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Review

Exploring an Integrated System for Urban Stormwater Management: A Systematic Literature Review of Solutions at Building and District Scales

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Abstract: Climate change has aggravated the frequency and severity of extreme weather events, particularly in flood-related hazards. Cities nowadays face significant challenges in stormwater management from frequent heavy rainfalls. Traditional urban drainage systems can no longer cope with large amounts of surface runoff; cities are searching for new ways to deal with urban stormwater. Green roofs and other nature-based solutions have been widely used for stormwater management by combining water purification and retention functions but have not yet fully solved the flood problems. This article aims to (1) explore the different aspects of urban water management, particularly the urban stormwater topic, and (2) identify the existing solutions and discuss the potential and barriers to integrated solutions implementation. By introducing the concept of four domains and finding the overlapping area to investigate, we analyzed different solutions to reduce rainwater runoff from the roof and ground level, aiming at building and district scales. This paper proves that further research direction could constitute an integrated system to work together for urban stormwater management.

Keywords: blue and green infrastructure; stormwater management; intense rain event; nature-based solutions; green roof; roof level; ground level

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1. Introduction

Today, 55% of the world's population lives in urban areas, and about two-thirds of the global population is projected to live in an urban environment by 2050 [1]. The expected population growth in urbanized environments and the corresponding increase in the density of urban fabric will make cities even more vulnerable to natural events. Climate change has been influencing the frequency and severity of these extreme events, including heatwaves, droughts, wildfires, and floods; this significantly harms people, property, and the environment [2–10]. Since the 1970s, 44% of all disaster events have been flood-related; the 2022 Intergovernmental Panel on Climate Change (IPCC) reports that water-related risks will increase with every degree of global warming and pose much greater risks to exposed regions and people [11]. Water management is a primary issue, and it will be much more in the future because water is a crucial resource for people to survive. However, fact is that about four-billion people experience severe water scarcity for at least one month of every year [12]. In addition, emerging research shows that stormwater can be used to generate electricity as a renewable energy source from solar cells and a pumped stormwater system, which can decrease carbon emissions and help mitigate climate change [13]. Thus, more attention needs to be given to urban water management to ensure essential water supplies and increase the capacity for adaptation and reduction of the vulnerability in cities [14].

Cities nowadays face significant challenges in water management, from frequent heavy rainfalls, water stress, and deterioration of the water environment, all of which impede efforts to improve living conditions [15]. In recent years, many countries worldwide, such as western Europe, China, the United States, and Australia, have suffered intense rain events, which has led to substantial floods and caused significant economic, social, and environmental losses. Urbanization has accelerated the increase of impervious urban areas, such as roads, buildings, and roofs, producing large amounts of stormwater runoff that may contribute flood problems [16].

Conventional stormwater management, also known as grey infrastructure, directly routes runoff to nearby bodies of water through storm drains, gutters, and underground systems [17]. However, pipe-based drainage systems alone have been proven inadequate for managing stormwater; cities are searching for new ways to achieve multiple sustainability goals simultaneously [18]. Several stormwater management strategies have been adopted in trying to solve these issues, such as sustainable drainage system (SUDS), low impact development (LID), water-sensitive urban design (WSUD), blue and green infrastructure (BGI) and sponge city (SC) by reducing stormwater runoff and increasing retention and infiltration capacity [19,20].

In 2015, the European Commission officially defined nature-based solutions (NBS) as "actions address environmental, social and economic challenges simultaneously by maximizing the benefits provided by nature . . . inspired by, supported by, or copied from nature" [21]. Green roofs (also known as "living roofs" or "vegetated roofs") have been widely recognized as sustainable nature-based solutions to mitigate floods in urban areas [22]. Typically, a green roof consists of three main groups of layers: growth substrate, vegetation, and drainage. The green roof can be classified as intensive or extensive vegetated roofs depending on the depth of the substrate layer and the vegetation typology with relation to water need and physiology [23]. In recent years, green roofs have received increased interest because it has been demonstrated to offer many benefits beyond hydrological ones, such as energy savings, thermal comfort, air pollution improvement, carbon sequestration, and aesthetic benefits [24–26]. Castleton et al. [27] demonstrated that green roofs could provide an annual energy saving of 1%, 6% in cooling, and 0.5% in heating. Luo et al. [28] investigated the thermal benefits of green roofs, demonstrating the air quality improvement function by performing a 24-h monitoring experiment in surrounding areas. Shafique et al. [29] gave solid evidence that green roofs could help to reduce carbon emissions in urban areas, thus mitigating the adverse effect of air pollution.

In developed urban areas, roof surface areas account for 40–50% of all total impervious surface areas [30], so green roofs can be regarded as an effective way to manage stormwater on the roof level. Other nature-based solutions (NBS)—e.g., blue and green infrastructure, rain gardens, and infiltration basins—have also been widely used for stormwater management by combining water purification and retention functions on the ground level [17,31]. Blue and green infrastructure (BGI) is ecosystem-based, relying on biophysical processes, such as detention, storage, infiltration, and biological uptake of pollutants, to manage stormwater quantity and quality [32]. Rain gardens serve as small sponges that soak stormwater into the ground through a soil-based medium, remove pathogens, and reduce nutrients, organic substances, and various heavy metals in stormwater runoff [33]. An infiltration basin is a shallow impoundment that capture, temporarily store, and gradually infiltrate runoff into the ground, thereby reducing the net volume of runoff leaving the site and can remove contaminants in stormwater runoff [34,35]. These NBS options from the ground level often implement separately in neighborhood planning and design, which can contribute to sustainability and resilience goals for urban development.

However, only a few studies have explored the effectiveness of their integrated solutions, while single facilities might be ineffective in bigger storms and would never fully solve the urban runoff problems [36–39]. Furthermore, several studies have suggested that combing multiple NBS can result in a more effective strategy than their single implementation [40]. In addition, it has to be highlighted that, according to different disciplinary perspectives—e.g., agronomy, infrastructural engineering, meteorology, etc.—the focus of the studies widely varies and rarely looks at the issue in a systemic way, which possibly would consider the built-natural environment interaction, especially in urban areas.

The scope of this paper is to perform a literature review that primarily focuses on urban water management. The review seeks viable and effective solutions that highlight common ground between the current literature and possible gaps in multidisciplinary boundaries, while also considering different scales. Despite widely available studies in the literature, advantages and disadvantages of each single specific solution are not discussed in this article, as the focus is on integrated approaches and not performance. Hence, the key objectives of this study can be listed as follows: (1) to explore the different aspects of urban water management particularly the urban stormwater topic; (2) to identify the existing solutions and discuss the potential and barriers to the implementation of integrated approaches.

2. Materials and Methods

The review was performed between October 2022 and March 2023, with regular updates after completing each round. According to the shared approach in the academic searches, the process initially considered 5 of the widest-used search engines or repositories, i.e., (1) Science Direct; (2) Web of Science; (3) Scopus; (4) Google Scholar; and (5) Research Gate. We then only proceeded with the first three, which are largely considered the most reliable and diffuse search engines. After some initial attempts, Google Scholar resulted in a high-repetition rate, with many irrelevant outcomes due to limited filtering possibilities. Research Gate—based on a voluntary product addition to collections—made it so that we could exclude certain irrelevant papers that were detected as relevant by other search engines.

The literature search process consisted of two steps. The first step was to explore the keywords about the "stormwater" topic separately because stormwater is an investigated phenomenon, and many scientists have been exploring possible strategies for managing it. It is a very interdisciplinary topic that involves various research fields, such as engineering, architecture, and urban planning, and thus corresponding solutions can arise from different perspectives to address this challenge and adapt to sustainable urban development. After having a systemic understanding of how stormwater was approached, the second step proceeded through the combination of keywords. It can be observed how these solutions for managing stormwater were studied, proposed, investigated, and adopted by exploring their common ground and possible gaps.

Figure 1 provides a conceptual workflow of the investigation process by implementing the above two steps.

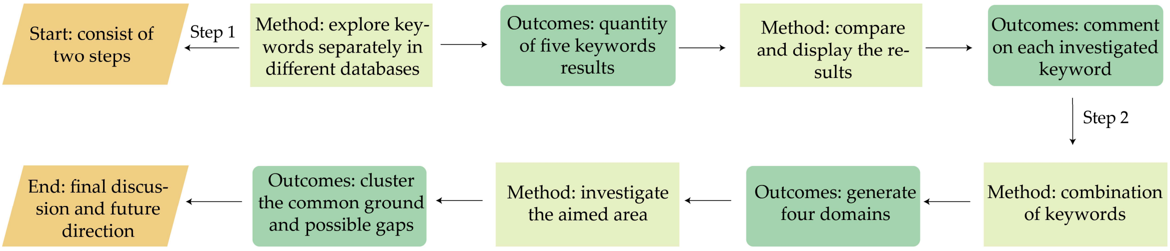

Figure 1. Overall workflow of the investigation process.

2.1. Step 1

Depending on the way the urban stormwater topic was approached (the generated problem or the possible solution), the search outcomes significantly varied. Therefore, a spectrum of 5 keywords reflecting these different visions was adopted: (1) blue and green infrastructure; (2) stormwater management; (3) intense rain event; (4) nature-based solutions; and (5) green roofs.

These given keywords were chosen because "blue and green infrastructure", "nature-based solutions", and "green roof" were regarded as effective methods for dealing with urban stormwater (as described in the introduction part). "Stormwater management" was considered to be the ultimate goal to achieve, and “intense rain event” was considered to be the major contributor for water-related hazards. They were separately put in different search engines because they represented different aspects of the investigated topic.

To keep the same search settings of Science Direct, Web of Science, and Scopus databases, article title, abstract, and keywords was chosen to perform the search. The years’ range was set to 2012–2022, which was assumed to be the “maturation period” during which a large amount of scientific activities were seen to have propagated. The document types were limited to “reviews” and “articles” to control the quality and uniformity of data. The language was set to English. A large number of results were accumulated, which were then processed as the following section reports.

Looking back at these 5 different keywords, they seem to have a close connection. “Stormwater” and “intense rain event” are hazards or problems influenced by climate change, and cities are presently dealing with these events; “blue and green infrastructure”, “nature-based solutions”, and “green roof” are considered to be powerful solutions that absorb and collect stormwater, as well as help cities address these challenges. Between the problems and possible solutions, there was a generator to serve as the “cause–effect engine”, such as “mitigation” or “adaptation”, which are considered to be the driving forces for lowering the negative impact of extreme rain events, as well as for building resilience in urban development. Scales were also investigated so that we could determine the severity of flood hazards at different levels. Knowing the scope of the current solutions was important because it helped establish the priority of scale of implementation in the future. Therefore, this research topic was composed of four domains, as shown in Figure 2.

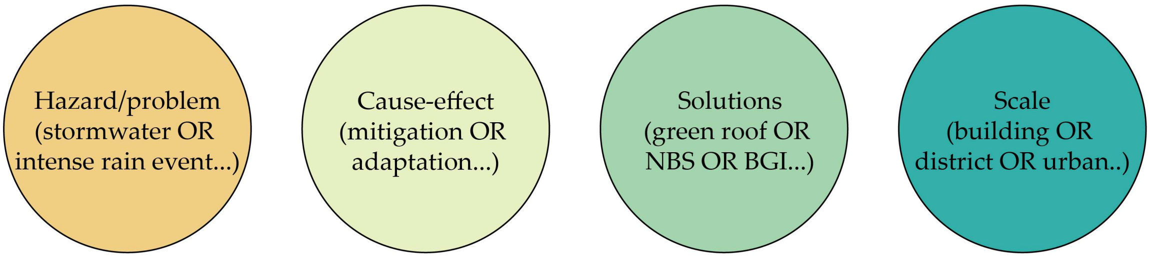

Figure 2. Four domains of the research topic.

2.2. Step 2

Based on step 1, the aim of step 2 was to explore the common ground and possible gaps between the following 4 domains: (1) hazards or problems; (2) cause–effect; (3) solutions; and (4) scale. This was done in order to explore different domains. More keywords were added to search strings and to cover this topic as comprehensively as possible. Below are the strings of 4 domains.

- Domain 1: Heavy rain OR flood* OR intense rain OR heavy storm OR storm water OR stormwater OR flash flood* OR extreme rainfall OR pluvial flood* OR heavy rainfall.
- Domain 2: Mitigation effect OR mitigation OR rainwater management OR water management OR adaptation OR water retaining capacity OR response capacity OR water detention OR stormwater treatment OR flood risk management.
- Domain 3: Green roof* OR vegetated roof* OR vegetative roof* OR eco-roof* OR nature-based solution* OR NBS OR ecosystem-based solution* OR (blue and green infrastructure) OR BGI OR green infrastructure OR bioretention system*.
- Domain 4: (1) Building*; (2) district* OR neighborhood* OR neighborhood* OR community*; (3) urban OR city*.

In this step, a technical limitation was detected in the Science Direct database, which did not support “*” and limited the Boolean connectors in the definition of the search script to 8 per field. Therefore, it was processed differently with respect to the Web of Science and Scopus database searches.

In the end, additional records were identified though hand-searching to have as comprehensive results as possible. The years' range was set to 2012–2022. The language was set to English. The document type was set to "article" and "review article". Table 1 shows the categories that were selected to ensure more relevant results.

Table 1. The selection of categories.

Database	Categories
Web of Science	Environmental Sciences Environmental Studies Green Sustainable Science Technology Water Resources Engineering Civil Engineering Environmental Ecology Geosciences Multidisciplinary Construction Building Technology Regional Urban Planning Urban Studies Architecture
Scopus	Environmental Science Engineering

Secondly, exploring the combination of 4 domains, 3 small steps were introduced to find inside relations, as shown in Figure 3. Step 1 examined water-related hazards at different scales to see the frequency and urgency of this severe hazard. Step 2 sought to discover research activities that attempted to solve this flood phenomenon. The last step was to evaluate whether or not systematic research was linking the problems to their potential solutions.

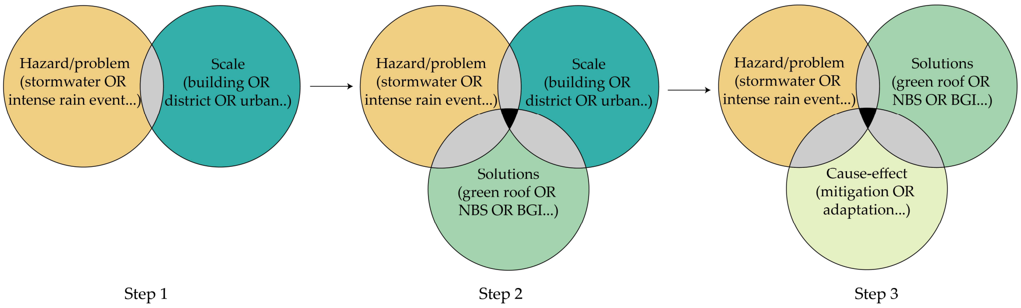

Figure 3. Three steps in the research exploration process.

Thirdly, Figure 4 illustrates the investigation area of the research focus, as well as the commonalities between these 4 domains considering the building and district scales. Figure 5 provides a workflow of how the final selection was obtained.

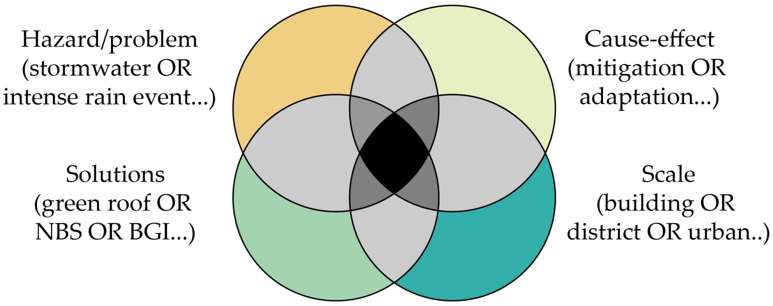

Figure 4. The investigation area (black) of the four domains.

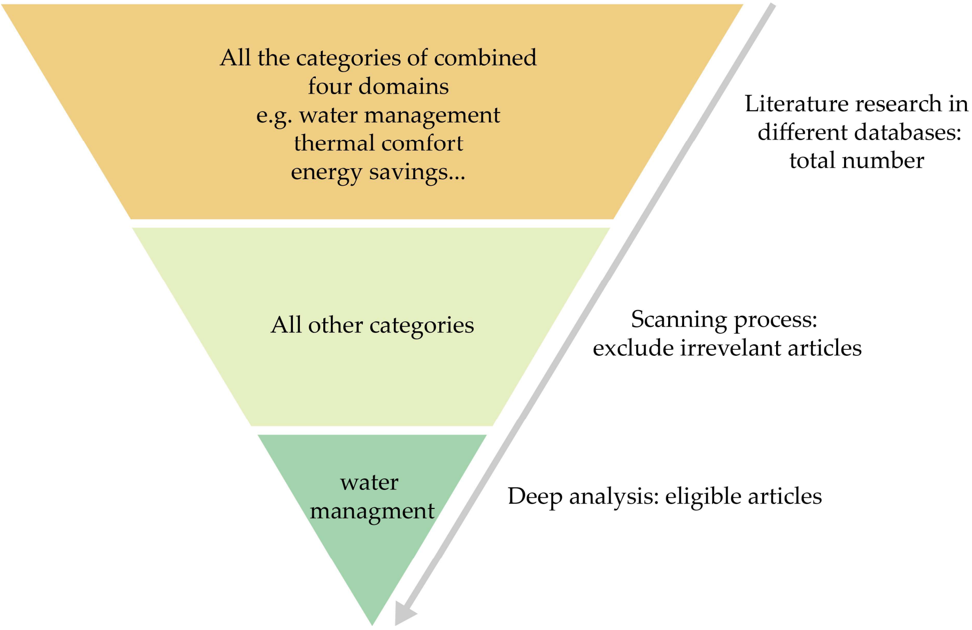

Figure 5. Conceptual workflow of the overall searching process. The research focus is in green.

A systematic review of the available scientific literature was performed according to the PRISMA workflow [41]. The search process for the building scale and the district scale were split into 2 separate streams. The titles and abstracts were first screened to check for compliancy with the research criteria. Then, the full-text reading followed in order to evaluate if the contents met the research focus. The results can be summarized as follows:

- Building scale: 416 records were identified; 130 duplications were removed; 286 records were selected for the screening process; and 37 articles were considered eligible.
- District scale: 604 records were identified; 169 duplications were removed; 435 records were selected for the screening process; and 36 articles were considered eligible.

Once the systematic review was completed, 5 additional records were added from other databases, including Science Direct. Hence, 78 articles were reached, but 28 of them were excluded because of (1) irrelevant scale, i.e., urban scale/infrastructure scale/watershed scale; (2) not being in a pertinent field, i.e., theoretical framework/survey; (3) or they had a models' approach. In total, 50 articles were included in this review.

3. Results

3.1. Results of Step 1

As previously stated, we classified three groups: (1) blue and green infrastructure, nature-based solutions, and green roof; (2) stormwater management; and (3) intense rain events. The following figures show the number of articles for the five keywords and their proportion in the three different search engines, as well as the annual distribution of results over the last decade. Due to this organization, there was a huge number of results with possible duplications that did not affect the observation for trends in each group. These duplications were solved at a further stage using a Microsoft Excel file, wherein titles were filtered, and then eventual irrelevant or unqualified records were manually removed.

Figure 6 shows the results of the first group. From the above bar charts, Web of Science and Scopus were observed to present more or less the same amounts of publications. "Nature-based solutions" had the most amount of results, followed by "green roof" and "blue and green infrastructure". This demonstrates that "nature-based solutions" was the most widely explored and investigated keyword. By looking at the distribution of the results over time, we can confirm that there has been increased interest in this topic over the past 10 years. Based on the statistical data of the previous three years, it is evident that a large number of scientists were working on exploring the possible response to deal with hazard problems.

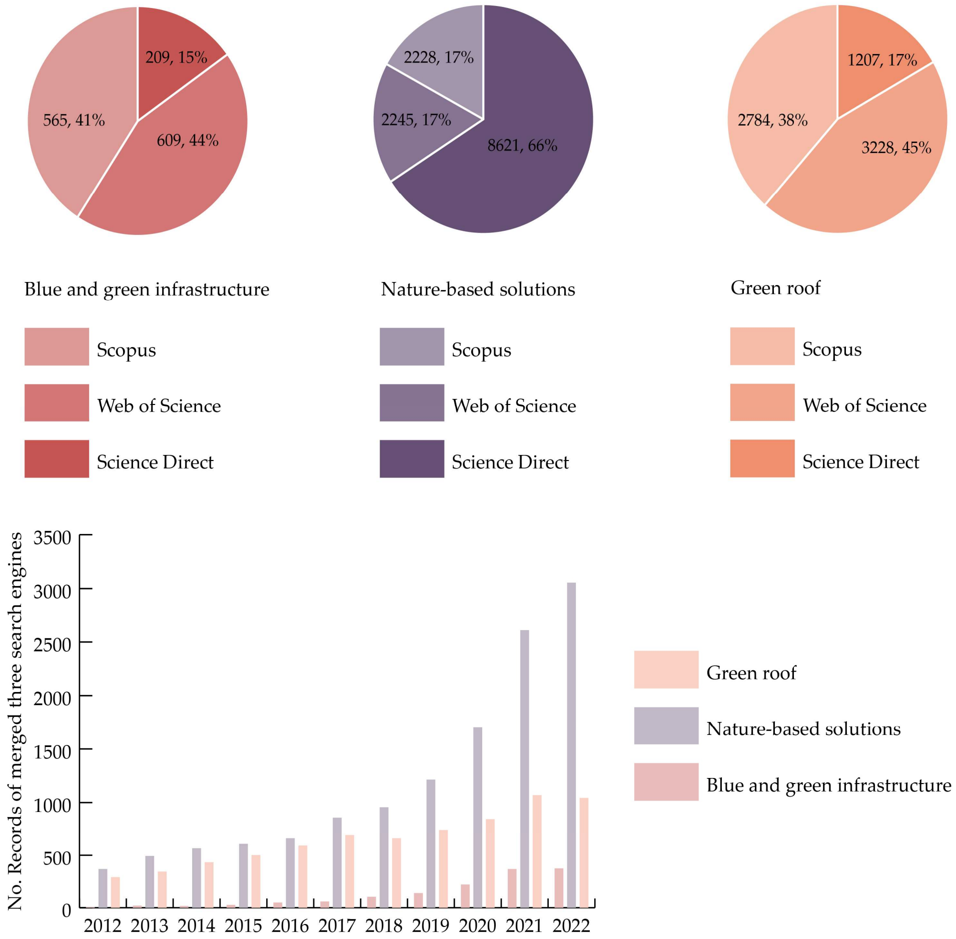

Figure 6. Results of the first group (includes duplications).

Figure 7 displays the distribution pattern by three different search engines and the time distribution of literature on the "stormwater management" topic. The total result numbers were very high, showing that many research activities have been actively carried out. By observing the annual distribution trend, we observed an urgent need for more studies on this topic, demonstrating that the scientific community has been devoting increased effort on how to manage stormwater during this period.

Figure 8 illustrates the distribution patterns of the selected search engines and the annual distribution of the records from 2012 to 2022. In comparison with Figure 7, it is obvious that there has been a reduction in quantity, showing that there is not enough research investigating this extreme weather phenomenon. However, it can also be detected from the records of annual distribution that the frequency of intense rain events has become high and unsteady, probably influenced by climate change, and may act as a major trigger for water-related hazards.

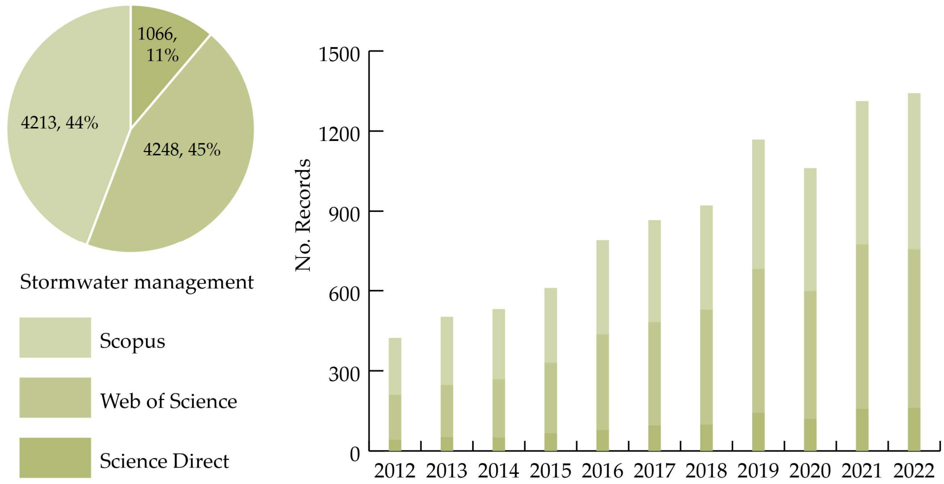

Figure 7. Results of the second group (includes duplications).

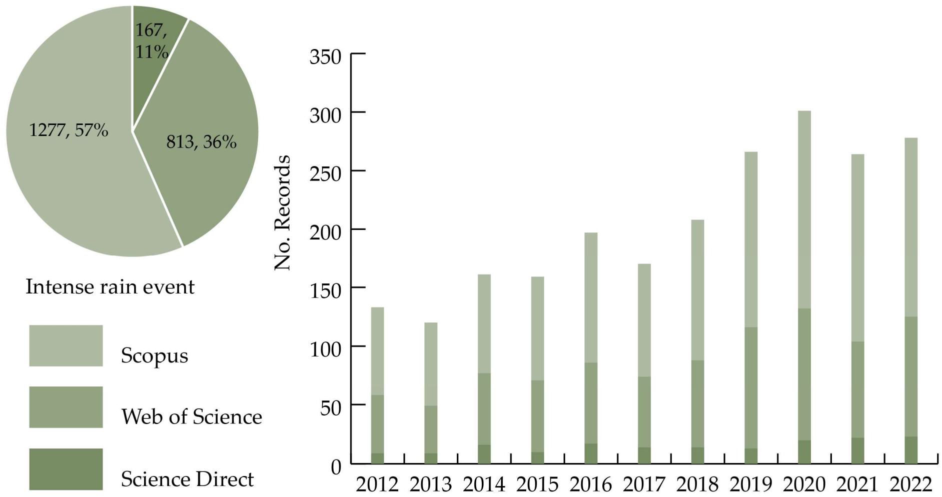

Figure 8. Results of the third group (includes duplications).

3.2. Results of Step 2

3.2.1. Analysis of the Inner Relations of Four Domains

Firstly, exploring the combination of four domains was divided into three small steps to inspect if these four domains had any inner connections or differences. Figure 9 shows the results of the three small steps. Domain 1 was the hazards or problems, domain 2 was the cause–effect, domain 3 was the solutions, and domain 4 was the scale.

Considering each domains' role, fields 2 and 3 represented the cause–effect and solutions, respectively. Therefore, the drop in the result reflects, on the one hand, that there is a wide understanding of hazards or problems (field 1), as well as the impacts or implications at the different scales (field 4), while, on the other hand, the causal chains or possible solutions still need to be further explored and defined.

The result of "domain 1 + 4" demonstrated that water-related hazards were frequent and severe at different scales, from micro to macro scales. "Domain 1 + 3 + 4" revealed that, compared to hazards or problems, there were not enough studies that sought to solve the flood phenomenon. As such, more efficient solutions must be put forward. With that said, it is also possible that many current solutions are still in the theoretical or experimental stage, and have not been put to use, which could lead to a significant reduction in the results number. Further, "domain 1 + 2 + 3" demonstrated that existing solutions could not fully solve the identified problems because the mitigation or adaptation effect showed low efficiency to address these challenges.

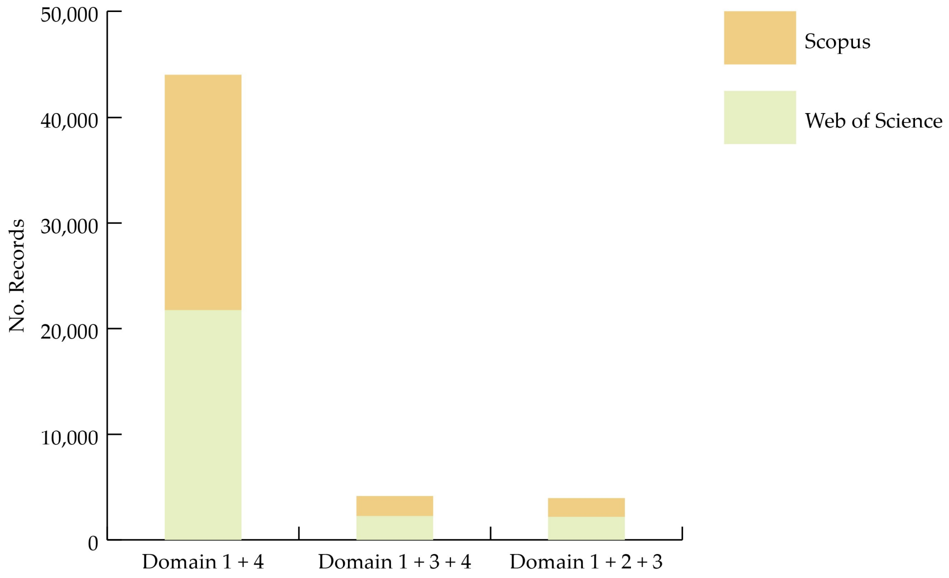

Figure 9. Results of combined with different domains (includes duplications).

3.2.2. Analysis of the Investigated Research Focus

Although the research scope had an intermediate scale (building scale and district scale), it was helpful to know that the existing literature research presents different scales. Figure 10 shows the results number at different scales (after removing duplications). It is obvious that stormwater problems have been widely explored at urban or city scales [42–48], but the building and district scales have not been thoroughly investigated. Therefore, this intermediate scale needs to have more attention paid to it.

As the investigated area of the research focuses on water management, we observed several commonalities recur after reading full texts, particularly concerning the combination of the four domains: (1) runoff reduction: hydrological performance; (2) runoff water quality: water purification of pollutants; (3) field test: propose multiple scenarios to test the efficiency of different solutions at selected areas; (4) experimental research: conduct in the laboratory or perform in physical modules/test beds to test the performance by varying different parameters (mainly in two categories: climate variables, such as the intensity and duration of rainfall, temperature, and wind speed, etc. [49,50]; design variables, such as plant species, soil type, and depth, etc. [51,52]). Figure 11 shows these recurring clusters.

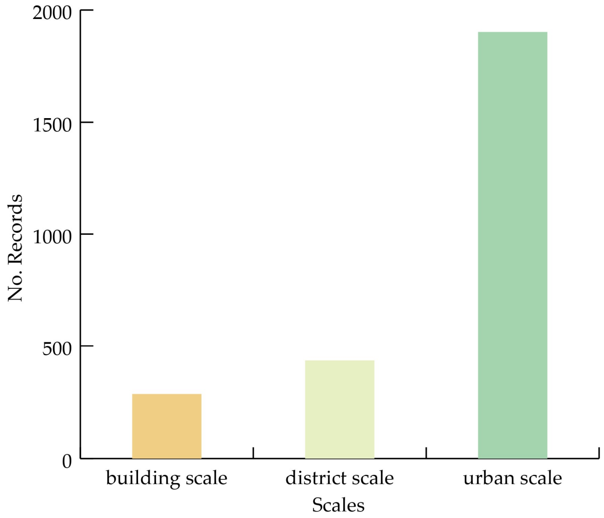

Figure 10. Numerical numbers at different scales: building, district, and urban/city.

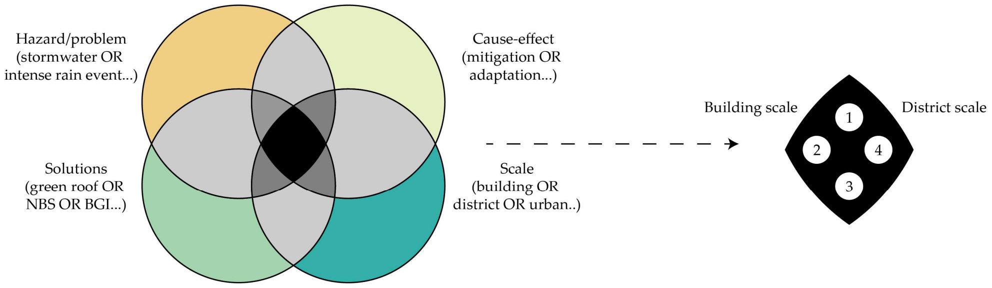

Figure 11. The investigated area and the recurring clusters.

Table 2 shows the classification of results by category. In this table, each record falls into one category only, even if some records consider more than one topic.

Table 2. Classification of results by category.

S. No	Cluster	Reference	No. of Records
1	Runoff reduction	[23,53–63]	12
2	Runoff water quality	[64–67]	4
3	Field test	[46,68–79]	13
4	Experimental research	[80–100]	21
	Total number of records	——	50

The "runoff reduction" refers to runoff quantity and it meets this research focus. As such, 12 articles were included and further divided into roof or ground levels. Actions to mitigate stormwater are listed below (Table 3). "Runoff water quality" was not our primary research interest, but it is addressed in detail in the following section.

It should be noted that the primary investigation of this review involved a practical application. Neither a field study nor experimental research was our focus.

Table 3. Detailed "runoff reduction" implementation levels and actions.

Scale	Level	Actions	Reference
Building scale: Building or plot	Roof level	Green roof	[23,55–59,62]
	Ground level	Infiltration basin	[53]
		Retention basin and rain garden	[60]
		Crushed stones, rain garden, infiltration pipes, etc.	[61]
District scale: District or neighborhood or neighborhood or community	Ground level	Permeable pavers, infiltration trench and rain gardens	[54]
		Rain gardens, bioretention lawns	[63]

4. Discussion

This paper aimed to explore the "urban stormwater" topic. We sought to determine a specific investigation area from a broad map, combining two steps to complete the search process.

In step 1, different aspects of urban water management were investigated using five keywords. "Nature-based solutions" had the highest number of results. The next highest were "stormwater management", "green roof", "intense rain event", and "blue and green infrastructure". This indicates that "nature-based solutions" are perhaps the most effective method for dealing with water-related hazards, as it has received a high amount of attention from the scientific community. Moreover, "stormwater management" refers to the managing of quality and quantity of water using specific techniques and treatments. "Intense rain event" is understood to be an extreme rain phenomenon influenced by climate change and that causes urban surface runoff, which then requires technologies for removal.

"NBS", "green roof" and "blue and green infrastructure" were all seen to treat urban stormwater. Furthermore, the three divided groups showed that, on the one hand, many scientists are exploring the reasons for extreme rain phenomena; on the other hand, they also actively find reactions and solutions to mediate urban stormwater problems.

In step 2, we observed various performances of current solutions that have been widely studied, including thermal comfort, energy savings, and water management. More importantly, many cities worldwide have suffered flood problems, but the existing solutions have not fully improved these severe issues; only several studies investigated the combined NBS options to deal with stormwater.

In the analysis of practical applications, greens roofs were found to be positive at the building scale in the hydrological response. Moreover, green roofs have the ability to hold 10% to 60% of total rainfall runoff in different rain events [23]. Nonetheless, research has shown that the reduction ability of green roofs decreases when storms have intense rainfall [56]. At the same time, the NBS solutions on the ground level have become an important part of the areas surrounding the buildings (or plot) at the community scale [53,54,60,61,63].

As for "runoff water quality", Biswal et al. [64] analyzed the effectiveness of NBS options for removal of stormwater pollutants, including total suspended solids (TSS), total nitrogen (TN), total phosphorous (TP), heavy metals, bioretention systems, green roofs, and constructed wetlands. They discussed the major factors that impact the performance of NBS and pollutant removal mechanisms. Moreover, Yang et al. [65] investigated continuous water quality monitoring by implementing bioswales in an American community. They found lower pollutant concentrations of TN, TP, TSS, and heavy metals (Cu, Zn, and Pb). Fleck et al. [66] compared green roofs with conventional roofs in terms of pollutant removal, finding that green roofs can effectively reduce zinc, chromium, and copper. Todorov et al. [67] monitored and tested the green roof on a commercial building in New York, showing that the green roof was a sink of nitrogen, total phosphorus, and chloride, as well as a source of phosphate. They also found that it dissolved inorganic and organic carbon.

In addition, most of the existing research were field tests or experimental research, which demonstrated that some scientists are still in the research proposal and testing stage and are not yet conducting research seeking to address solutions to the identified hazards or problems. This may be due to socio-cultural, socio-economic, and environmental barriers [101]. As for field tests, different scenarios have compared and tested solutions. For example, Barbaro et al. [79] tested the hydrological performance via a stormwater management model (SWMM) and urban flow-cell model (MODCEL). Then, they compared three scenarios with different combinations, demonstrating that the implementation of green roofs and rainwater revisors had the most significant results for stormwater management. Zhang et al. [77] adopted the SWMM model to test two scenarios in Chinese residential areas: (1) the traditional drainage system without sponge facilities; and (2) the drainage system with sponge facilities, i.e., bio-retention cells, permeable pavements, rainwater garden, and grassed pitches. They demonstrated that the combined system was able to reduce a storm with a five-year recurrence interval while also maintaining water quality. Steis Thorsby et al. [46] applied a calibrated EPA stormwater management model (EPA SWMM) to compare multiple scenarios of green stormwater infrastructure at a neighborhood scale. They proved that combining solutions (i.e., bioretention basin, bioswale, and green roofs) could help to effectively mitigate flood problems.

Moreover, a large number of current experimental research has focused on the performance of green roofs. Wong and Jim [90] tested the hydrological performance of green roofs under humid subtropical meteorological conditions and the effect of substrate depth. Castiglia and Wilkinson [94] evaluated stormwater runoff attenuation from green roofs with different soil depth. Bortolini et al. [83] tested hydrological behavior with different native plants. As for the combination of NBS options, these studies were more interested in testing different scenarios and comparing the performance of runoff reduction.

Based on the results of steps 1 and 2, it is reasonable to conclude that scientists from various perspectives, different academic fields, and multidisciplinary backgrounds have explored stormwater as an investigated phenomenon. Four domains were introduced to investigate the commonalities and the recurring clusters, demonstrating that the existing solutions have been limited to single facilities and have not fully solved water hazard problems. At the same time, many integrated options have been tested and can work with high efficiency, but they have not yet been implemented.

5. Conclusions

Given the complexity of urban development and climate change, the pressure on water resources is expected to continue. As a consequence, urban water management will continue to play a vital role not only in managing stormwater and improving flood problems but also in saving water for recycling in the face of water scarcity. Additionally, it is necessary to deal with existing grey infrastructure underground and to transform it into more resilient and sustainable solutions that can contribute to any given city's sustainability goals.

From the analysis of the results, it is possible to identify green roofs as being a very effective solution; they provide multiple benefits at the building scale. Additionally, permeable pavements, infiltration basins, and rain gardens are powerful methods for managing rainwater runoff on the ground levels at the district scale. Few studies, however, have dove deep into the analysis of the combination of these NBS options from either the roof or ground level. This represents promising research that deserves more attention and effort in the future so that we can better understand the deriving mitigation potential at the district level.

Considering the four investigated domains and their combinations, it can be clearly noted that the existing literature primarily focuses on addressing runoff quantity and runoff quality provided by green roof/NBS. However, quite a few studies (16 of 50) report and discuss their implementation in real life, using concrete applications. Most of them (34) are field tests and experimental research, which although they represent promising advances in the field, do not allow them to state that the proposed solutions are currently implemented at a wide scale. The limited level of implementation in real-life conditions may be due to different barriers and causes from the lack of adequate governmental plans to economic or technological issues hindering the diffusion of integrated solutions in different countries. This can also be explained by a lack of fully understanding interrelated elements that draft a comprehensive and adaptive framework which can connect various urban sectors to properly consider the social, technical, and economic implications.

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