms used in different world regions to encompass a set of technologies, documents, manuals, among others in favor of this management: Low Impact Development (LID); Best Management Practices (BMP); Green Infrastructure (IG); Sponge Cities (SC); Sustainable Urban Drainage Systems (SUDS); Water Sensitive Urban Design (WSUD); Stormwater Control Measures (SCM).

Source: The authors (2023).

Question 8 enabled the survey of works that are aimed on the focus on the user of the drainage system within their property, supporting the modeling of payment and incentives for urban drainage services provided with a view to greater sustainability in urban drainage management. Questions 6 and 7 allowed an essential survey of the technological apparatus that applies to such audiences.

Even though, comprehensively, the survey of terrestrial tropical zones, answering question 9 (Arctic Polar Zone, North Temperate Zone, Tropical Zone, South Temperate Zone, and Antarctic Polar Zone), made it possible to identify climatic characteristics that guide different practices of sustainable drainage.

To characterize the knowledge gap, a flowchart was structured (Figure 1).

RESULTS AND DISCUSSION

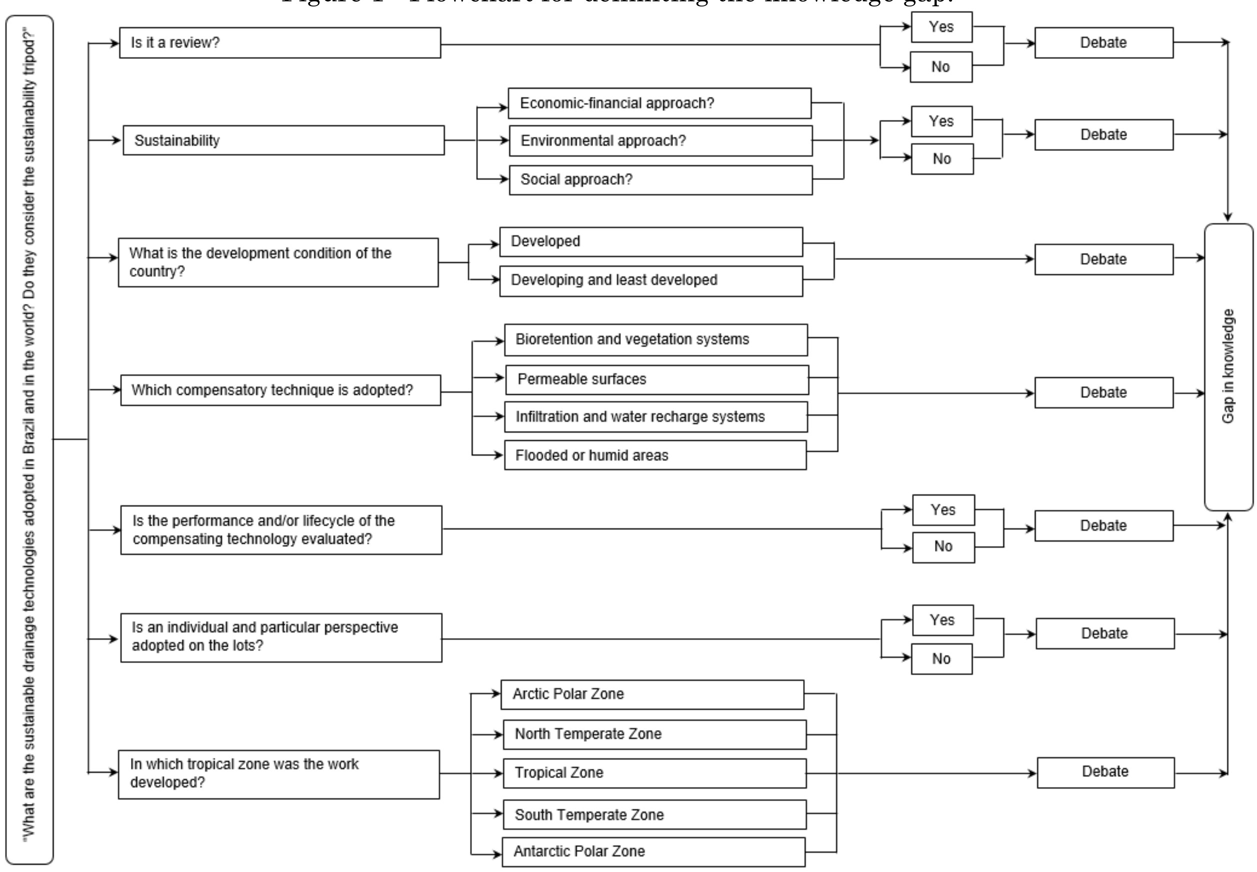
WoS data

The list obtained from WoS, on 07/15/2020, had 878 articles. When reading the abstracts, 15 articles were discarded, because they fled the theme researched, leaving 863 records eligible for data extraction.

Identification of systematic and literature reviews

The systematic or literature review works represented 3.70% of the total, which implies that engagement in review research is low compared to an analysis of sustainable drainage technologies associated with the tripod of sustainability.

Figure 1 - Flowchart for delimiting the knowledge gap.



Source: The authors (2023).

This theoretical finding is closely related to the effective adoption of these sustainable tools, because for, an effective, efficient and sustainable management of these technologies, it is necessary to master their design and maintenance.

Sustainability aspects and drainage technologies

Economic and social aspect

Were identified 22.48% of the works addressed the economic aspect. 4.12% of the works dealt with issues related to charges, fees and economic incentives in relation to drainage services. Costs and information related to the implementation and maintenance of sustainable technologies were addressed in 81.44% of the works. None of these works were carried out in Brazil. Even though the cost of implementing and maintaining sustainable drainage technologies has been significantly studied, it is observed that the economic aspect is hampered by the low engagement of works that consider charges, fees and economic incentives. This ratifies the challenging situation regarding the cost of urban drainage management through collection and drainage fees.

Among the studies analyzed, 59.58% were carried out in developed countries and 40.42% in developing and least developed countries. Among the works carried out by developing and least-developed countries, China stands out. It is engaged in researching various themes and so in the thematic focus of this work, given the development of Sponge Cities following local public policies.

Rosa *et al.* (2019) identified that the vast majority of research conducted was carried out in developed countries, which might derive from the investment capacity of these countries, as well as their concerns with alternative solutions based on the perspective of drainage, giving greater importance to environmental issues. But which, on the other hand, can characterize opportunities promising in the development of new locally appropriate technologies as well as the transfer of sustainable drainage technologies to these countries.

The social approach was identified in only 9.62% of the works, of which 3.03% were carried out in Brazil. This represents a theoretical and practical difficulty in considering social issues in the management of sustainable urban drainage. This difficulty intensifies mainly when it is proposed to deal with the implementation, maintenance and costing of sustainable technologies where there are conditions for access to drinking water by users, as in developing and less developed countries.

The conditions of land occupation, education, and income are the main factors that affected the willingness to support and pay for initiatives in favor of sustainable drainage (WANG et al., 2017). A solid assessment of the performance and cost of non-structural measures in storm drainage management can be challenging, especially for those measures that aim to change people's behavior (TAYLOR; FLETCHER, 2007).

Landowners who voluntarily adopted sustainable drainage practices were generally satisfied with their reliability and effectiveness (SHUSTER; RHEA, 2013). This motivation can be enhanced by receiving financial incentives (BROWN *et al.*, 2016). In these cases, the motivation was supported by the generalized positive perception that the practices offer personal benefit. In both studies, it was diagnosed that social conditions directly affect their engagement with the problem.

According to the data presented, even though the costs of alternatives for sustainable drainage are a much-researched topic, there is a demand for the association of these under the private and individual aspects and attention is paid to the less favored classes and the need for funding is not forgotten. Management of urban drainage through fees and economic incentives.

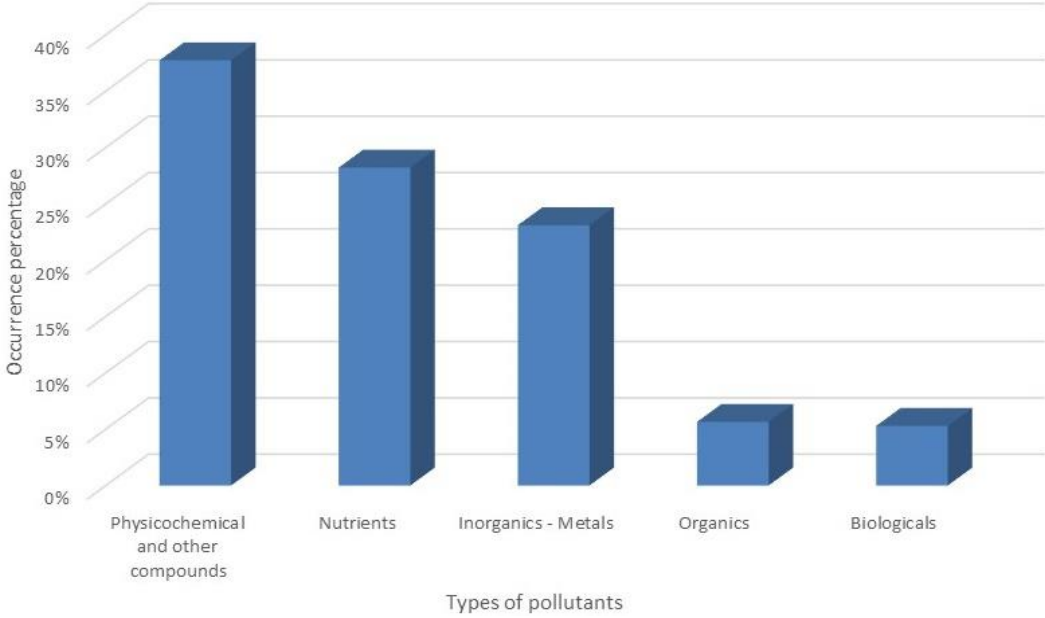
Environmental aspect

The environmental approach was adopted in 32.79% of the works and 2.52% of these were made in Brazil. This data allows us to infer that works that address environmental issues, identify pollutants and relate possible impacts to drainage systems, should be more prioritized in discussions on sustainable drainage technologies.

The indicator of this concern of Brazilian research is important, because in the country only 4.4% of Brazilian municipalities have rainwater treatment (SNIS, 2019).

Among the identified pollutants (Table 2), the physical-chemical parameters and other compounds appeared in 37.74% of the occurrences; nutrients in 28.22%; inorganics and metals in 23.10%; organic in 5.64%; biologics in 5.29% (Figure 2). Regarding the highlight of the physicochemical parameters, it should be noted that the SST and turbidity parameters are included in this group, which are related to the potential for drainage to carry sediments to watercourses and to the retention and treatment devices, which must be considered in the maintenance and operation conditions of these devices. Within this group, there are also the parameters of COD, BOD, DO, Nitrate and Nitrite, among others, which, as well as the second group of nutrients (N and P), influence the living conditions of the receiving bodies, which may justify the volume of appearances of these groups (Figure 2). The recording of these parameters makes it possible to indicate those relevant to the qualitative monitoring of urban rainwater and in the literature, it is verified that they are the priority parameters for analysis of the quality of water bodies (SANTOS *et al.*, 2018).

Figure 2 - Identified pollutants.



Source: The authors (2023).

Technologies trends for sustainable drainage

Among the technological approach, 76.01% of the works evaluated performance or life cycle and 76.94% considered devices for the retention and/or infiltration of rainwater. These values indicate an important commitment to approaching technologies for sustainable drainage, however, they do not guarantee wide adoption either in developed countries or in developing and less developed countries. This is a subject that has been much studied, but little implanted.

In this discussion, an overview of the study of these technologies is given individually. However, it is important to highlight the integrated use of these. Combinations of these should be explored to maximize environmental benefits with a minimal cost at river basin scales (LIU et al., 2015).

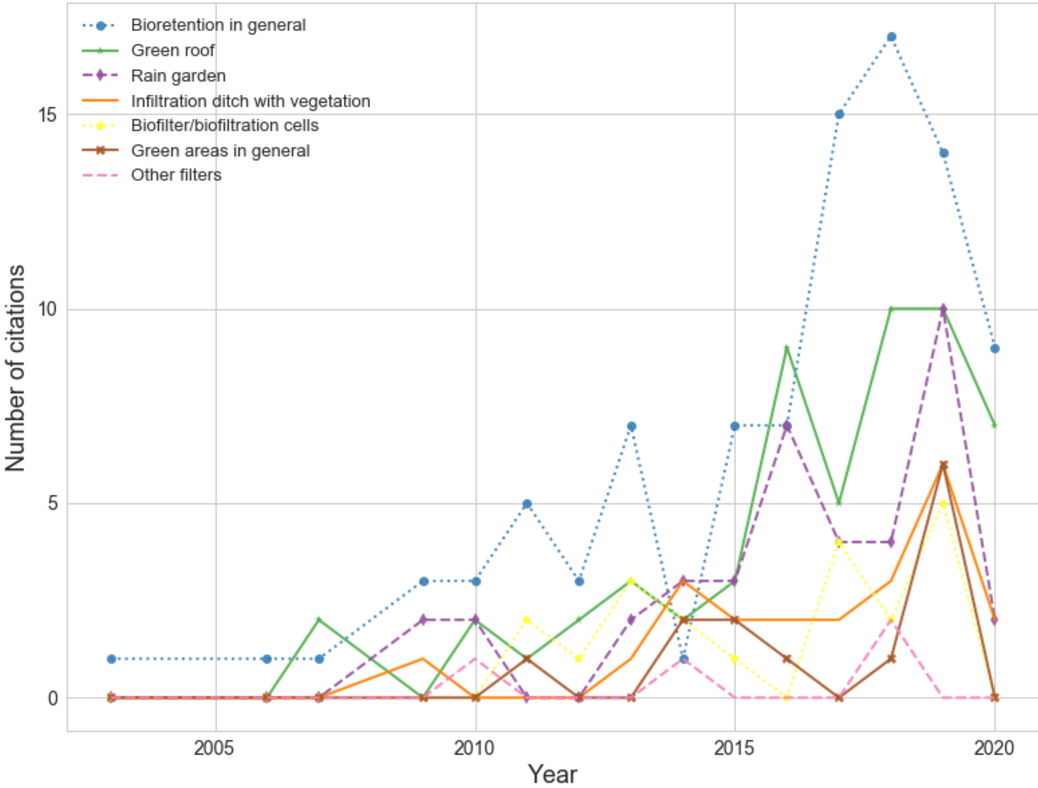
Based on the grouping of technologies presented in the methodology, its occurrence trends are verified which are discussed below (Figures 3 to 10).

Bioretention systems, in general, showed a predominance to other technologies in Group 1 (Figure 3), followed by the green roof, rain garden, infiltration ditch, biofilter, green areas in general, and other filters. In both cases, except for other filters representing isolated cases, evidence indicates an increase over time, characterizing a trend towards the future use of these technologies. It is observed that bioretention, in general, is a precursor of technologies among the works analyzed, whose first record appears in 2003.

In Group 2 of permeable surfaces (Figure 4), it is observed, as well as for bioretention systems (Figure 3), an essential usage of these technologies compared to other Groups 3 and 4 (Figures 5a and 5b). These technologies with more technically and economically viable implementation and maintenance costs (MONTALTO *et al.*, 2007), may explain this highlight. As it is a broad term, permeable pavements may be contemplating the alternatives of permeable roads and parking lots, which are presented in a more subtle way (Figure 4).

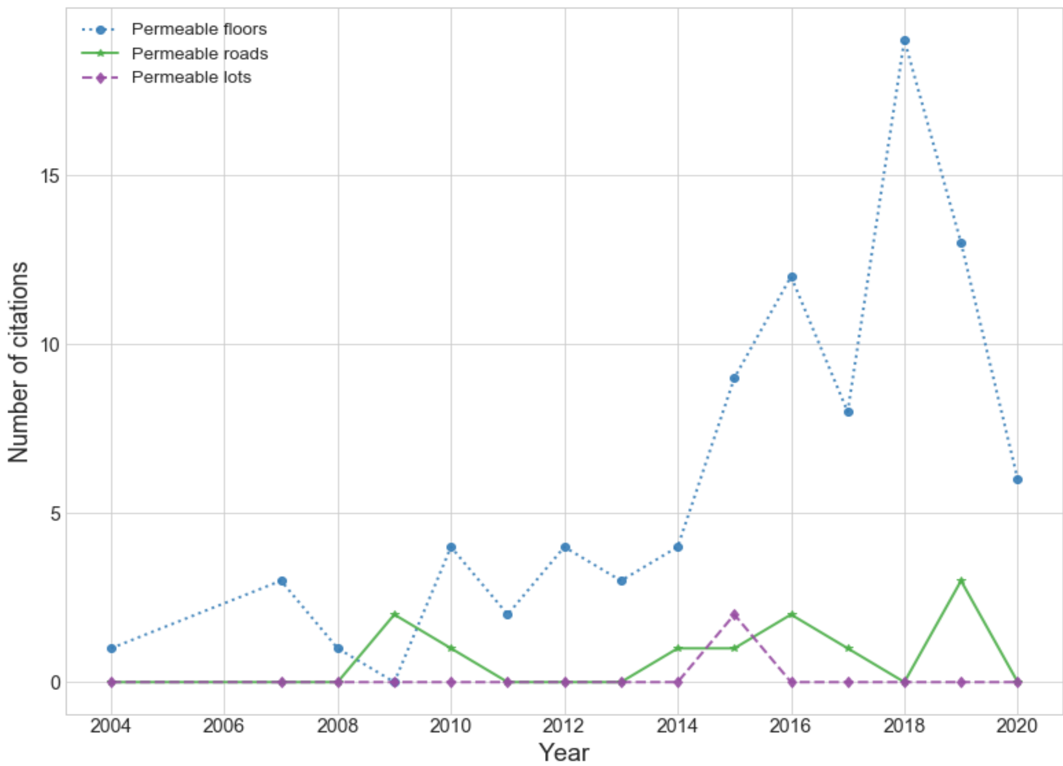
Records for water infiltration and recharge systems (Figure 5a) start in 2015, indicating that this is a more recently studied group whose implementation and maintenance may not yet have been discussed for technologies in Groups 1 and 2.

Figure 3 - Trends in the usage of bioretention and vegetation systems.



Source: The authors (2023).

Figure 4 - Trends in the usage of permeable surfaces.



Source: The authors (2023).

Figure 5 a- Trends in the usage of systems for water infiltration and recharge.

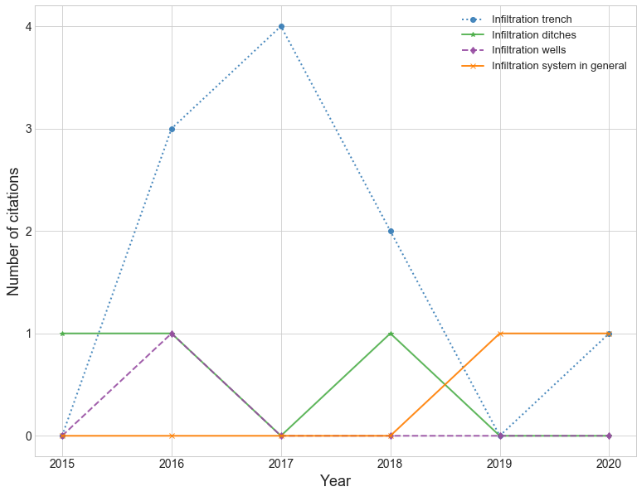
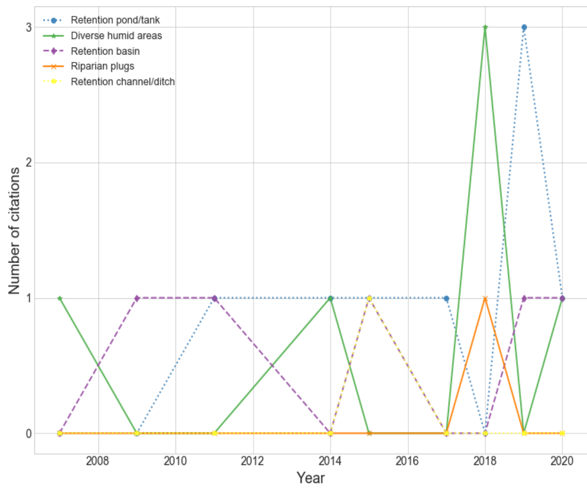


Figure 5 b- Trends in the usage of flooded and humid areas.



Source: The authors (2023).

Flooded and humid areas tend to require larger areas for their installation and which, as they have less flexibility in their use, may justify the scarce appearance (Figure 5b) concerning the other technologies presented by those in Groups 1, 2, and 3.

In Group 5 of other technologies and accessories (Figure 6), the unidentified ones appear in a more significant quantity compared to the others and continue to be presented in a comprehensive way to this day. In Group 5, records for unidentified technologies are observed in 1971, 1980, and 1996, and the identification of technologies starts to be made in 2003 (Figures 3 and 4). Thus, it is noted that the concern with the sustainable management of drainage is old, but that it gained notoriety with the development of technologies after three decades.

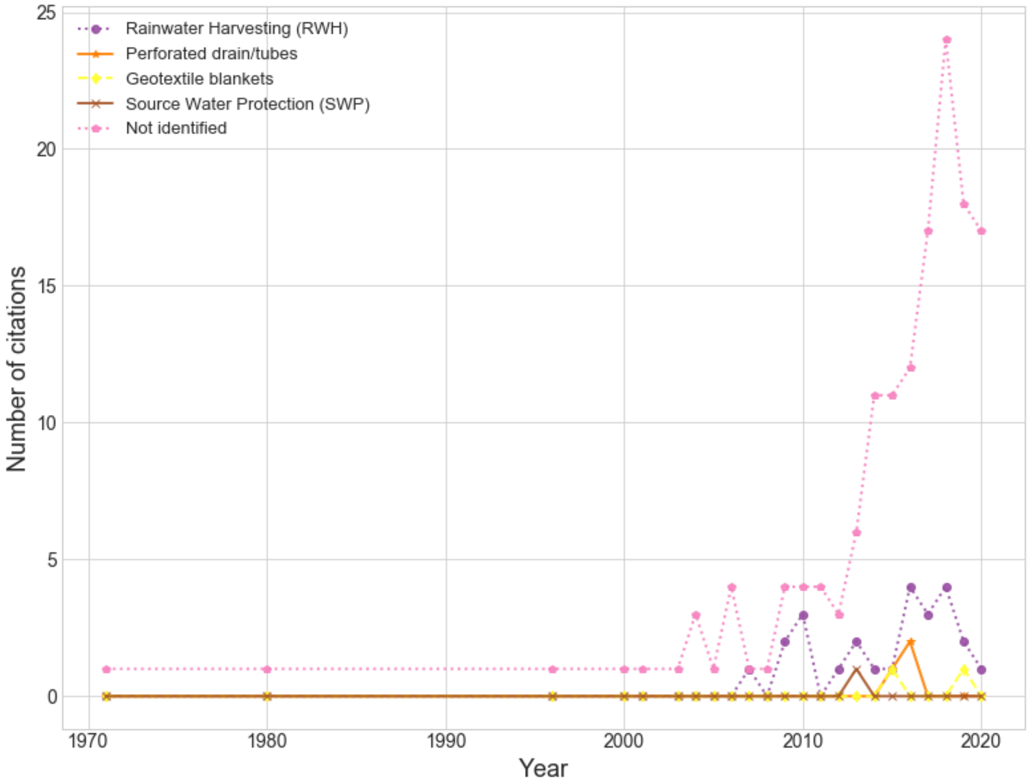
In a sequence (Figure 6), the RWH encompasses the devices that allow the storage of rainwater at the generation site, retaining part of the surface runoff and allowing its use. RWH, even though not officially considered a compensatory drainage technology (OLIVEIRA et al., 2016; GONÇALVES et al., 2018), is a crucial way to retain the flow of rainwater, which explains its appearance in this research. The acceptance of this device is linked to the benefit that the reuse of rainwater makes possible, minimizing the expenses of the collection of drinking water (BROWN *et al.*, 2016).

The SWP, which has a record (Figure 6), is a definition of the North American environmental agency, the United States Environmental Protection Agency (USEPA), for the practices and actions adopted to prevent the contamination of surface and underground sources of drinking water (BRASS et al., 2005).

Accessories such as drains, perforated pipes and geotextile blankets appear in isolation (Figure 6) given their significant use in the discipline of urban drainage.

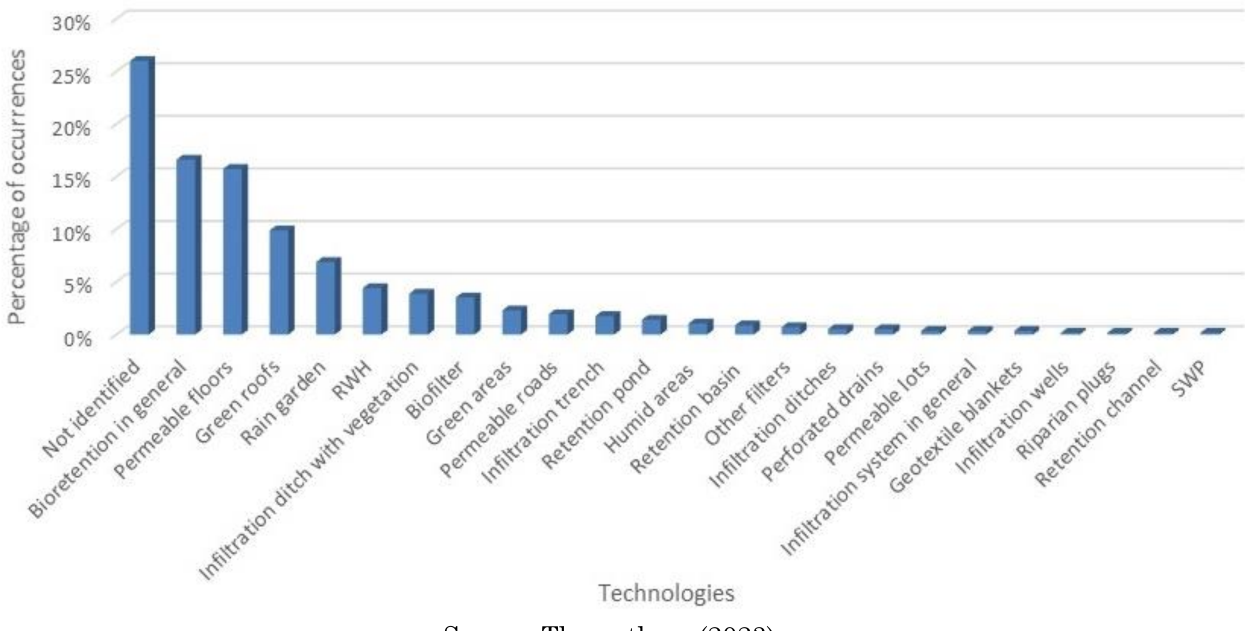
The analysis of the total quantity of detected technologies (Figure 7) indicates that unidentified technologies predominate with 26.02% of the sample, but sustainable technologies such as bioretention (16.64%); permeable floors (15.75%); green roofs (9.91%); rain garden (6.90%) and RWH (4.42%), are now highlighted and presented in the surveys.

Figure 6 - Trends in the usage of other technologies.



Source: The authors (2023).

Figure 7 - Quantitative technologies for sustainable management found.



Source: The authors (2023).

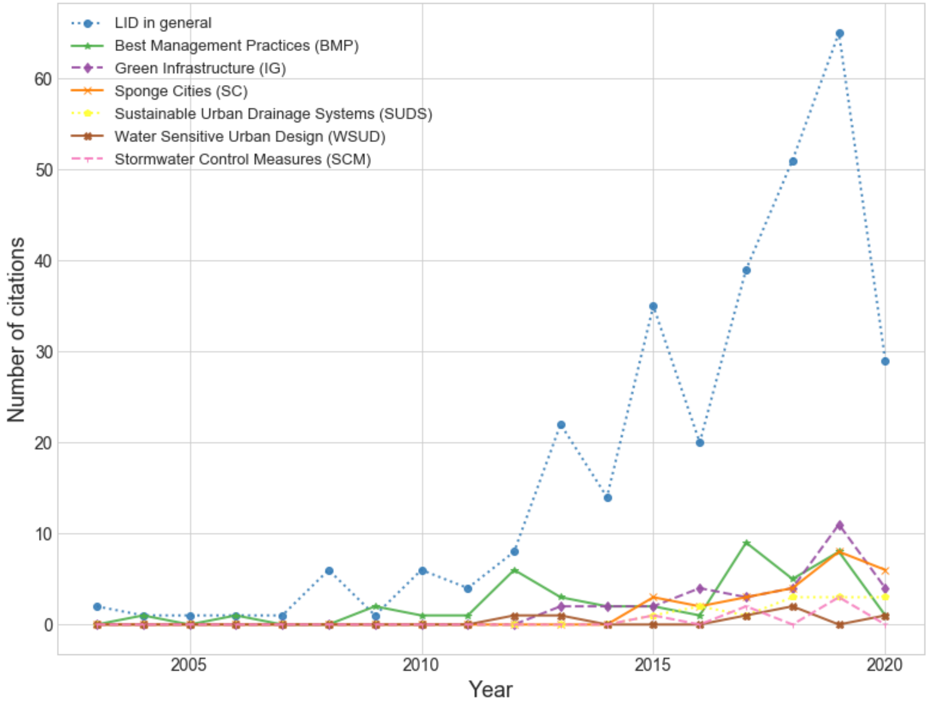
It was observed in the studies carried out in Brazil that the use of permeable floors in 25.00% of the works and green roofs, infiltration trenches, retention basin, retention pond and green areas in general in 12.50% of each of the options. The adoption of permeable floors and infiltration trenches may be related to a more technically and economically viable implementation and maintenance. In relation to the retention basin, retention pond and green areas, even if they demand larger areas, they may be suitable alternatives for Brazilian urban areas.

The individual perspective of the properties regarding these technologies was identified in 8.23% of the works. Greater attention was paid to public drainage system devices concerning individual systems of the system user. These data must be associated with the social and economic aspects, since there is a scenario of demand to strengthen the look at the potential of the user of the drainage system in its different economic and social conditions, not neglecting its potential for the general context of this system.

Sustainable drainage systems tend to be more effective when adopted in private urban areas than in public areas, which occupy a large portion of the landscape. Nevertheless, there must be efforts in the integrated planning of hydrographic basins involving public agencies and private owners (MONTALTO *et al.*, 2007). Public-private partnerships (PPP) are often cited in this context, as pointed out by various authors (JIA *et al.*, 2017; LI *et al.*, 2017; MONTALTO *et al.*, 2007; WANG et al., 2017).

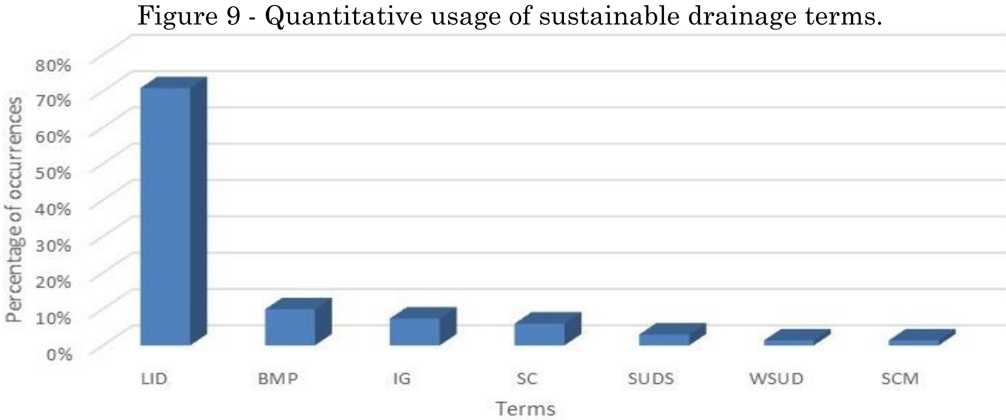
The evolution of terminology for sustainable drainage management can be observed, represented by Group 6 (Figure 8). New approaches consider local realities, reflecting not only technical advances but also evolving cultural, social and political contexts. The growth in the number of terms in urban drainage suggests that the choice of these can play an important role in the involvement not only of professionals in the segment, but of the community in general (FLETCHER et al., 2015).

Figure 8 - Trends in the usage of terms in sustainable drainage.



Source: The authors (2023).

Figure 9 - Quantitative usage of sustainable drainage terms.



Source: The authors (2023).

The following general quantitative was observed in the uses of the terms: LID (70.83%), BMP (9.95%), IG (7.41%), SC (6.02%), SUDS (3.01%), WSUD (1.39%) and SCM (1.39%) (Figure 9).

Initially, the prominence of the term LID was correlated with the fact that it was adopted as a search term, thus biasing the result. However, on search, but on Google Scholar, also identified an expressive value for this term (FLETCHER et al., 2015). Therefore, such evidence does not invalidate the presented result.

In general, all charts show drops in the year 2020, as the search considered only the first half of this year.

In Brazil, the most used term was LID (71.40%) followed by IG (14.30) and SUDS (14.30), which allows the conclusion that this ranking follows world trends, mainly regarding the use of the term most recurrent is LID.

General weather conditions

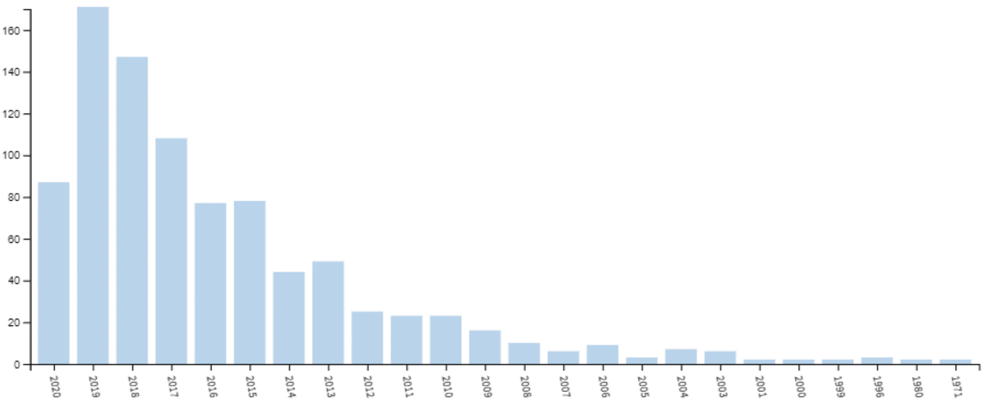
It was identified that 90.61% of the studies were carried out in the North Tropical Zone; 5.91% Tropical Zone; 3.94% in the Southern Tropical Zone; 1.74% in the Arctic Polar Zone, and no research was identified in the Antarctic Polar Zone.

There is a low effort in studies involving the Tropical Zone and Southern Tropical Zone, characterizing a research gap. Their low urban occupation justifies the low engagement in Polar Zones. However, it is worth noting that such classification of climate zones is significantly comprehensive, so when it comes to deliberation for urban drainage alternatives, specific local environmental conditions must be considered.

Characterization of the research gap

The timeline (Figure 10) indicates completing the surveys analyzed until the first half of 2020.

Figure 10 - Publication timeline.



Source: Web of Science (2020).

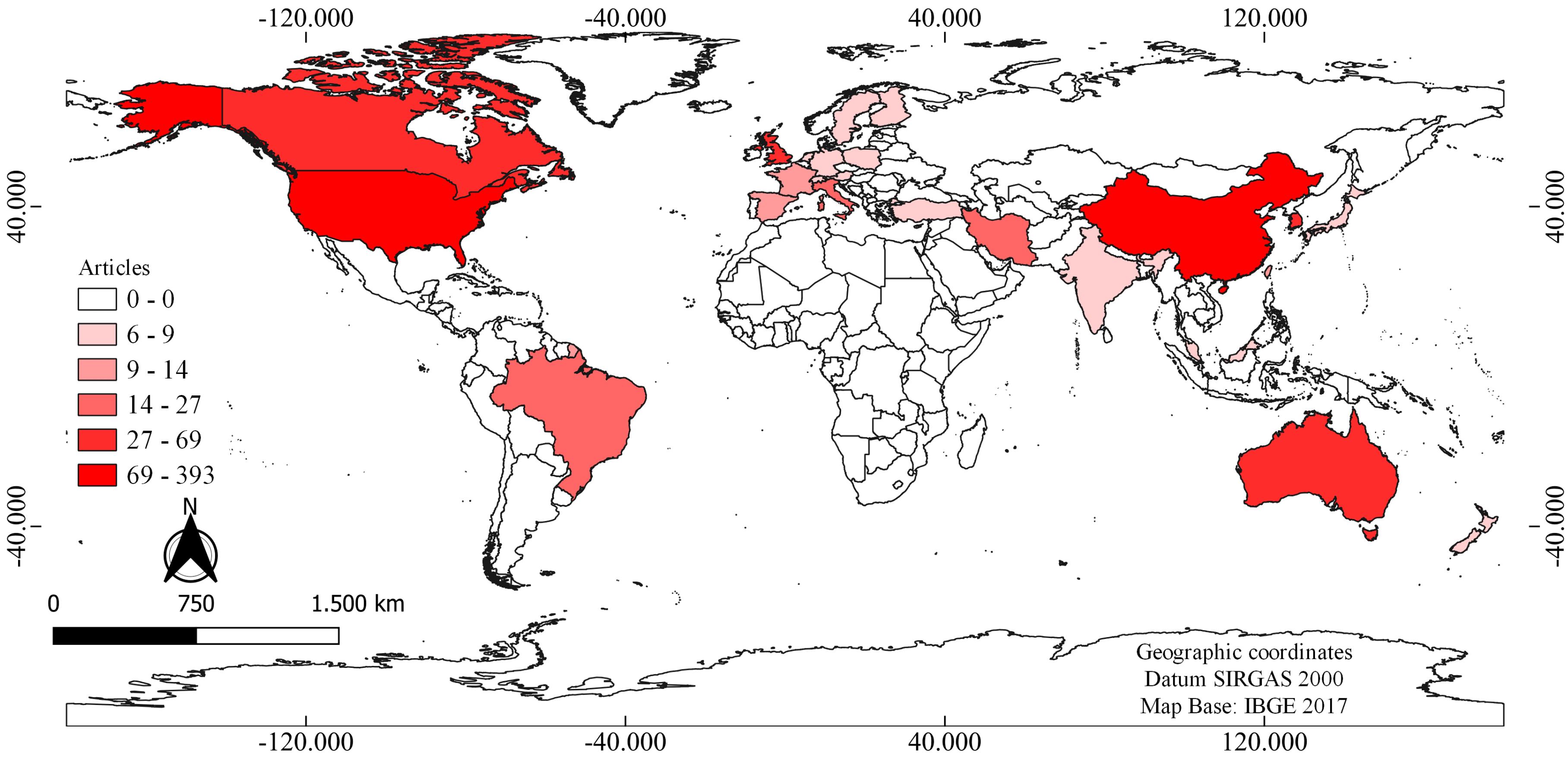
On the map (Figure 11), it is possible to observe that the works are not equally distributed worldwide, which was also identified by other researchers (CHANG et al., 2014). The map shows that socioeconomic inequality between countries influences scientific production, either by the availability of access to research resources or by their socioeconomic condition. Therefore, it is possible to infer that this influences the implementation of technologies favoring sustainable drainage. Such records also imply a characteristic spatialization of science that can be observed in other research themes, which justifies the demand for scientific development in developing and least-developed countries.

Given the results presented, there are, finally, the leading indicators for the characterization of the research gap (Figure 12).

Considering the aspects related to the sustainability tripod, environmental, social, and economical, it is possible to observe a more significant commitment to research the environmental aspect. It allows us to identify to the need to discuss sustainable urban drainage management involving the three items. This consideration does not invalidate the works that focused on a specific question, but registers a gap to be filled. Such specific discussions are very helpful in subsequent discussions dealing with all three aspects.

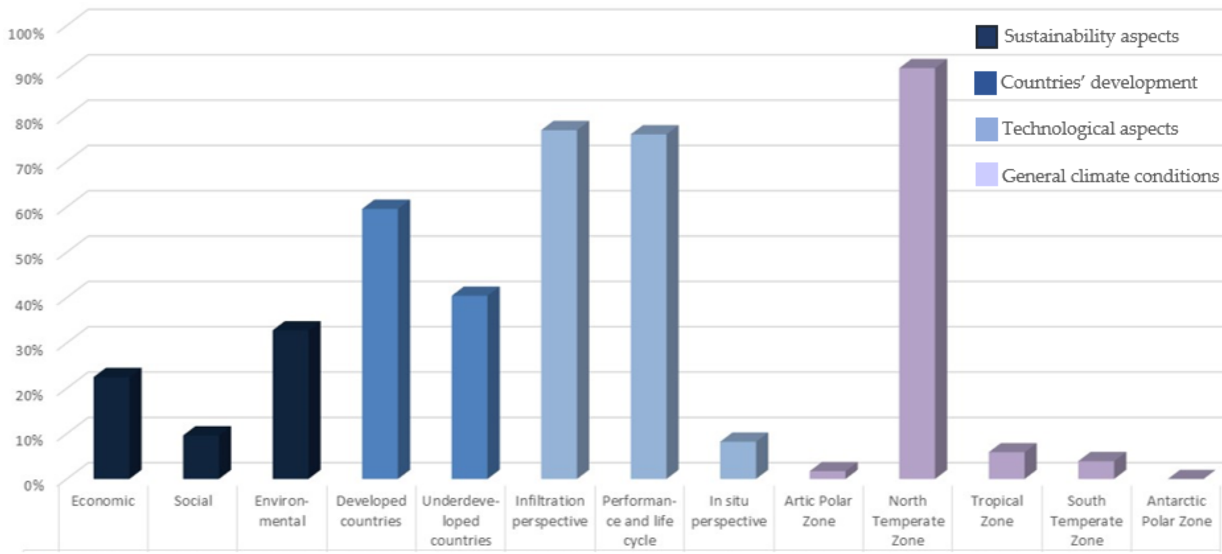
Research is more numerous in developed countries than in developing and least-developed countries ones (Figures 11 and 12), related to their research investment capacity. However, the fact that users of the drainage system in developing and least developed countries have fewer investment conditions, made it clear that incentive programs in these countries accompany charges for such services.

Figure 11 - Location of publications.



Source: The authors (2023).

Figure 12 - Research gap indicators.



Source: The authors (2023).

Considering the technological aspect (Figure 12) a lower indicator in developing, such as Brazil, in addition to the least developed countries with regard to the individual perspective, demonstrates the need for integration between public and private systems. This integration is potential given the economic, environmental and social gains of the entire process analyzed here.

Considering the climatic aspects, it is possible to associate the indicators in Figure 12 with the map in Figure 11. In the North Temperate Zone axis, there is a large portion of developed countries, which have a greater quantity of research concerning the other climate zones, whose incentives for research are more numerous and the economic capacity of users to adopt drainage systems are more favorable. The indicators show the need for attention to other climatic zones, especially in the Tropical and Southern Temperate Zones. Still, it is worth remembering that, concerning rainwater drainage, it is necessary to pay specific attention to local conditions that are even more detailed than such general climatic characterization.

This panorama allows visually verifying the relevance of carrying out research based on the analysis of sustainable drainage technologies from the perspective of the tripod of sustainability, mainly in developing and less developed countries.

FINAL CONSIDERATIONS

This study made it possible to identify trends in Brazil and in the world for the use and research of sustainable drainage technologies and sustainable drainage terms, relating them to the aspects of the sustainability tripod, which are social, environmental and economic.

It was observed, both in Brazil and in the world, that the approach to the theme begins with the technological aspect involving the implementation, life cycle and maintenance of sustainable technologies and, in sequence, the environmental, economic and social aspects unfold in this order, but they are not done in an integral way, that is, there is a need for research that addresses more technologies considering the three aspects of sustainability.

It is a fruitful scenario for developing and least developed countries in adverse climatic conditions that raise a series of problems in the management of urban drainage, as is the case in many countries such as Brazil.

The data presented by the SR are important for providers and users of drainage services, public agencies, and the academic community that engage in sustainable urban drainage.

SUPPLEMENTARY MATERIALS AND DATA AVAILABILITY STATEMENT

Data supporting the results of this study (PRISMA Checklist) are openly available on a page agreed with the journal.

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AUTHORS CONTRIBUTION

Ana Paula Camargo de Vicente collected and analyzed the data and wrote the text. Karla Maria Silva de Faria and Klebber Teodomiro Martins Formiga guided, analyzed data and revised the text.

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