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Incorporating Urban Drainage System Resilience in Public Policies for a City in a Developing Country—Colombia

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Scientific studies have shown that conventional practices on urban drainage management are not sustainable. Resilience has emerged to manage and protect socio-ecological and socio-technical systems. This paper reviews how urban drainage system resilience has been incorporated effectively into public policies worldwide to make recommendations for a city in a developing country. To this end, we carried out literature reviews to identify key actions that other countries have implemented and determine the policy baseline at the national level for Colombia. These findings were used to formulate recommendations for incorporating resilience in national Public Policies, which were validated during a workshop with experts. At the national level, we evidenced pathways to update public policies, involving a multi-step local and national activities process. A pilot project using the Santiago de Cali Resilience Strategy was proposed to implement the initial findings and identify actions by the stakeholder group. The process can be monitored and improved to be replicated in other areas.

Keywords: resilience, public policies, urban drainage, engineering resilience, SUDS, socio-ecological resilience

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INTRODUCTION

Cities are becoming a complex system of social, economic, and ecological factors (Liu et al., 2007). As a result, one of the more pressing challenges we are currently facing is how to adapt cities to critical shifts, such as climate change (Measham et al., 2011; Perry, 2015). Planning specialists have confronted this challenge using measures that focus on climate change mitigation and adaptation (Davoudi et al., 2009), while some emergency response agencies (Ward et al., 2017) and non-governmental organizations (NGOs) (Dynes and Quarantelli, 1975) have focused on sustainability and resilience (Redman, 2014).

In the urban research field, two approaches involving collective measures have emerged to manage and protect socio-ecological and socio-technical systems: urban sustainability and urban resilience. Zhang and Li (2018) reviewed the state of the art of the two concepts, observing that urban sustainability focuses on the active process of sustainable development over a long period. Conversely, urban resilience is a passive problem-solving process that occurs after facing several threats. Despite the differences between the two concepts, the authors consider that contemplating the two is necessary and relevant in decision-making and policy development processes. However, urban resilience is emerging as an attractive perspective for cities that are highly complex and adaptive systems (Meerow et al., 2016). According to Meerow et al. (2016),

> Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.

Urban resilience has two approaches, engineering and socio-ecological (Davidson et al., 2019). According to UN-Habitat (Fourniere et al., 2017), the socio-ecological approach s the best to capture the dynamism of cities, considering that the engineering approach is more appropriate for physical infrastructure, which requires a stable balance after a disturbance. Meanwhile, socio-ecological resilience focuses on strengthening resilience in governance systems through social learning and adaptation processes (Duit, 2016). The key characteristics of socio-ecological resilience are (i) persistence of the system; (ii) capacity for self-organization; (iii) capacity for learning and adaptation; and (iv) transformative capacity (Walker and Salt, 2012).

Regarding urban drainage, evidence and scientific studies have shown that conventional management practices are not sustainable (Savini and Kammerer, 1961; Chow et al., 1994; National Research Council, 2009). The population increase in urban areas has impacted basin hydrology, generating drainage problems (United Nations, 2010). Evidence of this is the rise in runoff rates and volumes and decrease in infiltration and base flow (Chocat et al., 2001; Fletcher et al., 2013). Urbanization also contributes to the potential loss of water uses, threatening the security of water supply and negatively affecting human health and biodiversity by increasing the frequency of floods and concentrations of pollutants in waterways (EURYDICE 92, 1991; Chocat, 1997; Pahl-Wostl et al., 2010).

Indeed, it is currently recognized that the traditional design approach of urban drainage systems (UDS) has neglected key aspects such as environmental protection, economic and financial management, system maintenance, regulatory and design standards, and information management. Given this oversight, it is clear that it is necessary to rethink traditional urban drainage practices (Thomas et al., 1997; Newman and Kenworthy, 1999; Wong and Eadie, 2000). In this regard, developed countries have endeavored to make changes in urban drainage management since the 1970s (Barlow et al., 1977; Chocat et al., 2001; Marsalek and Chocat, 2002). As a result, there has been a transition from a flood control approach to a more holistic approach, considering multiple objectives in the design and decision-making processes (Fletcher et al., 2014). This approach is known as water-sensitive urban design (WSUD) (Whelans et al., 1994; Wong, 2007) or sustainable urban drainage systems (SUDS) (CIRIA, 2000). Within this focus, urban waters have become a resource (Mitchell et al., 2006; Hatt et al., 2006).

Butler et al. (2014) defined three urban drainage mechanisms to increase resilience: mitigation, adaptation, and coping strategies. According to them, mitigation involves the development of long-term measures to reduce the threat. Adaptation refers to a series of actions that increase the UDS' reliability and resilience. When mitigation and adaptation fail, attention centers on coping mechanisms, focusing on protecting from or preparing for a risk situation. Specifically, adaptation strategies involve changes in the characteristics of a system to improve its responsiveness to a disruptive event, minimizing the magnitude and duration of the system's service failure. Therefore, implementing adaptation strategies in a specific UDS means expanding its flexibility and redundancy properties (Butler et al., 2014).

The implementation of resilience in UDS is restricted by the lack of guidelines, standards, and evaluation methods (Ofwat, 2012; Park et al., 2013; Butler et al., 2014). Developing countries, specifically Colombia, are no strangers to this issue. A lack of institutional efficiency is common, and the existing laws do not support water management changes (IANAS and UNESCO, 2015). Therefore, identifying the strategies used by countries that have succeeded in urban water management is key. This paper focuses on identifying the characteristics, instruments, and methodologies involved in these strategies and how they can be incorporated in the normative to promote resilience in an urban water management context in cities in developing countries.

In this study, a literature review was carried out to identify the fundamental characteristics and tools that have been used to include resilience in public policies worldwide effectively. A second review provided the Colombian policy baseline. The national policies and regulations of two major Colombian cities were considered: Bogotá and Santiago de Cali, given that the former is the nation's capital and Cali is the capital of the department of Valle del Cauca and subject of the subsequent case study. Key elements were identified that could feasibly be used to implement resilience in UDS in Colombian policy. Workshops were held with experts and representatives from local institutions in this city to obtain feedback on the results of our review, and the tools and means found that could be implemented in national policy to promote resilience.

MATERIALS AND METHODS

We first carried out a literature review to identify the fundamental characteristics and tools used to include resilience in public policies regarding international UDS management. For this purpose, we employed the following steps suggested by Hosseini et al. (2016): (i) online database search, (ii) research article abstract review refinement, and (iii) full-text review refinement. The search was done in the Web of Science database, focusing on the period from 2009 to 2019 and using the keywords resilience, resilient cities, urban politics, policy, urban resilience, urban sustainability, stakeholder participation, legislation, and urban planning. Next, we selected research articles involving urban resilience and infrastructure and urban drainage and resilience, then examined all the selected articles with specific documents including local strategies.

Then, we searched the available literature to establish the Colombian policy baseline. This search was done using the keywords policy, regulations, resilience, urban drainage, resilient cities, and sustainable urban drainage systems. We also searched national government and municipal documents that included the words resilient and water. This normative search focused on two

TABLE 1 | Summary of articles founded of each keyword's combination.

Keyword combinations	Articles 2009–2019
Resilient cities	289
Resilient cities and infrastructure	55
Urban resilience	599
Urban resilience and infrastructure	151
Urban sustainability and infrastructure	239
Urban drainage and resilience	71
Resilience and policy and urban water	64
Resilience and stakeholder participation	75
Resilience and urban planning	5
Total	**1,548**

major Colombian cities: Santiago de Cali and Bogotá, considering that Bogotá is the nation's capital and our case study involved Cali. This information was used to establish our baseline and determine what we could use to make the recommendations.

We conducted a workshop with experts and representatives of institutions from the city of Santiago de Cali on October 24th, 2019, at the MH Hotel in Cali. Twenty-seven attendees from the Municipal Public Utilities Company of Cali (EMCALI), the Administrative Department of Environmental Management (DAGMA), Santiago de Cali's Mayors Office's Resilience Office, the Community 17 Action Board, and the Universidad del Valle (organizing body). They participated in the activity to verify the viability of our results to update public policies and technical regulations implement resilience in national UDS and obtain feedback on the proposed recommendations.

In the workshop, we first presented the concept of resilience and resilience in a UDS. Then, we presented our findings on resilience and public policy and the initial recommendations for implementing the resilience concept on urban drainage management. During the last part of the workshop, the groups participated in the following tasks: (i) identifying and discussing the actions needed to implement the concept of resilience in UDS; (ii) indicating the identified actions on cards; and (iii) classifying the actions according to their implementation term (i.e., short, medium, and long). Each group selected a representative, and that person shared the answers and discussions with the audience. Finally, based on the results of this activity, we adjusted the initial recommendations to update public policies and technical regulations.

RESULTS AND DISCUSSION

Bibliometric Analysis

The literature review in the Web of Science database to identify the principal aspects of resilience regarding UDS management in worldwide public policies from 2009 to 2019 yielded a total of 1,548 articles. **Table 1** summarizes the results for each keyword combination.

Figure 1 illustrates the contributions per country for urban resilience, urban drainage & resilience, and urban resilience & infrastructure.

In terms of resilience studies, researchers from the USA led, followed by England, Italy, and the Netherlands. In general, the number of publications per year is growing, except for the "resilience & stakeholder participation" combination, which has decreased since 2015. This review indicated a lack of research in this area in Latin-American countries. Mexico is the leading country, with <20 articles. In Colombia, research efforts have focused on Risk Management and the emergence of the urban resilience concept. The results of our main findings regarding local strategies on resilience in UDS are presented in the following subsections.

International Resilience Strategies

Many researchers believe that the transition to sustainable water management has been slow (Brown et al., 2007; Cettner et al., 2013; Dhakal and Chevalier, 2015; Jiménez Ariza et al., 2019). A critical obstacle has been the absence of a comparative evaluation tool that facilitates communication between stakeholders to develop long-term policies and improve sustainable water management between cities (Gleick, 2003). Additionally, urban water managers lack a clear vision or objective that can lead to the development of a sustainable city. Responding to the previous, Brown et al. (2009) developed an urban water transition framework. This framework acts as a conceptual tool to communicate the development of a transition policy and the comparative evaluation at the macro level of the city. It has three parts that are in parallel, (i) the cumulative socio-political drivers that (ii) characterize the city and (iii) the service delivery functions. The cumulative socio-political drivers range from "Water supply access and security," then "Flood protection," to "Inter-generational equity, resilience to climate change." The city begins as a "Water supply city," then a "Drained city," finally a "Water sensitive city." The service delivery functions range from "Supply hydraulics," then "Drainage, channelisation," to "Adaptive, multi-functional infrastructure and urban design reinforcing water-sensitive behaviors." For more detail see Brown et al. (2009).

Lundqvist et al. (2001) proposed the concept of "hydro-social contracts," which are dominant values or implicit agreements between the community, government, and companies on water management. This framework contemplates the temporal, ideological, and technological contexts in which cities transition to sustainable water cities, considering variables such as specific-to-the-city historical and socio-political dynamics.

Zhang and Li (2018) carried out a study at the city level regarding resilience in public policies and technical regulations. They found that the action considered most important in most urban resilience management research was to strengthen the institutional agreements of elastic urban structure. These agreements seek to guarantee the adoption of measures toward resilient cities, hence having the potential to lead to flexible or innovative solutions. Additionally, the global level metropolitan strategies have been recognized as key to addressing contemporary urban challenges (Finco and Nijkamp, 2001;

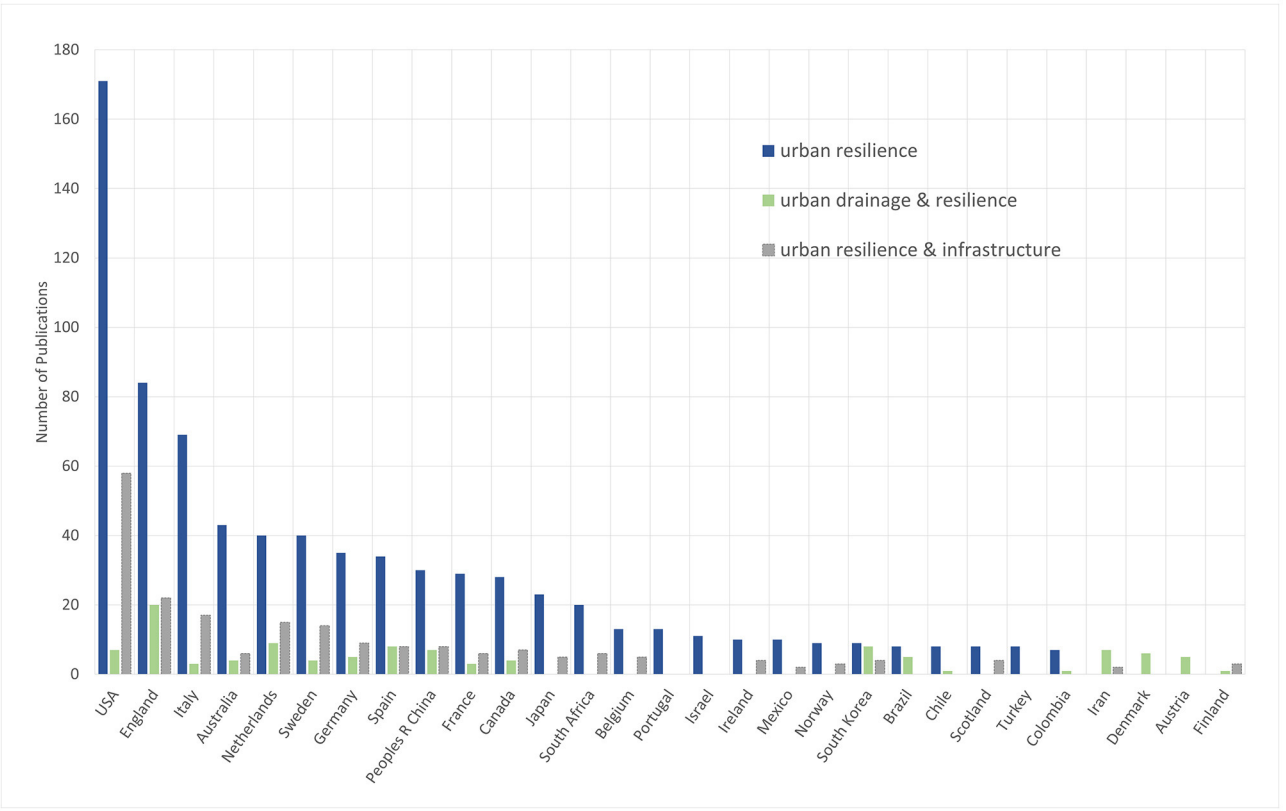

FIGURE 1 | Numbers of publications per country for urban resilience, urban drainage & resilience, and urban resilience & infrastructure.

Pinson, 2002; Gleeson et al., 2004; Davidson and Arman, 2014; Nguyen et al., 2018).

Henstra (2012) researched the process of policy development for resilient cities in two Canadian towns with extreme climates, Toronto and Halifax. The author examined the elements of the urban climate adaptation policy, mainly focusing on adaptation, one of the climate change response policies. Henstra (2012) observed that the critical step in developing adaptation policies was determining climate hazards, vulnerability, and risks from current and future climate, then identifying and prioritizing the risks and selecting the most appropriate responses. This step requires expert knowledge and specialized information analysis, for example, in socioeconomic, hydrometric, and meteorological data (Fünfgeld, 2010). Another crucial element identified was internal steering committees to adapt policies and integrate principles into existing policies, official community plans, and programs, constituted by individuals representing the departments of environment, public health, and water (Henstra, 2012).

The formulation of adaptation policies of both Toronto and Halifax was initially based on the construction of information-based tools to visualize the current state of climate change and generate ideas to reduce vulnerability. Then, through forums, obtain public feedback on the formulated ideas. For example, in Toronto's case study, the adaptation committee aimed to project adaptation strategies. Their first initiative was to develop a panel of experts. Government scientists, university researchers, and non-governmental organizations attended this panel. After this panel, the committee led workshops with focus groups and community information sessions for several months. The main objective was to motivate decision-makers and the community to generate ideas and provide feedback on previous related projects. With this process, Toronto obtained short-term adaptation actions toward transforming into a resilient city (Henstra, 2012).

Davidson et al. (2019) developed a methodology to evaluate the inclusion of socio-ecological resilience within the urban planning practice. The authors reviewed local strategies such as "Our People, Our Place" of Greater Manchester in the United Kingdom and "The 30-Year Plan for Greater Adelaide: Living Adelaide" in Australia. They found that the only strategies involving socio-ecological resilience were "One New York: The Plan for a Strong and Just City" (OneNYC) and the Melbourne Plan. The authors used these plans as a study case. They noted that the dominating concept in both plans was engineering resilience, suggesting that it is easier to translate engineering resilience into planning instruments. However, they noted that these plans lacked the essential components of resilience (e.g., economic resilience). Because both plans use the resilience concept essentially as a response to climate change or natural disasters, the strength of the concept is reduced. The use of resilience should aim to build a society and a flexible economy capable of adapting to uncertainty (Drobniak, 2012). It is crucial

to highlight that Davidson et al. (2019) identified the implications of using resilience for the theory and practice of urban planning, which can potentially generate proactive policy changes and support the beginning of a new planning paradigm. The authors observed progress in its inclusion in management plans in terms of engineering resilience. However, it is necessary to continue efforts to include socio-ecological thinking to potentially provide innovative ideas for city governance.

In 2011, MWH (engineering, consulting, and construction management firm) developed a study for OFWAT, the water services regulation authority in England and Wales, to know how other countries (USA, Switzerland, the Netherlands, New Zealand, Australia, and Scotland) have implemented innovative approaches in urban drainage compared to England and Wales. Based on this information, six main characteristics were identified: (i) management responsibility; (ii) funding source; (iii) society commitment; (iv) incentives for urban drainage management; (v) regulations for urban drainage management; and (vi) urban drainage integration with planning.

Concerning management responsibility, England and Wales's privately managed urban drainage schemes do not promote public participation or work between stakeholders (MWH, 2011). The study notes that responsibility from a sole point does not promote more innovative approaches. The key is to generate decisions from a group of stakeholders with the community's support to manage the UDS better.

The financing of UDS, the sources are similar among the countries surveyed. The key here is cross-financing between different organizations, which is common for most countries surveyed except in England and Wales. The study results showed that incentives play a fundamental role compared to the legislative part by being more successful in encouraging innovative approaches. Besides, a commitment from society allows for effective public participation and good stakeholder management. These practices facilitate the adoption of innovative measures in UDS (MWH, 2011).

Regarding the regulations and standards to implement new methods in UDS, the MWH (2011) showed that their use increased when directed toward pollution control. Therefore, the change in planning regulations has served as a vehicle for change. The study showed that most countries integrate UDS into planning, mainly because UDS innovation requires a larger group of bodies responsible for urban environment. Finally, the MWH (2011) identified five lessons to implement innovative measures in UDS:

i. A culture of fear of risk does not encourage innovation, especially when products must be safe and delivery times are short.
ii. A history of failure exists for first-time measures.
iii. Time is a requirement for the full involvement of all the key stakeholders in the innovative approach; for example, in Sweden, it took 10 years.
iv. Developing national long-term infrastructure programs requires appropriate funds, which was the case with the Dutch system.
v. UDS management information in the public domain supports public participation and work among stakeholders.

National Policies and Regulations Review

Table 2 presents the regulation and strategies related to resilience, sustainability, and UDS at the national level. Based on the findings, we observed that there are already advances and some supporting pillars. Law 1523 of 2012, from de Congress of Republic of Colombia, adopted the national disaster risk management policy and established the national disaster risk management system. Also, through it, the term resilience entered into the definition of the word adaptation (Ley 1523 de 2012, 2012). Law 1931 of 2018 determined the guidelines for climate change management. In Article 16, the government defined the National Climate Change Policy; its aim includes climate change management in public and private decisions to advance toward climate-resilient and low carbon development to support the reduction of risks associated with climate change (Ley 1931 de 2018, 2018).

In 2019, the newly elected Colombian government presented the "National Development Plan 2018–2022 Pact for Colombia, Pact for Equity" under Law 1955 of 2019 (Ley 1955 de 2019, 2019) to boost economic growth to improve the country's development. This plan has three structural agreements: legality, entrepreneurship, and equity and incorporates 12 transversal agreements to fulfill these objectives. The Pact for Sustainability (Pact IV) includes the term resilience in the following subchapters: (i) Resilient Colombia: knowledge and prevention for disaster risk management and climate change adaptation; (ii) Modern environmental institutions, social appropriation of biodiversity, and effective management of socio-environmental conflicts (DNP, 2019).

In the "Resilient Colombia" subchapter, the government proposed the details of the activities to reduce risk conditions, increase climate resilience, and limit the sectors' losses. There are also technical guidelines to analyze climatic risks and adaptation criteria in new projects, built environments, and basic sanitation infrastructure. The Ministry of Housing, City, and Territory (MinVivienda) oversees this segment, with the support of the Ministry of the Environment (MinAmbiente) and the National unit for risk disaster management (UNGRD). It also proposed the design of a public policy to reduce the risk conditions in the event of climatic variability, headed by the National Planning Department (DNP), MinAmbiente, the Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), and the UNGRD. In the second subchapter, "Modern environmental institutions," the government identified that there is no integrated vision to promote resilient and sustainable territories between the National Environmental System (SINA), SNGRD, and National Climate Change System (SISCLIMA). Thus, they proposed to strengthen the mechanisms of articulation and coordination for sustainability (DNP, 2019). This subchapter places more emphasis on the term sustainability than on resilience.

At a local level, in Santiago de Cali, the Corporation of Valle del Cauca (CVC), the Administrative Department of Environmental Management (DAGMA), and the International Center for Tropical Agriculture (CIAT) combined technical

TABLE 2 | Regulations and strategies related to resilience, sustainability, and UDS.

	Normative/Strategy	Subjects related to resilience, sustainability, and UDS			
		Water	**Land use**	**Risks**	**Sustainability**
Colombia					
1973	Law: Ley 23 de 1973 (1973)	Use			
1978	Decree (Decreto 541 de 1978, 1978; Decreto 597 de 2018, 2018)	Use (rainwater)			
1993	Law: Ley 99 de 1993 (1993)		Landscape protection		
1997	Law: Ley 388 de 1997 (1997)		Management Green areas		
	Law: Law 1450 de 2011 (2011), Ley 373 de 1997 (1997)	Efficient use			
2011	Law: Ley 1523 de 2012 (2012) (Development Plan)	Integrated management			
2012	Law: Ley 1523 de 2012 (2012)			Management	
	Decreto 1640 de 2012	Management			
2015	Resolution: Resolución 0549 de 2015 (2015)	Efficient use			Sustainable construction
2017	Resolution: Resolución 0330 de 2017, 0330 (2017)	Management			
2018	Law: Ley 1931 de 2018 (2018)			Climate change	
2019	Law: Ley 1955 de 2019 (2019) (Development Plan)			Management Resilience	Sustainability
Bogotá					
2000	Decree: Decreto Distrital 619 de 2000 compiled by Decrees: Decreto 190 de 2004 with Decreto 469 de 2003	Management	Management	Mitigation	
2005	Decree: (Decreto Distrital 215 de 2005, 2005)		Green areas Main ecological structure Public space		
2006	Decree (Decreto Distrital 314 de 2006, 2006)	Management			
	Decree (Decreto Distrital 319 de 2006, 2006)		Green areas		
2009	Agreement: Acuerdo 391 de 2009 (Acuerdo 391 de 2009, 2009)			Climate change	
	Agreement: Acuerdo 418 de 2009 (Acuerdo 418 de 2009, 2009)				SUDS
2010	Decree: Decreto 043 de 2010		Management		SUDS
2011	Resolutions: Resolución 6523 de 2011 (2011)				SUDS
	Resolución 6524 de 2011 (2011)			Climate change	
	Resolución 3654 de 2014 (2014)*				Sustainable construction
2014	Decree: Decreto 528 de 2014				SUDS
	Decree (Decree 088 de 2017, 2017)		Management		SUDS
2018	Technical standard (EAAB, 2018)				SUDS
2019	Resolution: SPN IDU (2019)		Green areas		SUDS
Santiago de Cali					
2014	Agreements: Acuerdo Agreement 0373 de 2014, 2014; Acuerdo 418 de 2009, 2009	Management	Management	Mitigation	Sustainable construction SUDS
2017	Plan (Climate change mitigation and adaptation)			Climate change	
2018	Guidelines (rainwater flows)	Management (stormwater)			SUDS
2019	Program Cali Resilient (Alcaldía de Santiago de Cali, 2019)			Resilience	

**Repealed, UDS, Urban Drainage Systems; SUDS, Sustainable Urban Drainage Systems.*

and economic efforts in response to the global climate change management initiative and the ratification by the national government. They suggested actions to be implemented within the Comprehensive Climate Change Adaptation and Mitigation Plan framework for Santiago de Cali. Resilience is part of this plan's conceptual and methodological framework as a tool to

promote the adaptation of social, economic, and environmental systems (CVC et al., 2017). These entities defined programs within each line, comprising objectives, activities, approximate costs, and goals. They proposed five programs for the integrated water resources management line, including (i) protection and restoration of water-producing areas under a scheme of payment for environmental services; (ii) water and biodiversity management guidelines update with a climate change approach; and (iii) a comprehensive rainwater management program using SUDS as an instrument to build climate change resilience.

In 2015, Santiago de Cali became part of the program "100 resilient cities" of the Rockefeller Foundation. Engagement in this program helped the city build its resilience strategy using a robust methodology (The Rockefeller Foundation, 2019). However, before the resilience strategy, the city committed to demonstrating its involvement and empowerment. Hence, the city created the "Cali Resilient" program within the "Secretariat of territories of inclusion and opportunities." With this program, the mayor launched the resilience strategy in 2018. The strategy has five action lines: (i) education for opportunities; (ii) coexistence for life; (iii) mobility for development; (iv) sustainability for the future; and (v) planning for progress. Urban drainage is addressed within the line of action of sustainability for the future, which proposes the following two objectives: (i) to strengthen the use of the territory to preserve natural resources and (ii) to establish effective mechanisms for decision-making. They will develop these objectives through ten initiatives, five for each (Alcaldía de Santiago de Cali, 2019).

Based on international evidence, we identified the fundamental characteristics and tools used to include resilience in UDS public policies. The findings at the national level gave us a broad scenario and where to start to generate recommendations on the inclusion resilience of UDS in public policies and technical regulations.

Recommendations for the Incorporation of Resilience in UDS in Public Policies

According to the international literature review, the concept of resilience in public policies is a contemporary issue, especially in socio-ecological resilience terms. The key factors found for incorporating urban drainage resilience were summarized in **Figure 2**. The arrows in this figure represent that the movement of each gear is relevant for achieving urban drainage resilience, so each factor is needed. We recognized management tools, such as the urban water transition framework to support stakeholders interested in having a clear vision of developing a sustainable and resilient city in terms of urban drainage. Also, we observed that management instruments, such as metropolitan plans, contribute to making a city more efficient in initiatives execution (Davidson et al., 2019), and they must have a long-term vision. For local development, it is also necessary to consider establishing hydro-social contracts (Lundqvist et al., 2001) and evaluate if they must remain the same or change. Additionally, to implement innovative approaches in the UDS, we recommended adapting and applying the identified characteristics of countries' strategies with successful cases to facilitate resilience of UDS implementation. We identified the implications of collaborative work, the use of information tools for decision-making (Henstra, 2012), and the importance of having information in the public domain to include the concept of resilience (MWH, 2011). The use of these tool types appears to encourage more efficient processes of the cities toward resilience.

The findings at the national level evidenced pathways to update public policies, involving a multi-step process regarding local and national activities. One recommendation could be to propose a pilot project using the Santiago de Cali Resilience Strategy, choosing one program of the lines of action (e.g., Integral rainwater management program through SUDS) to develop. This part could begin with implementing engineering resilience and gradually integrating the socio-ecological component. Parallel to the above, a strategic ally of the Multilateral Banking (e.g., IDB or the World Bank) could help secure resources. This project could be scalable to a body such as the Departmental Council of Environmental Policies and Integral Management of Water Resources (CODEPARH) of the Governance of Valle del Cauca. Through this body, we could seek to replicate this strategy to other Valle del Cauca towns and, thus, give technical guidelines for the formulation and updating of public policy.

Case Study Outcomes

During the first two parts of the workshop conducted with experts and representatives of institutions in Cali, we introduced the urban water transition framework to open dialog and facilitate communication in terms of urban water management. We then shared the importance of the hydro-social contract updating and the main characteristics of the innovative implementation of approaches in urban drainage, emphasizing that one of the main drivers is pollution control and that culture with a fear of risk does not encourage innovation. We also illustrated the key factors identified for urban drainage resilience incorporation and the opportunities that we evidenced with the implementation of the Santiago de Cali Resilience Strategy (section Recommendations for the Incorporation of Resilience in UDS in Public Policies).

During the last part of the workshop, which consisted of group work on the proposed strategies and their socialization, the stakeholder groups suggested actions to implement the concept of resilience in UDS for the short and medium term. However, they did not identify any for the long term. **Figure 3** summarizes the results of the last workshop's group activity.

From the workshop results, we identified that it is crucial to include the visualization of inter-institutional coordination in the development of the pilot project, with the definition of roles and participation of each body to generate visibility and an implementation model. We could also emphasize the planning part of the pilot project in communications with the stakeholders. Additionally, developing a project that focuses on disseminating the concept of resilience at the institutional level could create ownership and facilitate its implementation.

CONCLUSIONS

With the development of this project, we were able to identify key actions to modify and formulate public policies and technical regulations to achieve resilience in urban drainage systems

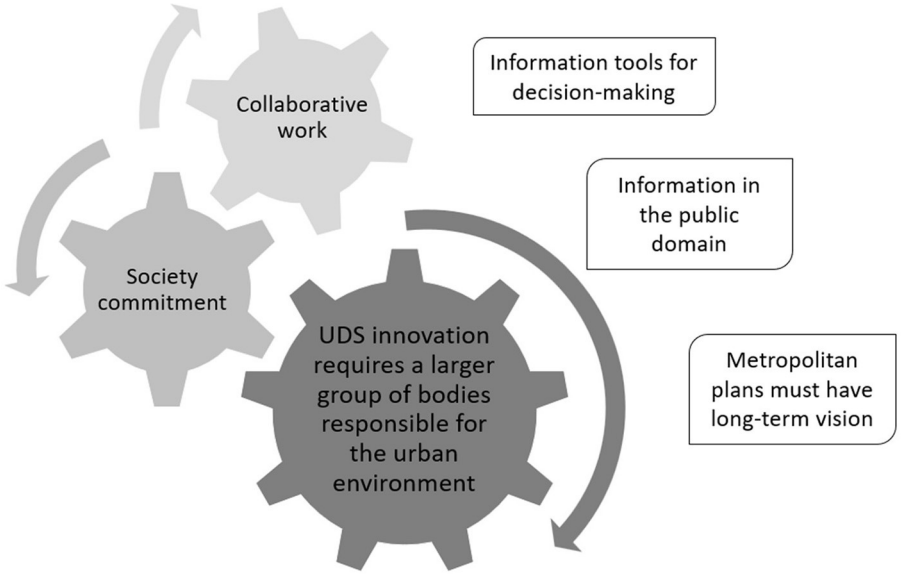

FIGURE 2 | Key factors identified for urban drainage resilience incorporation.

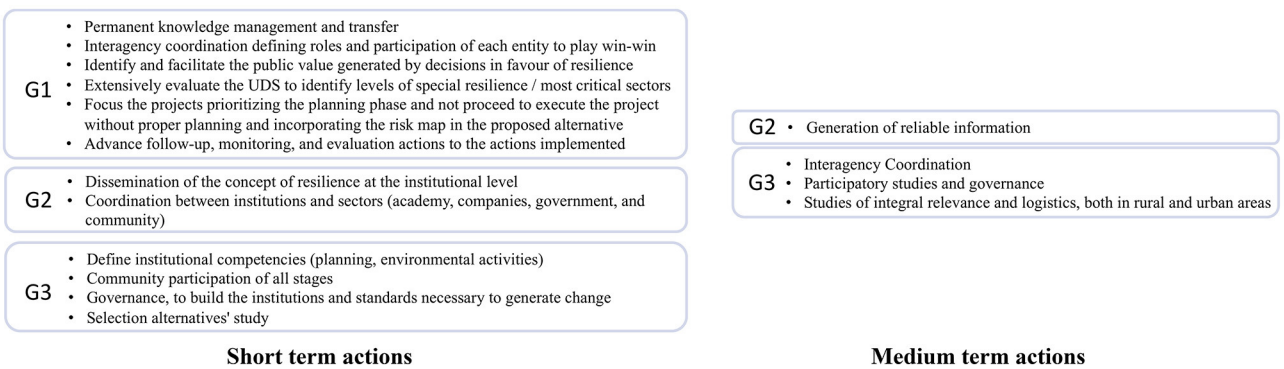

FIGURE 3 | Actions identified to be executed in the short and medium term.

(UDS) in a city of a developing country like Colombia. Firstly, we recognized management tools, such as the urban water transition framework, to support stakeholders interested in having a clear vision of developing a sustainable and resilient city in terms of urban drainage. Additionally, the concept of the hydro-social contract stood out as an element of analysis that contemplates the temporal, ideological, and technological contexts. Through this concept, cities can transition to sustainable water cities. Moreover, this concept is sensitive to other variables such as the city's historical and socio-political dynamics, potentially adjusting to the contemporary context of urban drainage management.

Furthermore, integrating the new adaptation policies into existing policies, official plans, and communities' programs is imperative to create internal steering committees made up of key representatives of government departments (water or environment offices). Within this line, we identified the role of technical boards, workshops with focus groups, and information sessions with the community to motivate decision-makers and the public to generate ideas and obtain feedback. The above has an essential technical component: the use of information-based tools to visualize the current status of UDS and the results of implementing possible solutions.

The workshop demonstrated the importance of the support from stakeholders outside the developed project, who enriched the recommendations proposal from their expert knowledge in UDS. These experts focused on short and medium-term actions, including aspects involving knowledge transfer, inter-institutional and inter-sectoral work, diagnostic of the UDS, monitoring of future projects, the indispensability of the planning stage, and governance.

One of the limitations of our study is that before implementing what we suggested, we need to know if the workshop attendees are still the same people. Or if the

experience was documented, given that is relevant to the institutional commitment, through people, to achieve strategy's successful development.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The aim and scope of this research paper was defined by all the authors. SG-M was part of the research project *Gestión de la resiliencia en sistemas de drenaje urbano* (Resilience management in urban drainage systems) project implemented by the Universidad del Valle. She wrote the paper and made all the analyses during her work. AG-C (Project Supervisor) and Patricia Torres Lozada (Project Co-supervisor) guided the research. They revised and corrected the paper. All authors contributed to the article and approved the submitted version.

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