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Systematic Review

Revisiting Urban Resilience: A Systematic Review of Multiple-Scale Urban Form Indicators in Flood Resilience Assessment

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Abstract: Despite the increasing number of flood studies, the interrelationships between urban form indices (UFIs) and flood resilience (FR) have received little attention and hold miscellaneous perspectives. Consequentially, this study identifies how UFIs at various spatial scales affect FR by synthesizing article findings and proposing insights for future research. Scientometric analysis has been used to analyze the gathered peer-reviewed articles from nine research engines without time restrictions. One hundred and eighteen relevant articles were included and thoroughly investigated using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. Our findings indicate that divergent and dialectical perspectives about the efficacy of UFIs are due to multiple disciplines, methodologies, and different case study contexts. The included studies were classified according to urban scale as macro (citywide), meso (districts), micro (block), and multi-scalar analysis by 80.5%, 6.8%, 10.2%, and 2.4%, respectively. Furthermore, the included studies were categorized based on analysis type into realistic case studies, literature reviews, modeling, and hybrid analysis, with 74.6%, 7.6%, 14.4%, and 3.4%, respectively. At the macroscale, city density and spatial distribution degree have the most significant effect on FR. At the same time, mixed uses, connectivity, coverage ratio, block arrangements, and street characteristics are on the meso and micro scales. Further studies on the trade-offs and commonality between UFIs, FR, and overall urban resilience are required to shape climate-adaptive, sustainable communities.

Keywords: urban planning; urban form; flood resilience; PRISMA; climate change; scientometric analysis

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1. Introduction

Currently, 55% of the global population lives in urban areas, with projections to rise to 68% by 2050 [1]. Amidst rapid urbanization and urban vulnerability, cities are confronted with a panoply of natural disasters, jeopardizing their sustainability and exacerbating socioeconomic inequalities, particularly in marginalized communities and hinterlands [2–7]. In September 2015, the United Nations (UN) endorsed Sustainable Development Goal 11 (SDG11) to make cities and human settlements inclusive, safe, resilient, and sustainable. This goal is part of the 2030 Agenda to ensure that urban areas are socioeconomically vibrant, environmentally sustainable, and adaptable to climate change [2–4,8]. Despite SDG 11, urban communities frequently stray from these aspirations, and numerous cities worldwide suffer from natural disaster susceptibility. A recent UNDRR report, "Human Cost of Weather-Related Disasters 1995–2015", revealed the staggering toll on human lives and well-being since the Climate Change Conference (COP1) in 1995 [9,10]. Six hundred and six thousand lives have been lost, and 4.1 billion people have been injured, left homeless, or in need of emergency assistance [11]. According to EM-DAT, climate change contributed to a USD 203.35 billion loss in 2023, four times higher than in 2000, and about 100.26 million people were displaced from their habitats [12]. These effects differ from place to place based on individual contexts and risk characteristics. For example, cities in low-income countries with the most urban residents face more climate risks, lower resilience, and higher economic losses than high-income cities [13,14]. Moreover, rural areas are even less prepared against natural disasters than cities, with more than 80% of disaster-related casualties and economic losses occurring in rural areas [15].

Among previous natural disasters is urban flooding, the riskiest and most frequent, affecting more than 10% of the world's population in the last ten years, according to the Emergency Events Database (https://www.emdat.be/, accessed on 17 November 2023). Floods and other water-related threats caused by climate change, such as waterborne diseases or water scarcity, have increasingly become hazards in many parts of the globe [16]. A UNDRR report revealed that flooding alone constituted 47% of all weather-related disasters between 1995 and 2015 [7,17]. Alarmingly, the vast majority of these losses (89%) occurred in low-income countries, despite these nations experiencing only 26% of all floods [11]. Climate-induced changing precipitation patterns are the primary reason for the 181% increase in flooding frequency and severity worldwide in 2010–2020 compared to 1980–1989. A large ensemble of numerical simulations revealed that 64% (14 of 22 events) of floods analyzed in 2010–2013 were affected by anthropogenic climate change [18]. Another reason for flooding is human activities like rapid expansion, unsustained densification in flood-prone communities, land cover changes, aging drainage systems, and disinvestments in hazardous districts [19–28]. For several decades, structural measures have been widely used in flood-proofing; however, these measures have shown weaknesses. These measures create a false sense of security in people and policymakers who rely solely on them and neglect other flood risk management measures [29,30]. Implementation and maintenance can also strain public budgets, especially in low-income countries. Based on historical data and current conditions, structural measures are typically designed to protect against floods. However, they may not be effective in the long term and fail during extreme weather events, leading to catastrophic consequences such as levee breaches or structural collapse [22,29,31,32]. A contemporary approach has emerged in recent years, combining structural and non-structural measures during spatial planning in flood-prone areas. This approach reaches the root causes of flood risk and makes communities more resilient through spatial planning mechanisms [22,31,33,34].

Spatial planning is one of the essential non-structural approaches to improving FR by directing sustainable land use development and management in flood-prone areas [29,32,35]. Effective spatial planning integrates flood risk considerations, including zoning regulations, land-use planning, floodplain preservation, and natural buffers to absorb and mitigate floodwaters. Additionally, spatial planning can promote resilient building designs, facilitate the coordination among flood risk management strategies across different scales, and foster community engagement [25,36]. Urban form, a non-structural spatial planning tool, is one of the main paths that help planners efficiently intervene and change undesirable trajectories in the city system [37–39]. It creates a synergistically interconnected and protective tissue that facilitates effective emergency response in the disaster aftermath [40–43]. For example, compact urban forms can limit sprawl into flood-prone areas and preserve valuable agricultural land and natural habitats. Additionally, mixed-use development supports resilient communities with access to essential services and amenities even during flood events [44,45]. Due to the recognition of the importance of urban form, many global strategies have been implemented, focusing on changing city morphology by incorporating sustainable storm management strategies in densely built areas [7]. These include LID (low impact development) in North America, sponge cities (SC) in China [46], green infrastructure (GI) or best management practices (BMPs) for water management, sustainable urban drainage systems (SUDS) in the United Kingdom [47], and water-sensitive urban design (WSUD) in Australia [48,49].

Despite the significance of urban forms, debates about the most influential urban form in FR have arisen [50]. Some studies have regarded the compact form as a symbol of modern urban planning; at the same time, recent discussions have focused on whether this form is ideal for FR. A compact urban form may expose many assets and lives to risk due to the higher concentration of runoff volume in a limited area. On the other hand, higher population densities and mixed land use can minimize urban sprawl, leaving more open space for runoff absorption [51]. Some scholars present several counterarguments that increasingly intense and unpredictable rainfall patterns can overwhelm even the most well-designed urban form strategies, making them less effective at flood reduction. Additionally, retrofitting cities and modifying urban forms to prioritize flood reduction may lead to sophisticated consequences, such as increased traffic congestion or reduced housing affordability. All previous discussions raised the necessity of assessing the trade-offs between urban form and FR in alignment with broader efforts in disaster risk reduction. Therefore, our main research question is: What are the critical urban form characteristics at different scales that enhance FR? And why have divergent opinions been raised about the effectiveness of urban forms on FR? Consequently, a systematic review was conducted using nine scientific database engines to find peer-reviewed articles and classify them using the PRISMA method. Studying this point is a critical research area with far-reaching implications, in addition to combining several disciplines (urban planning, environmental management, disaster risk reduction, etc.) that add scientific value to the disaster management field.

2. Theoretical Background

Before exploring potential associations between UFIs and FR, we clarify the meanings of urban resilience and vulnerability, multiple-scale urban form and hierarchy, and flood resilience, as shown in the following sections.

2.1. Urban Resilience and Vulnerability

Vulnerability and resilience often exist on opposite ends, yet they influence each other. While vulnerability highlights weaknesses and susceptibilities, resilience focuses on strengths and adaptive capacities. There is a negative correlation between vulnerability and resilience, as vulnerability decreases, resilience increases, and vice versa. Vulnerability refers to the susceptibility of individuals, communities, or systems to harm or adverse impacts stemming from various factors such as socioeconomic disparities, environmental degradation, or inadequate infrastructure [21,52–54]. According to the Sendai Framework for Disaster Risk Reduction (SFDRR), 2015–2030, assessing vulnerability is a significant stage in disaster risk management and reinforcing resilience [55,56]. The SFDRR defines vulnerability as how climate events can harm human beings, their livelihoods, property, capital assets, and the urban environment [57]. The Intergovernmental Panel on Climate Change (IPCC) describes it as a system's capacity or incapacity to be resilient in dealing with the negative influences of variability and the extremes of climate change [25,58–60]. Vulnerability can help policymakers identify highly vulnerable areas and system flaws and allocate resources for adaptation and alleviation [5,61,62]. The vulnerability paradigm has evolved over the years, with three key stages: disaster management in the 1990s, disaster risk management in the 2000s, and resilience management and development in the 2010s [63].

On the other hand, resilience refers to cities' ability to withstand and recover from various forms of stress, including natural disasters, economic downturns, and social unrest. The United Nations Office for Disaster Risk Reduction (UNISDR) offers a commonly cited definition of urban resilience, which entails the urban system's ability to anticipate and handle risks, absorb disturbances, and adapt to changing conditions by reorganizing itself [64,65]. This resilience is not just about physical structures but also involves socioeconomic, environmental, and institutional capacities that enable communities to bounce back and thrive [33,66–69]. Resilience theory drives two primary approaches: the equilibrium approach, which restores a city to its pre-disaster state, and the evolutionary approach, which advocates for a comprehensive transformation of the city system [70–73]. Many frameworks have emerged to measure disaster resilience, such as the disaster resilience of place (DROP) model and the operationalized version called "the baseline resilience indicators for the community" (BRIC) framework [69,74]. The DROP framework has been constructed to demonstrate the link between resilience and vulnerability and present a holistic evaluation of disaster resilience at multiple scales [17,66,75,76]. Nevertheless, the BRIC assesses intrinsic resilience, also known as pre-event resilience, using six dimensions: socioeconomic, community, financial, institutional, infrastructure and built environment, and ecological [74,77,78].

Urban resilience comprises many characteristics, as shown in Table 1: redundancy, complexity, collaboration, efficiency, adaptability, self-organization, multifunctionality, productivity, agility, resourcefulness, foresight capacity, modularity, diversity, creativity, connectivity, independence, flexibility, and deformability [79]. Redundancy, exemplified by duplicate infrastructure or services, ensures urban systems can continue functioning even if one component fails [80,81]. Complexity recognizes the intricate interconnections within cities, acknowledging that disruptions in one area can have cascading effects. Collaboration fosters synergy between various stakeholders, promoting coordinated responses and resource sharing during crises. Efficiency ensures optimal resource utilization, minimizes waste, and maximizes output [17]. Adaptability allows cities to adjust to changing environmental, social, or economic conditions by implementing responsive policies and infrastructure upgrades [82,83]. Self-organization empowers communities to mobilize resources and initiatives independently, bolstering resilience at the grassroots level. Multifunctionality promotes versatile urban spaces that serve diverse needs, fostering resilience through flexibility and adaptability. Productivity ensures efficient resource utilization and wealth generation, reinforcing a city's ability to withstand and recover from shocks [84–86]. Agility denotes the capacity to adapt, respond, and navigate change rapidly and effectively, which involves being flexible and proactive in adjusting to evolving circumstances, seizing opportunities, and overcoming challenges [10,87,88].

Resourcefulness encourages innovative solutions and alternative approaches to problem-solving, enabling cities to overcome challenges with limited resources [80,89]. Foresight capacity involves proactive planning and risk management, anticipating and mitigating potential threats before they materialize [80]. Modularity allows for flexible adaptation and expansion of infrastructure and systems as needed, enhancing resilience through scalability and versatility. Diversity fosters resilience by promoting a range of perspectives, skills, and resources within a city, enhancing its ability to adapt to changing conditions [90–92]. Creativity encourages the development of innovative solutions and approaches to urban challenges, fostering resilience through continuous adaptation and improvement [75,93,94]. Connectivity facilitates information exchange and collaboration between sectors and stakeholders, enhancing resilience through shared knowledge and resources. Independence promotes self-reliance and autonomy within communities, reducing dependence on external resources and improving resilience to disruptions [81]. Flexibility and deformability enable urban systems to absorb and recover from shocks by allowing for adjustments and transformations, ensuring resilience in the face of uncertainty and change [43]. Deformability recognizes that cities are dynamic, constantly evolving entities that must adapt to changing conditions and challenges. This adaptive capacity allows urban systems to bend, stretch, or reshape themselves to better withstand and recover from adverse events, thereby reducing vulnerabilities and enhancing overall resilience.

Table 1. A concise overview of urban resilience characteristics.

Shocks and Stressors	Resilience Stages	Sub-Stages	Definitions	Resilience Characteristics
- Natural (earthquakes, hurricanes, floods, wildfires, volcanic eruptions, tsunamis, and droughts) - Environmental (habitat destruction, pollution, deforestation, climate change, and loss of biodiversity) - Social (demographic changes, cultural shifts, social movements, political upheavals, conflicts, and migrations) - Economic (economic downturns, inflation, currency crises, market crashes, trade disputes, and disruptions to supply chains) - Technological (breakthroughs in technology, technological accidents, infrastructure failures, cyberattacks, and data breaches) - Attacks and terrorism (terrorist attacks, bombings, cyberattacks, and acts of warfare)	Awareness and understanding	Pre-disasters	This stage involves recognizing potential threats and vulnerabilities a community or organization faces. This stage includes conducting risk assessments, gathering data on hazards, vulnerabilities, and capacities, and engaging stakeholders to understand the challenges.	Collaboration; efficiency; resourcefulness; foresight capacity; creativity; connectivity
	Planning and preparation	Pre-disasters	This stage includes creating emergency response plans, developing early warning systems, establishing communication protocols, and identifying the resources and capacities needed for an effective response.	Redundancy; complexity; collaboration; efficiency; resourcefulness; foresight capacity; creativity; connectivity
	Adaptation	During-/post-disasters	Adaptation refers to adjusting or modifying urban systems, policies, and practices to better cope with and respond to changing environmental, social, and economic conditions.	Collaboration; independence; flexibility and deformability; resourcefulness; agility; modularity; redundancy
	Absorption	Post-disasters	Absorption refers to a system's capacity to absorb and manage the initial impacts of disruption without experiencing catastrophic failure or significant damage.	Modularity; diversity; independence; efficiency; multifunctionality; robustness; redundancy
	Self-organization	Post-disasters	This capability is needed to restore the urban system's performance to its baseline in the short to medium term after an event.	Adaptability; self-organization; diversity; efficiency; independence; multifunctionality; connectivity; productivity

Source: the authors (depending on [20,41,76–78,80,84,86,87,89,92,95–101]).

2.2. Urban Form Characteristics

Urban form describes the physical layout, design, and spatial organization [10,38]. It encompasses the arrangement of buildings, streets, open spaces, infrastructure, and land uses within a city, as well as the patterns of connectivity and urban density. Urban form plays a crucial role in shaping cities' functionality, livability, and sustainability, influencing various aspects of urban life: transportation, land use, social interactions, and quality of life. Different urban forms can result in distinct urban experiences and outcomes, reflecting diverse cultural, historical, economic, and geographical contexts. It fosters urban resilience to various environmental challenges and pressures [51]. For example, compact and mixed-use urban forms promote efficiency and connectivity by minimizing mobility distances between land uses, reducing energy consumption, and fostering social interaction [102–104]. Additionally, it supports public transportation networks, reducing reliance on private vehicles and mitigating traffic congestion and air pollution [105–107]. Figure 1 illustrates three forces that shape urban forms. The first is the centrifugal force, called urban proliferation, which incorporates fragmented settlements in the city's periphery or diffused-haphazard buildings characterized by low density with the existing urban masses [108,109]. The second is the centripetal force, called “compactness forces” or monocentric high-density development, which intensifies built-up areas through infill development, reusing brownfields, and replacing existing buildings with new ones [104,110,111]. The hybrid force, also known as the topo-diverse form, is the last [112]. The topo-diverse city, as envisioned by Samuelsson, represents an urban form that adheres to these principles. It is characterized by a macroscale polycentric structure, balancing spatial containment and urban sprawl. This form supports active movement and psychological restoration, providing a variety of environments that cater to different needs and preferences.

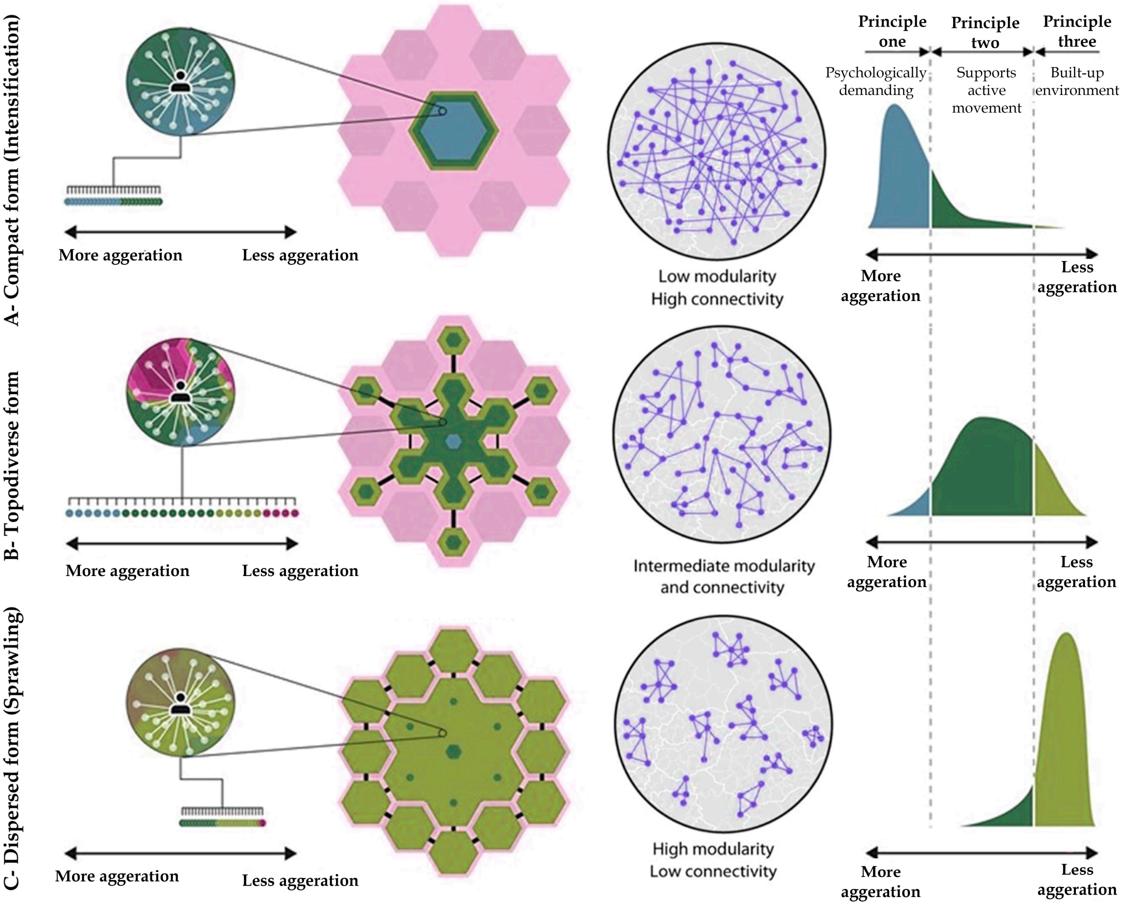


Figure 1. Classification of urban forms. The first row illustrates schematic histograms of the aggregation degrees, while the second row shows each pattern’s connectivity and modularity. In contrast, the last row indicates the characteristics of each pattern, such as the built-up environment, movement, and psychological demands—source: adapted from [112], after modification by the authors. The authors added mobility and connectivity networks to the three urban forms.

2.3. Multiple-Scale Urban Form and Hierarchical Approaches

The scale hierarchy of urban form is a conceptual framework that organizes urban elements into a hierarchical structure, reflecting the complexity and interconnectedness of urban systems [113]. As shown in Table 2, the macroscale is at the top of the scale hierarchy, encompassing the entire city. Macro and meso scales are divided into districts, neighborhoods, and smaller urban areas, focusing on individual buildings, streets, and public spaces. Finally, the nanoscale is at the bottom of the scale hierarchy, including the tiny elements of the urban environment, such as individual rooms, furniture, and even objects within these spaces.

- **Macroscale urban form** refers to the overall urban structure and layout, including its current configuration and future development plans, considering urban systems’ complex dynamics and interdependencies [43]. The macroscale category incorporates several key attributes that define urban form, encompassing the scale hierarchy, city size, development type, distribution pattern of people and jobs, degree of clustering, and landscape connectivity [10,43,114]. City size and density are two critical indicators of urban form, measured by gross and net density [101,115]. City size refers to the total area, including built-up and non-built-up areas, whereas density measures how many people are packed into a given area [111,116]. Development-type indicators assist in understanding the nature of urban development, encompassing aspects such as formality level versus informality and the specific location of the development [5,73,117,118]. These indicators assess a development's characteristics, whether characterized by a formal, structured approach or a more informal development style. Additionally, they provide insights into growth location, distinguishing between infill and greenfield developments built on undeveloped land [5]. Indicators related to clustering degree are essential for understanding whether a city exhibits a uniform, monocentric, polycentric, or hybrid development pattern [112,119]. Clustering degree is closely linked to well-known urban form characteristics such as centrality and accessibility, which are critical for assessing urban infrastructure and service efficiency [6,103,120,121]. Another critical development indicator is the distribution of jobs and employment, which helps analyze residents' mobility patterns and choices [98]. Finally, landscape connectivity is a crucial indicator that examines the nature and extent of connections between the city and other settlements within the broader system of settlements, as well as between ecosystem components within and beyond the city's boundaries [92,122–124].

- **Mesoscale urban form** examines the broader layout of neighborhoods and districts, focusing on key characteristics such as the arrangement and dimensions of these areas, the mix of land uses, transportation infrastructure, accessibility, and green spaces [82,98]. Neighborhood configuration shapes mobility patterns and has far-reaching implications for urban resilience, affecting socioeconomic and environmental aspects. For example, historically, urban planning has favored segregating land uses to prevent conflicts, such as mixing undesirable uses with residential areas. However, mixed-use development is now recognized for creating vibrant, walkable communities, reducing long commutes, and promoting sustainable lifestyles [10,117,119,125,126]. Districts may exhibit distinct urban forms such as gridiron layouts, radial configurations, or mixed-use cores surrounded by residential peripheries. These structural elements influence connectivity, shaping how people interact within urban spaces. Additionally, the diversity and heterogeneity of districts contribute to the richness and complexity of urban environments, with neighborhoods often reflecting a mix of architectural styles, land uses, and cultural influences. This diversity fosters a sense of place and identity within communities, supports social cohesion, and encourages creativity and innovation [65,114,127–130]. Moreover, the typology of transportation networks shapes mobility patterns and accessibility, including various modes such as roads, sidewalks, bike lanes, and public transit routes, each serving different mobility needs and preferences [22,131]. Transport infrastructure design influences urban mobility's efficiency, safety, and convenience, with well-connected networks providing seamless connections between residential areas, commercial centers, and recreational amenities [10,132]. Intrinsically tied to 'connectivity' and 'centrality', 'accessibility' reflects the ease of reaching urban amenities and is influenced by factors like the distribution of facilities [10]. Open and green spaces offer ecosystem services and serve as natural buffers against environmental risks [128,133–135]. Additionally, it promotes community cohesion and mental well-being, fostering social connections and adaptive capacity among residents during times of crisis [136–139].
- **Microscale urban form** refers to the detailed physical characteristics and spatial arrangements of elements within a small area, focusing on the specific features and interactions at the street level, within individual blocks, or around particular land-

marks [140,141]. These elements encompass various components, including streets, buildings, open spaces, and infrastructure, and collectively contribute to urban livability. One key element of block-scale urban form is street design, which influences layout, accessibility, and circulation patterns within a neighborhood. Streets vary in width, orientation, and configuration, affecting pedestrian and vehicular movement, safety, and social interactions. Well-designed streetscapes with sidewalks, bike lanes, street trees, and lighting enhance walkability and encourage active transportation. Another essential aspect of block-scale urban form is building morphology, which refers to the form, scale, and architectural character of buildings within a block. Building morphology influences urban environments' visual identity, density, and spatial quality, shaping the streetscape and urban experience. Building height, setback, facade design, and material use contribute to a neighborhood's character and sense of place. For example, superblocks, which are large, monolithic areas typically used for a single purpose, limit subdividing or consolidating urban spaces. This monocultural approach to urban planning can lead to a lack of diversity and redundancy, negatively impacting the urban landscape.

Additionally, superblocks often result in long, impermeable street edges, which hinder accessibility within the built environment [142]. Site arrangement, focusing on the dimensions of the land and the positioning of buildings and the surrounding streets, is a critical aspect of urban planning and encompasses considerations such as the lot size, the configuration of buildings, and the uniformity or variability of the layout. Building design, including size, compactness, orientation, and space between them, is critical to resilience [10,143]. Street design, including street edge configuration, has profound implications for walkability, socioeconomic factors, and environmental sustainability. Street edges, which serve as a boundary between properties and adjacent streets, are critical for facilitating connectivity [10,80,139,144]. These areas can achieve permeability through physical modifications, such as smaller lots with multiple access points, reduced distances between buildings, and non-physical factors like active businesses that encourage walkability.

Table 2. Multiple-scale urban form.

Classification	Features	Sub-Features
Macroscale	City size	City area
		Population density
	Scale hierarchy	Regional and local connectivity
	Distribution of the population and employment	Degree pattern of equal distribution
	Development type	Planned/unplanned; formal/informal
		Infill, sprawl, etc.
	Degree of clustering	Degree of compactness/centrality/uniformity/monocentric/polycentric
	Landscape/Habitat connectivity	
Mesoscale	Shape of districts	District size and shape; sanctuary area
	Diversity/Heterogeneity	Mixed land uses; open space ratio.
	Typology of transportation network	Route type; street width; street orientation; street layout
		Centrality and spinally of street network segments
		Permeability/connectivity; access to amenities
	Open and green spaces	Size; shape; distribution pattern

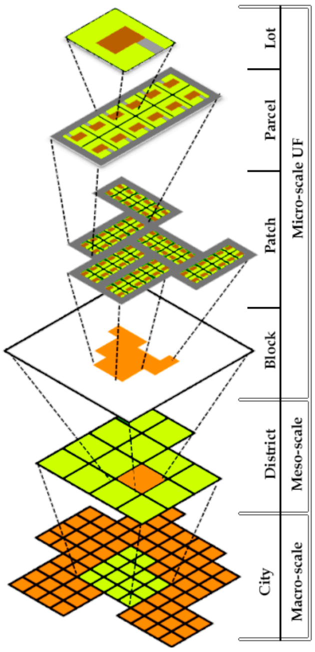
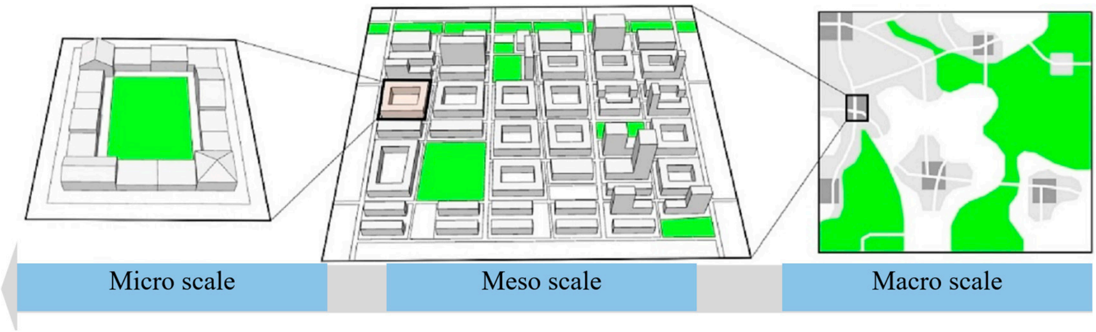


Table 2. *Cont.*

Classification	Features	Sub-Features
Microscale	Site layout	Layout configuration (uniform/random); lot size and geometry; site coverage
	Block type	Block size; perimeter
	Building configuration and density	Dwelling size, orientation, setbacks, floor area ratio
	Building typology, furniture, and facade	Townhouse; detached; courtyard; roof type
	Street elements	Aspect ratio; front setback; front usage; emergency route design
Sample of multiple-scale urban form		

Source: the authors (depending on [43,143,145–147]).

2.4. Urban Flood Resilience (FR)

FR is about creating sustainable, adaptable, and environmentally friendly cities that can withstand and recover from flooding. FR is a shift from traditional flood management practices to a more holistic, integrated approach that leverages natural processes and green infrastructure [76,93,138]. FR refers to the capacity of urban areas to anticipate, withstand, recover from, and adapt to flood events while maintaining the functionality, integrity, and sustainability of the built environment, infrastructure, and communities, enhancing preparedness, and promoting long-term resilience in urban settings [66,138,148]. Keating et al. describe FR as the ability of a community to pursue its development and growth objectives while managing its flood risk over time in a mutually reinforcing way [149]. Implementing FR strategies involves a combination of physical and socioeconomic measures, including developing flood-proof infrastructure, establishing early warning systems, creating floodplain management plans, and promoting community preparedness and response [33,69,150]. The Environmental Protection Agency (EPA) provides a comprehensive framework to comprehend flooding threats and detect practical mitigation alternatives to protect critical assets [128,137,151,152]. Indicators that measure FR relate to the system's response to flood waves or rainfall intensity, including the reaction threshold, amplitude, graduality, and recovery rate. These indicators provide insights into the system's performance but cannot be aggregated into a single numerical value due to the need to assign weights to the indicators [152–154].

Barsley, in his book "*Retrofitting for Flood Resilience*", outlines six critical strategies for building flood-resilient environments [155]. These strategies are about mitigating flooding risks and leveraging these challenges as opportunities for improvement, such as enhancing biodiversity and creating adaptable, sustainable, and beneficial environments for communities. One of the strategies highlighted is alleviation, which involves increasing the capacity of water systems or creating supplementary floodable areas to lower peak flood levels and limiting the exposure of vulnerable locations to flood risks. An example of this strategy is the Yanweizhou Park project in China. In this project, removing flood walls and implementing a cut-and-fill terracing strategy allows the park to accommodate additional floodwater, thereby reducing flood risks to the city and surrounding areas [156]. Another strategy is attenuation, which uses natural or artificial structures and spaces to reduce water velocity and turbidity while providing more time for infiltration. The "Climate District" in Copenhagen is a prime example of this approach, where streetscapes are retrofitted into "Cloudburst Roads", which serve as green routes for cyclists, pedestrians, and vehicles, as well as channels for slowing, storing, and discharging water during heavy rainfall [157]. Restriction strategies aim to reduce flood risk by preventing water entry through structural and non-structural flood risk management measures. Here is an example of the BIG U project in New York, where a 16-km-long system is being developed to protect Manhattan from flooding [158]. Each neighborhood tailors the system with specific programs and functions at various scales. A realignment strategy involves reducing exposure to flood risk by repositioning critical infrastructure, properties, or land use classifications. The "managed retreat" in areas like Oakwood Beach in Staten Island, as part of the NY Rising Community Reconstruction Program, is an example of this, where buildings have been removed to restore the land to its natural floodplain functions [159].

Another strategy is incorporating flooding into the scheme as a design driver to organize and adapt the built and natural environments. SCAPE's work with the City of Boston to create a "resilient Boston Harbor" vision includes interventions like elevated landscapes, protective parks, and resilient retrofitting of vulnerable buildings [160]. Schwarz et al. analyzed and mapped FR in Australia's Hawkesbury-Nepean Catchment. This study utilizes a comprehensive set of indicators, including government grant density, motor vehicle density, index of economic resources, unemployment rate, tertiary qualification rate, community service workers, internet access, median personal income, and flood project density [161]. Another significant case study is North Carolina, which showcases how natural ecosystems can enhance FR, particularly in coastal areas vulnerable to sea-level rise and storm surges [162]. Rotterdam, Netherlands: Known as the "Venice of the North", Rotterdam has a long history of dealing with water challenges based on "living with water" rather than keeping water out entirely [163]. The "living with water" strategy includes creating parks and green spaces that double flood retention areas and developing innovative flood barriers like the Maeslantkering. Singapore faces significant challenges protecting itself against rising sea levels and extreme weather events [164,165]. The city-state has adopted a holistic approach to FR, integrating it into its broader urban planning and infrastructure development. This approach includes the construction of the Marina Barrage; additionally, Singapore invests heavily in researching and developing cutting-edge technologies such as drones for real-time flood monitoring and smart sensors for early warning systems.

As shown in Figure 2, FR encompasses a multifaceted approach that hinges on four critical processes: recovery, protection, preparedness, and prevention. These processes are interconnected and essential for minimizing flooding damage, ensuring less risk to people and infrastructure, and facilitating quicker and more efficient recovery [166,167]. Recovery efforts entail reconstructing infrastructure and communities using lessons from previous flooding events [148]. After a flood event, the focus shifts to restoring the community to its pre-flood state as quickly and efficiently as possible. Achieving this entails quickly communicating information to residents, understanding the recovery resources available, assisting them in navigating the repair or rebuilding process, and implementing mitigation measures to prevent future damage. Additionally, flood insurance and compensation mechanisms alleviate the financial burden on affected individuals and businesses, facilitating a smooth transition toward normalcy post-disaster [131,137,168]. Protection entails constructing and maintaining physical barriers and infrastructure to defend against floodwaters. Examples include levees, dikes, seawalls, and flood-proof measures such as elevating critical equipment or placing it within waterproof containers or foundation systems. These protective measures are crucial for safeguarding critical infrastructure and reducing flooding impact [31,169–171].

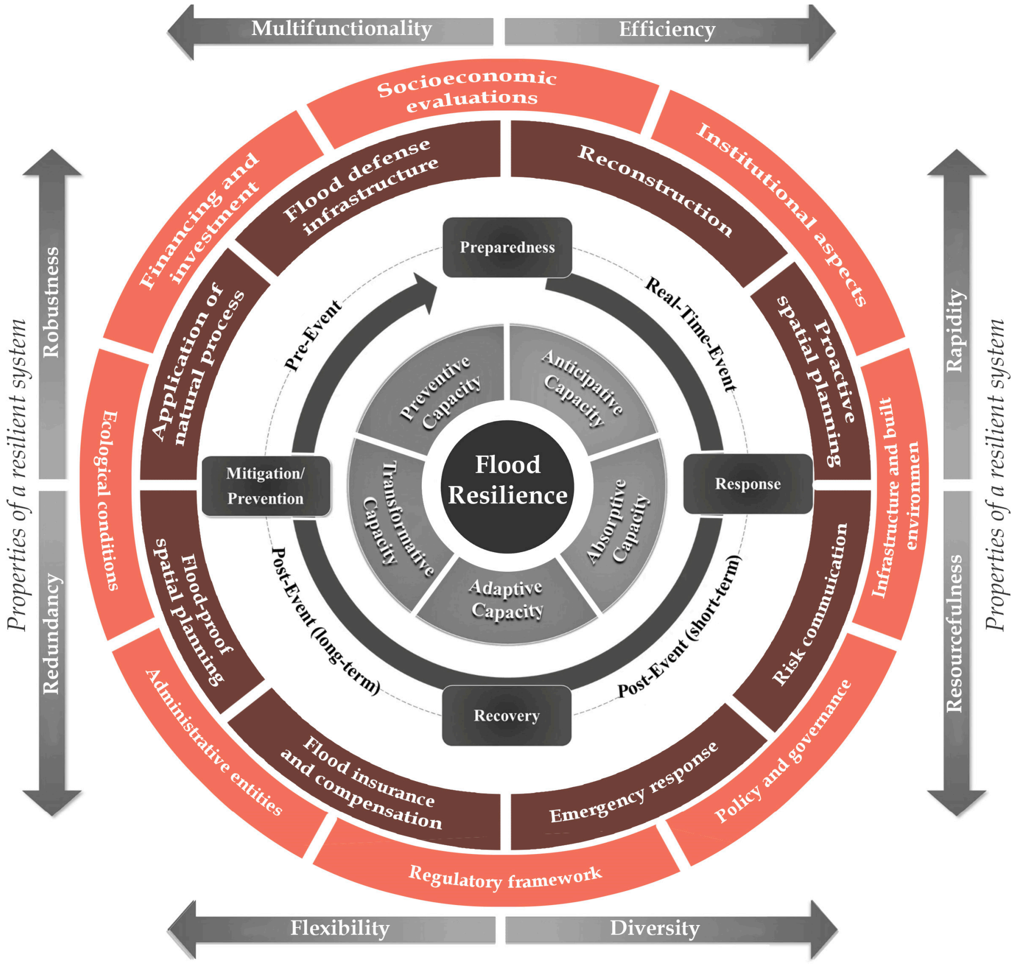


Figure 2. A multi-layered FR strategy. The first circle encompasses a multifaceted approach that hinges on four critical processes: recovery, protection, preparedness, and prevention. The second circle includes essential strategies for creating flood-resilient environments. The third circle defines the main dimensions used in FR assessment, including socioeconomic evaluations, institutional, infrastructure, built environment, ecological conditions, administrative entities, regulatory framework, policy, and governance. The last frame shows the properties of a flood-resistant system: redundancy, efficiency, adaptability, multifunctionality, resourcefulness, flexibility, rapidity, and robustness.

Preparedness is vital in assessing urban vulnerability and implementing flood mitigation measures. Part of the preparedness measures is evaluating land use plans and policies to minimize conflicts between built infrastructure and floodplains. Preparedness also involves educating the public on flood risks and evacuation procedures [114,152,172]. Communities with well-coordinated emergency plans can swiftly mobilize resources and aid evacuation efforts. Furthermore, transparent risk communication fosters a collective understanding of flood risks, empowering individuals and communities to mitigate potential damages proactively. Prevention focuses on reducing flooding likelihood through strategic planning and management. It includes developing and implementing flood protection master plans, such as the Virginia Flood Protection Master Plan and the Coastal Resilience Master Plan. These master plans collect data on historical and forecasted flooding conditions, conduct risk and vulnerability analyses, and identify strategies for reducing vulnerability and bolstering resilience. Prevention also involves informed decision-making based on the best available flood and flood damage reduction data, allowing for anticipatory planning and preparation [114,138,173,174].

3. Systematic Review Method

The systematic literature review process comprises three primary stages based on the PRISMA 2020 statement, the explanatory paper [175], and Supplementary Table S1:

- **Database search and retrieval:** This initial stage identifies and retrieves an extensive set of potentially eligible publications for inclusion in the review. This stage involves comprehensive searches across relevant scientific databases and information sources, utilizing carefully crafted search terms, keywords, and subject headings. Next, the search process begins, where the reviewers execute the predefined search strategies across the identified databases and sources, retrieving potentially relevant studies based on the search criteria.
- **Screening and preliminary analysis:** The second stage entails applying predefined inclusion and exclusion criteria to evaluate the retrieved publications systematically. Irrelevant publications are excluded, while those meeting the eligibility criteria are retained for further analysis. Additionally, a preliminary bibliometric analysis is conducted to gain insights into the characteristics and distribution of the identified literature. In the eligibility assessment stage, the remaining studies undergo a full-text review, in which the reviewer carefully evaluates each study against the eligibility criteria. Additionally, the reviewers identify and include relevant studies from other sources, such as reference lists or expert consultations, based on the inclusion criteria.
- **Full-text review and analysis (interpretation and presentation):** This stage involves synthesizing the included studies' findings and analyzing the evidence's heterogeneity and quality. This stage conducts meta-analyses, if appropriate, or provides a narrative synthesis of the results. The full-text versions of the remaining publications are thoroughly analyzed and the findings are presented clearly and in a structured manner, using tables, figures, and other visual aids to facilitate understanding and interpretation. Our study follows these processes, as shown in the following sections.

4. Results

4.1. Systematic Review Results

4.1.1. Search Strategy and Data Extraction

Studying UFIs and FR is a multidisciplinary field encompassing various keywords related to urban planning, climate change, and disaster mitigation strategies. This methodical inclusion of terms related to urban form characteristics, resilience, low-impact development, spatial planning, green infrastructure, and flooding enabled us to perform a focused and targeted search across multiple databases. This search strategy gathers theoretical and empirical literature to provide a solid analytical foundation and incorporates many perspectives. Our study relies on established and reputable databases widely recognized in academic fields for their comprehensive coverage, indexing standards, and search functionalities. These databases, such as PubMed, Web of Science, and Scopus, have extensive collections of peer-reviewed journals, conference proceedings, and scholarly publications, making them preferred for literature reviews and research inquiries. These databases often offer advanced search features, citation tracking, and filtering options tailored to researchers' specific needs, enhancing the efficiency and effectiveness of literature searches. This paper gathered peer-reviewed articles without time restrictions based on nine search databases, as shown in Table 3: Nature, Taylor & Francis, Wiley, Science Direct, ASCE, MDPI, JSTOR, ASCE, and Springer. As shown in Figure 3, the VOSviewer tool facilitates article classification and visualization of these relationships. VOSviewer, developed by Leiden University, is a powerful software tool for visualizing and analyzing bibliometric networks: co-authorship, co-citation, and keyword co-occurrence networks derived from scientific literature databases [176,177]. The visualization produced is a distance-based map that features clustered keywords in various colors and sizes, reflecting their frequency in the publications analyzed. Lines connecting two keywords signify their co-occurrence, with the thickness of these lines representing the strength of their co-occurrence. Keywords are grouped into clusters according to how often they co-occur. Only keywords that appeared at least ten times were included in this analysis.

Table 3. Journals, titles, keywords, database classifications, and a list of selected literature categorized by subject area.

S. No		**Journal Database**									**References**
		Taylor & Francis	**Wiley**	**Science Direct**	**ASCE**	**Nature**	**Springer**	**JSTOR**	**MDPI**	**Science**	
	String	**Urban form; urban pattern; spatial planning; urban planning; climate change; floods; resilient cities; disasters; vulnerability; flood mitigation; flood resilience; risk management; spatial analysis; flood recovery; sustainable cities; resilience; flooding; runoff; nature-based solutions; low impact development; land use and cover change; street layout; layout configuration; built-up mode**									
1	Urban form	584,016	490,473	70,244	15,31	13,186	740,311	989,223	3155	4679	[51,102,103,105,112,178–182]
2	Urban resilience	158,599	178,830	197,391	1632	15,246	260,116	177,915	1958	3361	[10,17,20,29,33,43,67,75,79–81,83,88,94,96,100,113,117,138,143,147,148,157,183–216]
3	Resilient urban form	10	34	98	4	27	14	19	144	14	[10,43,50,89,99,144,184,209,215,217–221]
4	Flood	232,553	299,632	202,085	13,289	12,796	431,248	427,793	10,463	10,000	[20,23,35,40,62,71,166,167,214,222–238]
5	FR	20,530	27,180	6326	2051	876	52,710	17,468	778	387	[29,148,166,167,214,222,238–250]
6	Urban form and FR	9	17	120	2	201	7	22	12	72	[51,79,96,139,230,251,252]

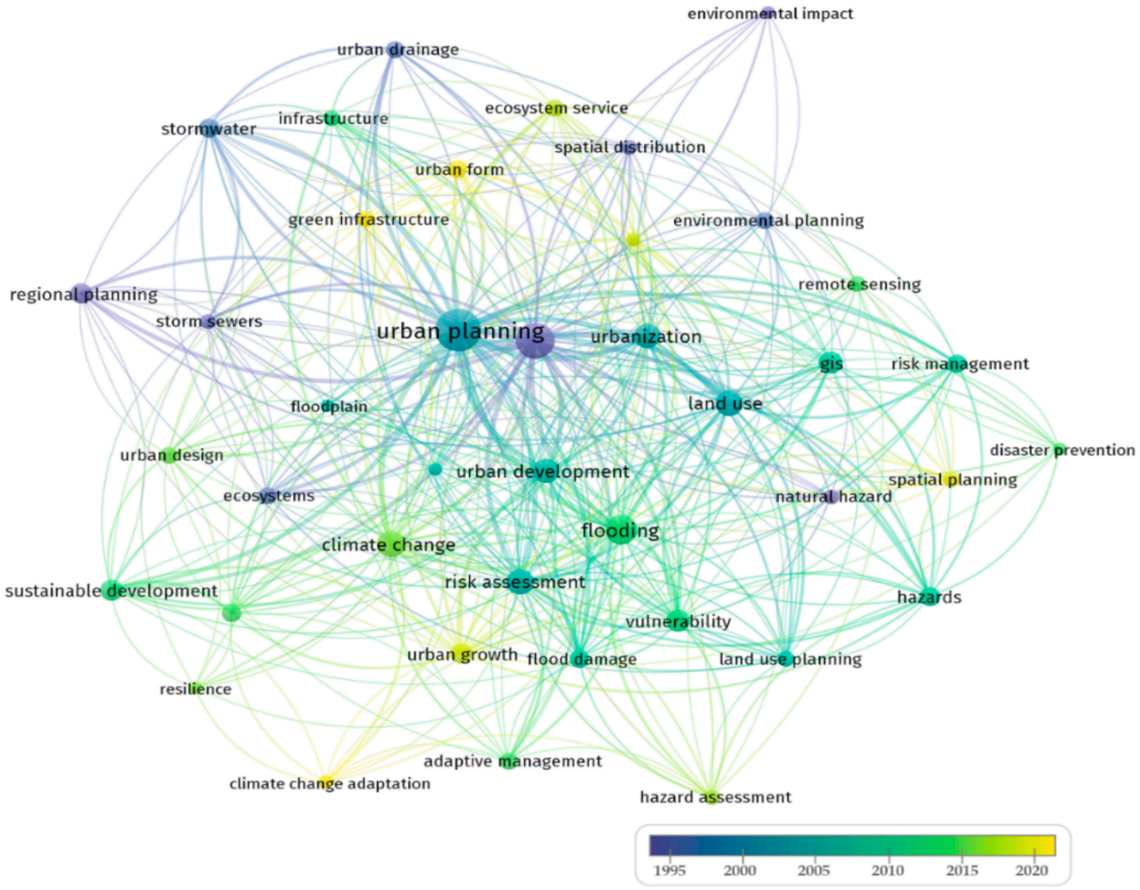


Figure 3. The most relevant keywords for urban form and FR; the figure's node size represents the frequency of words, and the circle color represents the year of publication.

4.1.2. Screening, Inclusion, and Exclusion Process

The third step is identification and searching, for which we thoroughly checked each paper to make sure it met the eligibility criteria. Initially, there were 176 articles that included "urban form" and "flood resilience" in their abstracts, titles, or keywords (both author and indexed keywords) and were categorized as articles. Screening is the fourth step, and involved exporting the bibliographic data for these 176 articles into a CSV file and checking for duplicates and missing data. The fifth step, eligibility and assessment, involved a detailed review of the full text of the selected articles. Publications were included if they discussed UFIs and FR, such as research papers, method papers, theory papers, case studies, viewpoint/commentary papers, and secondary sources like narrative reviews, systematic reviews, and meta-analyses. After this step, 81 articles were selected for urban form and 52 for flood resilience, as depicted in Figure 4. From the 133 selected papers, 15 were excluded because they did not contain relevant discussions on either UFIs or FR in their full texts. Ultimately, 118 papers were chosen and are presented in detail in Section 4.2.

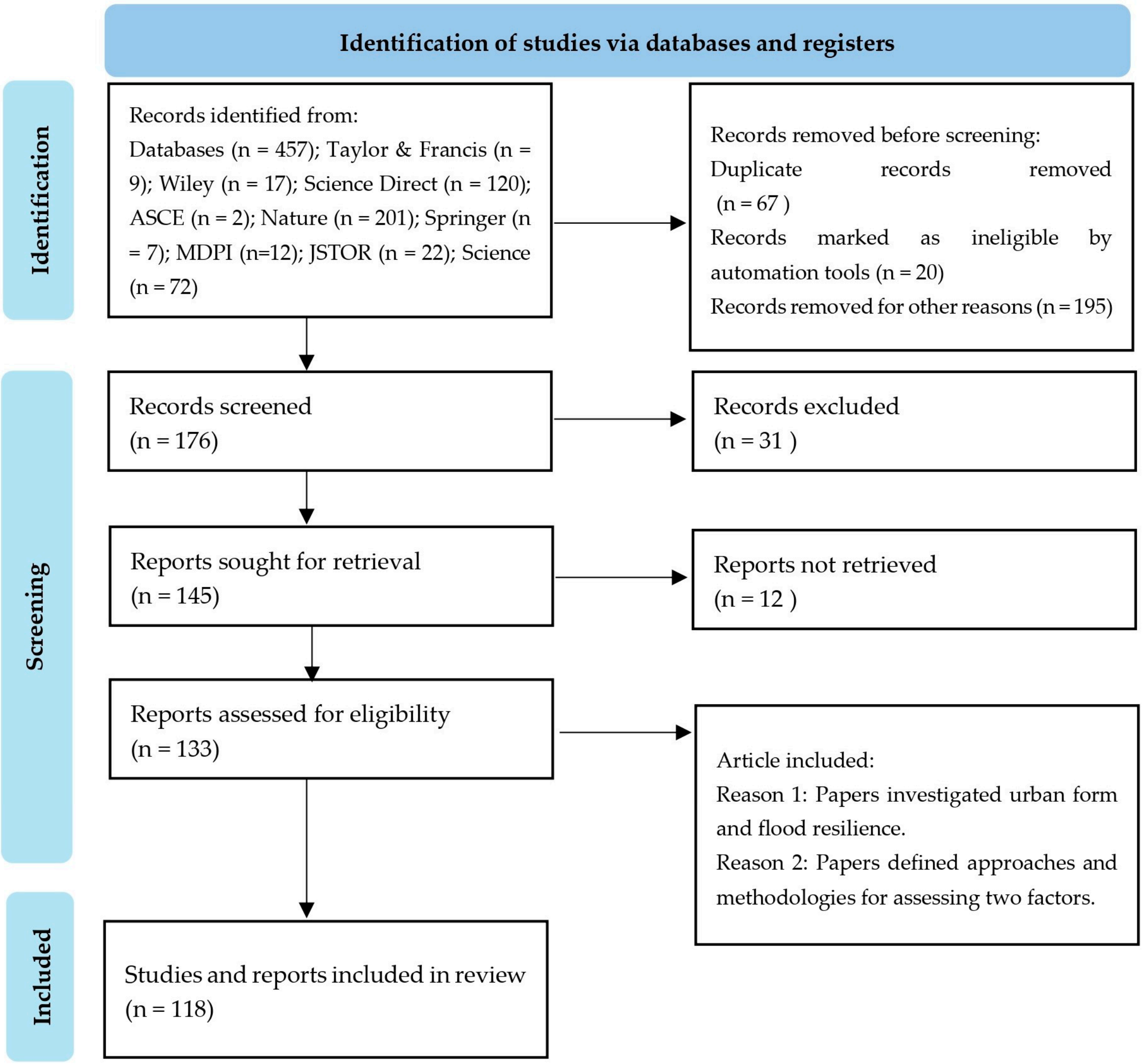


Figure 4. Stages of systematic literature review using the PRISMA method.

4.1.3. Classification of the Studies Included in the Systematic Review

One hundred and eighteen selected studies on UFIs and FR were classified based on the scale and type of analysis, as shown in Table 4 and Figure 5. Most of the studies 80.5%, focused on the macroscale, encompassing city-wide or regional analyses. These studies typically examine broad urban form characteristics such as land use patterns, large-scale infrastructure systems, and regional hydrology. Only 6.8% of the studies were conducted at the mesoscale pertaining to neighborhood or district-level analyses. The microscale, which involves a detailed examination of small areas such as individual buildings or specific sites, was addressed in 10.2% of the studies. A small fraction of the research, 0.8%, integrated analyses across micro, meso, and macro scales, while another 0.8% combined micro and meso scales, and yet another 0.8% combined macro and meso scales, reflecting a comprehensive approach to understanding urban form and flood resilience across different scales.

Table 4. The 118 articles selected, with their publication year, source title, title, analysis type, and urban scale.

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
1	2011	12th International Conference on Urban Drainage	Spatial metrics modeling to analyze correlations between urban form and surface water drainage performance	Modeling	Micro
2	2019	International Journal of Disaster Risk Reduction	Urbanization and floods in the Seoul Metropolitan area of South Korea: What old maps tell us	Realistic case study	Macro
3	2021	Natural Hazards	Urbanization impacts on flood risks based on urban growth data and coupled flood models	Realistic case study	Macro
4	2023	Journal of Asian Architecture and Building Engineering	Urban and architectural design from the perspective of flood resilience: framework development and case study of a Chinese university campus	Modeling	Micro
5	2020	Sustainability (Switzerland)	Influence of the built environment on community flood resilience: Evidence from Nanjing City, China	Realistic case study	Macro
6	2015	Environmental Research	Urban flood risk warning under rapid urbanization	Realistic case study	Macro
7	2024	Science of The Total Environment	Spatial congruency or discrepancy? Exploring the spatiotemporal dynamics of built-up expansion patterns and flood risk	Realistic case study	Macro
8	2019	International Journal of Disaster Risk Reduction	Urbanization and floods in the Seoul Metropolitan area of South Korea: What old maps tell us	Realistic case study	Macro
9	2020	Hydrology Research	Quantifying effects of urban land-use patterns on flood regimes for a typical urbanized basin in eastern China	Realistic case study	Macro
10	2015	Science of the Total Environment	Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data	Realistic case study	Macro
11	2006	Landscape and Urban Planning	The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Peñasquitos Creek, California	Realistic case study	Macro
12	2015	Global Environmental Change	Changing global patterns of urban exposure to flood and drought hazards	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
13	2018	Science of the Total Environment	Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed	Realistic case study	Macro
14	2018	Journal of Environmental Management	Effects of spatial planning on future flood risks in urban environments	Realistic case study	Macro
15	2020	Earth's Future	The role of urban growth in resilience of communities under flood risk	Realistic case study	Macro
16	2019	Science of the Total Environment	Comparison of urbanization and climate change impacts on urban flood volumes: Importance of urban planning and drainage adaptation	Realistic case study	Macro
17	2023	Sustainability (Switzerland)	Global Megacities and Frequent Floods: Correlation between Urban Expansion Patterns and Urban Flood Hazards	Realistic case study	Macro
18	2019	American Geophysical Union	The Impact of Urban Form on Urban Flood Hazards	Modeling	Micro
19	2017	International Journal of Environmental Research and Public Health	Exploring the linkage between urban flood risk and spatial patterns in small urbanized catchments of Beijing, China	Realistic case study	Macro
20	2023	International Journal of Disaster Risk Reduction	Towards flood risk reduction: Commonalities and differences between urban flood resilience and risk based on a case study in the Pearl River Delta	Realistic case study	Macro
21	2023	Journal of Environmental Management	Assessing the effectiveness of nature-based solutions-strengthened urban planning mechanisms in forming flood-resilient cities	Realistic case study	Macro
22	2021	Environmental Research Letters	Shaping urbanization to achieve communities resilient to floods	Realistic case study	Macro
23	2019	Advances in Water Resources	Flood inundation modeling in urbanized areas: A mesh-independent porosity approach with anisotropic friction	Modeling	Micro
24	2020	Journal of Environmental Management	Urban flood risk assessment and analysis with a 3D visualization method coupling the PP-PSO algorithm and building data	Realistic case study	Macro
25	2023	International Journal of Disaster Risk Reduction	Urban resilience assessment: A multicriteria approach for identifying urban flood-exposed risky districts using multiple-criteria decision-making tools (MCDM)	Realistic case study	Meso
26	2011	Journal of Planning Education and Research	Examining the influence of development patterns on flood damages along the Gulf of Mexico	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
27	2022	Frontiers in Sustainable Cities	Distributive Justice and Urban Form Adaptation to Flooding Risks: Spatial Analysis to Identify Toronto's Priority Neighborhoods	Realistic case study	Meso
28	2024	Communications Earth & Environment volume	Urban Form and Structure Explain Variability in Spatial Inequality of Property Flood Risk among US Counties	Realistic case study	Macro
29	2023	Environment, Development and Sustainability	Assessment of urban form resilience: a review of literature in the context of the Global South	Review	Macro
30	2019	Land	Planning in Dhaka, Bangladesh	Realistic case study	Macro
31	2017	Hydrology and Earth System Sciences Discussions	Comparison of the impacts of urban development and climate change in exposing European cities to pluvial flooding	Realistic case study	Macro
32	2021	Urban Science	Urban Form Resilience: A Comparative Analysis of Traditional, Semi-Planned, and Planned Neighborhoods in Shiraz, Iran	Realistic case study	Meso
33	2017	Journal of Geographic Information System	Flood Resilient Cities: A Syntactic and Metric Novel on Measuring the Resilience of Cities against Flooding, Gothenburg, Sweden	Realistic case study	Macro
34	2017	Urban Floods Community of Practice Knowledge Notes	Land Use Planning for Urban Flood Risk Management	Realistic case study	Macro
35	2021	Journal of Hydrology	Influence of urban forms on long-duration urban flooding: Laboratory experiments and computational analysis	Modeling	Micro
36	2020	Science of the Total Environment	The growth mode of built-up land in floodplains and its impacts on flood vulnerability	Realistic case study	Macro
37	2021	Advances in Water Resources	Experimental and numerical model studies on flash flood inundation processes over a typical urban street	Realistic case study	Macro
38	2021	Environmental Research	Investigating the influence of three-dimensional building configuration on urban pluvial flooding using random forest algorithm	Realistic case study	Macro
39	2019	Cities	Building urban resilience with nature-based solutions: How can urban planning contribute?	Realistic case study	Macro
40	2023	Urban Climate	An integrated indicator-based approach for constructing an urban flood vulnerability index as an urban decision-making tool using the PCA and AHP techniques: A case study of Alexandria, Egypt	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
41	2009	Water Science and Technology	Flood vulnerability indices at varying spatial scales Flood vulnerability indices at varying spatial scales	Realistic case study	Macro
42	2019	Journal of Environmental Planning and Management	Flood resilience: a systematic review	Review	Macro
43	2020	Annals of the American Association of Geographers	Understanding Urban Flood Resilience in the Anthropocene: A Social–Ecological–Technological Systems (SETS) Learning Framework	Realistic case study	Macro
44	2018	Science of the Total Environment	Flood risk assessment in metro systems of mega-cities using a GIS-based modeling approach	Modeling	Marco
45	2018	Wiley Interdisciplinary Reviews: Water	Pluvial flood risk and opportunities for resilience	Realistic case study	Macro
46	2024	Nature Communications	Urban development pattern's influence on extreme rainfall occurrences	Modeling	Macro
47	2019	International Journal of Disaster Risk Reduction	A multi-criteria approach for assessing urban flood resilience in Tehran, Iran	Realistic case study	Macro
48	2016	Landscape and Urban Planning	Urban design principles for flood resilience: Learning from the ecological wisdom of living with floods in the Vietnamese Mekong Delta	Realistic case study	Macro
49	2021	Land	Integrating sponge city concept and neural network into land suitability assessment: Evidence from a satellite town of Shenzhen metropolitan area	Realistic case study	Macro
50	2024	Journal of Hydrology	Analyzing urban form influence on pluvial flooding via numerical experiments using random slices of actual city data	Modeling	Micro
51	2023	Natural Hazards and Earth System Sciences	Assessment of building damage and risk under extreme flood scenarios in Shanghai	Realistic case study	Macro
52	2021	Sustainability (Switzerland)	Urban form and natural hazards: Exploring the dual aspect concept of urban forms on flood damage	Realistic case study	Macro
53	2022	Sustainability (Switzerland)	Flood Resilience and Adaptation in the Built Environment	Realistic case study	Macro
54	2017	Natural Hazards and Earth System Sciences	Development and testing of a community flood resilience measurement tool	Realistic case study	Macro
55	2022	Theoretical and Applied Climatology	Urban flood vulnerability assessment in a densely urbanized city using multi-factor analysis and machine learning algorithms	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
56	2020	Remote Sensing	Impact of expansion pattern of built-up land in floodplains on flood vulnerability: A case study in the North China Plain area	Realistic case study	Macro
57	2020	Environment and Planning B: Urban Analytics and City Science	Procedural generation of flood-sensitive urban layouts	Realistic case study	Macro
58	2019	The Eleventh International Conference on Advanced Geographic Information Systems	Investigating the Impact of Urban Layout Geometry on Urban Flooding	Realistic case study	Macro
59	2018	PhD thesis	Spatiotemporal modeling of interactions between urbanization and flood risk: A multi-level approach	Modeling and Realistic case study	Micro, meso, and macro
60	2015	Regional Environmental Change	Flood exposure and settlement expansion since pre-industrial times in 1850 until 2011 in north Bavaria, Germany	Realistic case study	Macro
61	2020	Urban Ecosystems	Flood-resilient urban design based on the indigenous landscape in the city of Can Tho, Vietnam	Realistic case study	Macro
62	2021	Sustainable Cities and Society	Urban Flood Modeling Application: Assess the Effectiveness of Building Regulation in Coping with Urban Flooding Under Precipitation Uncertainty	Modeling	Micro
63	2018	Springer International Publishing	Resilient urban form: a conceptual framework chapter 9 resilient urban form: a conceptual framework	Review	Macro
64	2018	IOP Conf. Series: Materials Science and Engineering 413	Impact of flood danger in built-up areas in Nigeria and floor management systems for espousal	Realistic case study	Macro
65	2018	Georgia Tech Library	Urban form and neighborhood vulnerability to climate change case study: Jakarta, Indonesia	Realistic case study	Meso
66	2013	Natural Hazards and Earth System Sciences	Reduction of maximum tsunami run-up due to the interaction with beachfront development—Application of single sinusoidal waves	Realistic case study	Macro
67	2017	Natural Hazards	Use of LSPIV in assessing urban flash flood vulnerability	Realistic case study	Macro
68	2016	Journal of Hydrology	A step towards considering the spatial heterogeneity of urban key features in urban hydrology flood modelling	Realistic case study	Macro
69	2017	Journal of Hydrology	Assessment of urban pluvial flood risk and efficiency of adaptation options through simulations—A new generation of urban planning tools	Modeling	Micro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
70	2021	Master thesis	A computational approach to integrating non-structural flood risk mitigation strategies into the urban planning process	Modeling and Realistic case study	Micro and meso
71	2021	Journal of Hydrology	Sustainable stormwater management under the impact of climate change and urban densification	Realistic case study	Macro
72	2007	Journal of Hydraulic Research	Flash flood flow experiment in a simplified urban district	Realistic case study	Meso
73	2016	Coastal Engineering	Physical modelling of tsunami onshore propagation, peak pressures, and shielding effects in an urban building array	Realistic case study	Macro
74	2023	Water Security	A review of recent advances in urban flood research	Review	Macro
75	2019	Sustainable Cities and Society	Mapping urban resilience to disasters—A review	Realistic case study	Macro
76	2018	Water Resources Research	The influence of urban development patterns on streamflow characteristics in the charlanta megaregion	Realistic case study	Macro
77	2021	IOP Conference Series Materials Science and Engineering	Building climate resilient city through multiple scale cooperative planning: Experiences from Copenhagen	Realistic case study	Macro
78	2021	Natural Hazards	Urbanization impacts on flood risks based on urban growth data and coupled flood models	Realistic case study	Macro
79	2022	Handbook of Environmental Chemistry	Nature-Based Solutions for Flood Mitigation and Resilience in Urban Areas	Realistic case study	Macro
80	2021	Environmental Evidence	What evidence exists on the possible effects of urban forms on terrestrial biodiversity in western cities? A systematic map protocol	Realistic case study	Macro
81	2023	Urban Studies	Urban development and long-term flood risk and resilience: Experiences over time and across cultures. Cases from Asia, North America, Europe and Australia.	Realistic case study	Macro
82	2022	Sustainability	Flood Resilience and Adaptation in the Built Environment: How Far along Are We?	Realistic case study	Macro
83	2019	Journal of Environmental Planning and Management	Flood resilience: a systematic review.	Review	Macro
84	2020	Natural Hazards and Earth System Sciences	Are flood damage models converging to “reality”? Lessons learnt from a blind test	Realistic case study	Macro
85	2024	Scientific Data	Mapping urban form into local climate zones for the continental US from 1986–2020	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
86	2021	Cities	Adapting cities for climate change through urban green infrastructure planning	Realistic case study	Macro
87	2017	Environmental Science & Policy	A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas	Realistic case study	Macro
88	2018	International Journal of Disaster Risk Reduction	Resilience assessment of complex urban systems to natural disasters: A new literature review	Realistic case study	Macro
89	2024	Sustainable Cities and Society	Impact of urban built-up volume on urban environment: a case of Jakarta	Realistic case study	Macro
90	2010	Landscape and Urban Planning	Urban form revisited—Selecting indicators for characterising European cities.	Realistic case study	Macro
91	2018	Water (Switzerland)	Urban floods and climate change adaptation: The potential of public space design when accommodating natural processes	Realistic case study	Macro
92	2021	Natural Hazards and Earth System Sciences	Assessment of building damages and adaptation options under extreme flood scenarios in Shanghai	Realistic case study	Macro
93	2024	International Journal of Disaster Risk Reduction	Resilient urban expansion: Identifying critical conflict patches by integrating flood risk and land use predictions: A case study of Min Delta Urban Agglomerations in China	Realistic case study	Macro
94	2023	Urban Climate	Spatial-temporal evolution of urban form resilience to climate disturbance in adaptive cycle: A case study of Changchun city	Realistic case study	Macro
95	2018	Science of the Total Environment	Influence of urban pattern on inundation flow in floodplains of lowland rivers	Realistic case study	Macro
96	2018	Environmental Modelling and Software	Variance-based sensitivity analysis of 1D and 2D hydraulic models: An experimental urban flood case	Modeling	Macro
97	2018	Science of the Total Environment	The changing pattern of urban flooding in Guangzhou, China	Realistic case study	Macro
98	2020	International Journal on Emerging Technologies	Causes and Impacts of Urban Floods in Indian Cities: A Review	Review	Macro
99	2021	Journal of Hydrology	Impact of the porosity of an urban block on the flood risk assessment: A laboratory experiment	Modeling	Micro
100	2014	Sustainability (Switzerland)	Urban land pattern impacts on floods in a new district of China	Realistic case study	Meso
101	2011	Landscape and Urban Planning	The impact of urban development on hydrologic regime from catchment to basin scales	Realistic case study	Macro

Table 4. *Cont.*

Paper ID	Year	Source Title	Title	Analysis Type	Urban Scale
102	2020	Scientific Reports	A network percolation-based contagion model of flood propagation and recession in urban road networks	Realistic case study	Macro
103	2022	IOP Conference Series: Earth and Environmental Science	Flood resiliency approach for urban planning: critical review and future research agenda	Review	Macro
104	2008	Urban Design and Planning	The absorbent city: urban form and flood risk management	Review	Macro
105	2003	U.S. GEOLOGICAL SURVEY	Effects of urban development on floods	Realistic case study	Macro
106	2023	Urban Planning International	Empirical correlations between urban form and climate resilience: A study of flooding events in Macau	Realistic case study	Macro
107	2022	Urban Science	An Urban Density-Based Runoff Simulation Framework to Envisage Flood Resilience of Cities	Review and realistic case study	Macro
108	2024	Environmental and Sustainability Indicators	Analysis of sustainable urban forms for climate change adaptation and mitigation	Review and realistic case study	Macro
109	2023	NA	Adaptation to Flooding and its Effect on the Urban Form	Modeling	Macro
110	2022	Scientific data	Laboratory modeling of urban flooding	Modeling	Meso
111	2022	Journal of Urban Design	Multi-functional urban design approaches to manage floods: examples from Dutch cities	Realistic case study	Macro
112	2018	International Society of City and Regional Planners (ISOCARP)	A methodological approach to measure interrelations between urban form and flood-related risks in Kampala, Uganda	Review	Macro
113	2023	Research Square	How urban form impacts flooding	Modeling	Micro
114	2023	International Conference of Contemporary Affairs in Architecture and Urbanism	The resilient city: What urban form characteristics to adapt to flood risks? (Case of the city of Skikda-Algeria)	Realistic case study	Macro
115	2023	Land	Spatial correlation between urban planning patterns and vulnerability to flooding risk: a case study in Murcia (Spain)	Realistic case study	Macro
116	2017	Journal of Hydrology	Assessment of urban pluvial flood risk and efficiency of adaptation options through simulations—a new generation of urban planning tools	Modeling	Meso
117	2021	UC Irvine Electronic Theses and Dissertations	The effect of urban texture on flood behavior	Modeling	Micro
118	2016	International Journal of Disaster Resilience in the Built Environment	The impact of urban form on disaster resiliency: A case study of Brisbane and Ipswich, Australia	Realistic case study	Macro, and meso

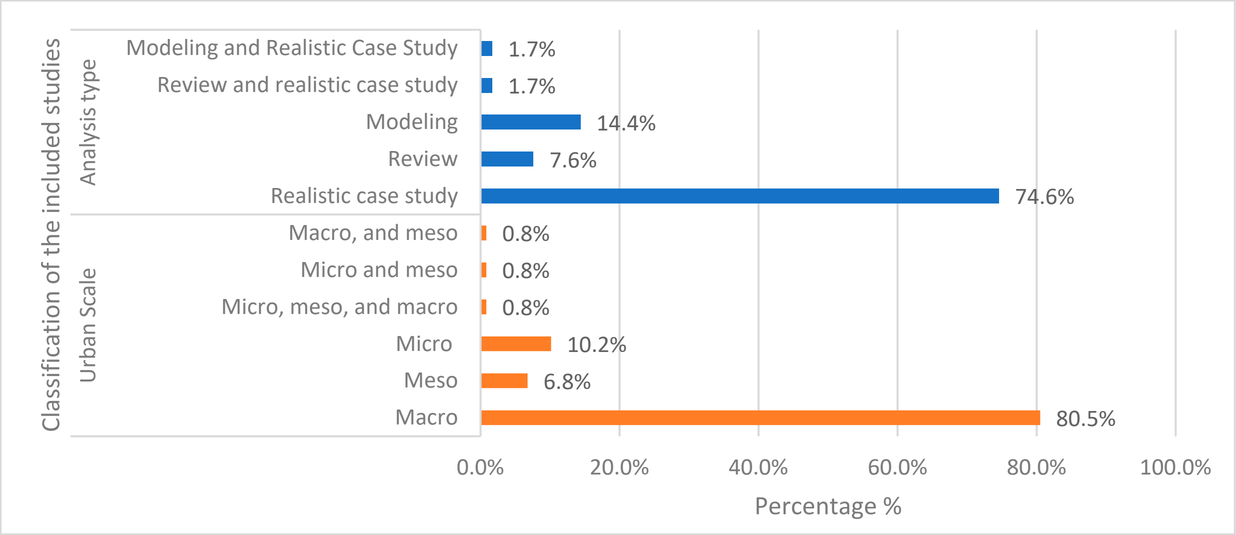


Figure 5. Classification of the studies included in the systematic review based on spatial scale and analysis type.

Regarding the type of analysis conducted, the review revealed that 74.6% of the studies utilized a realistic case study approach. These studies focused on specific real-world scenarios to explore the interplay between urban form indicators and flood resilience, providing practical insights and empirical data. Of the studies, 7.6% are literature reviews, offering comprehensive summaries and syntheses of existing literature. Modeling studies used computational simulations and predictive models to analyze urban form and flood resilience, accounting for 14.4% of the research. A small proportion of the studies, 1.7%, combined review methodologies with realistic case studies, while another 1.7% integrated modeling with realistic case study approaches, demonstrating a blend of theoretical and practical perspectives in the research landscape.

4.2. Divergent Perspectives on Urban Form and FR

Urban form and flood resilience are often viewed from divergent perspectives. These contradictory perspectives are due to the complexity of urban hydrology, the influence of local topography and drainage infrastructure, and the heterogeneity of urban development patterns across different regions. Urban planners prioritize compact, dense city layouts to optimize land use and infrastructure efficiency. However, such designs can exacerbate flood risks by reducing natural drainage areas and increasing impervious surfaces. Environmentalists advocate green infrastructure and decentralized water management systems to enhance FR and promote ecological sustainability. Proponents of scattered urban forms often highlight the role of low-density development in reducing runoff volumes and velocities. They argue that dispersed development allows for more natural rainwater infiltration into the soil and promotes the preservation of open spaces, which can serve as protective buffers against flooding.

Additionally, dispersed development may offer more flexibility for implementing decentralized stormwater management practices, such as green infrastructure and rain gardens [44,48,65,154,253,254]. Conversely, advocates for compact urban forms emphasize the benefits of higher population density and mixed land use in promoting sustainable water management. Compact development patterns, characterized by higher building densities and reduced lot sizes, can support efficient land use in limited spaces, reduce urban sprawl, and encourage pedestrian-friendly neighborhoods [103,105,107]. Proponents argue that compact urban forms facilitate the implementation of centralized stormwater management systems and enable better coordination of flood protection measures. For example, Yao et al. explained that if flood mitigation policies are not promoted, high-density development exposes more population, residential and commercial buildings, and infrastructure to risk than low-density development on equivalent land units [124].

Brody et al., on the other hand, argue that fragmentation or leapfrog development could increase stormwater runoff due to the vast expansion of impervious surfaces and fragmented drainage networks. They discovered that more connected and concentrated development patterns reduce flood losses in the Gulf of Mexico [133]. Han et al. assessed the modes of built-up land in floodplains (BLF). They elucidated their differing impacts on flood vulnerability through a case study in the Yangtze River Economic Belt (YREB), China. The findings reveal a nearly two-fold increase in BLF within the YREB from 1990 to 2014. 35.43% of this BLF expansion occurs in small patches ($\leq$1 km^2), which exhibit a notably stronger correlation with flood incidents than other patch sizes. Both leapfrogging and edge-expanding BLFs exhibit significant associations with flood incidents, whereas the infilling type does not [71]. Diwangkari indicated that urban fringes and peripheral nuclei are less vulnerable and sensitive than clustered urban settlements [255]. The sprawl pattern has probably included hazardous regions and placed more structures and residents in flood-prone areas by spreading across the landscape [93,101]. Additionally, sprawling development and outside extraterritorial jurisdictions may infringe on floodplains left initially as open space or for low-impact uses. Mabrouk et al. analyzed the relationship between the spatiotemporal dynamics of built-up expansion patterns (BE) and flood risk. Their findings indicate a strong correlation between the unplanned-infilling pattern and areas prone to flooding, with a coefficient of 0.975 and a p-value of less than 0.05 [5]. Wang et al. examined the built-up land in floodplains (BLF) (patch size and expansion type) in the North China Plain from 1975 to 2014. The results show that flood vulnerability significantly correlated with the small (R = 0.36, $p < 0.01$), edge expansion (R = 0.53, $p < 0.01$), and outlying patches (R = 0.51, $p < 0.01$). Large patches significantly correlated with flood vulnerability (R = 0.18, $p > 0.1$), but there was a negative trend. Over a long time, infilling patch growth was highly associated with flood vulnerability (R = 0.27, $p < 0.05$) [62].

4.3. Effectiveness of UFIs on FR at the Macroscale

Table 3 shows that macroscale UFIs significantly impact FR by altering flow patterns and determining floodwater speed and depth [131,256]. The relationship between city size and FR is multifaceted; larger cities tend to have more resources, including financial, infrastructure, and human capital [93,139]. These resources enable larger cities to invest in comprehensive flood management strategies such as sophisticated drainage systems, flood barriers, and early warning systems [153]. Additionally, more prominent cities often have more diversified economies and faster flood recovery. However, larger cities can also pose challenges to FR, where urban sprawl and extensive infrastructure networks can increase impervious surfaces, reducing natural drainage and exacerbating flood risks [20,42,117]. Moreover, large cities' dense populations and infrastructure concentration can amplify flood impacts, leading to more significant disruptions and higher economic losses [5]. Scale hierarchy, from local to regional, plays a critical role in FR. At the regional level, larger geographical entities, such as river basins or watersheds, exhibit significant connectivity through water flow, which can influence flood patterns across broader areas. For instance, implementing flood control measures upstream in a river basin can reduce downstream flood risk for communities situated further along the watercourse [22,133,152]. At the local scale, the focus shifts to specific communities, infrastructure, and land-use practices that directly influence flood vulnerability. Local connectivity can improve FR by fostering effective communication, evacuation routes, and community-based adaptation measures [10,133]. Moreover, localized land-use planning and zoning regulations can minimize flood exposure by restricting development in high-risk areas and promoting green infrastructure solutions [75,138,257].

Regarding urban growth rates, increasing growth leads to impervious surfaces, reduces natural water absorption, and contributes to surface runoff. As cities grow, they infringe on natural floodplains and wetlands that provide natural buffers against flooding.

Previous studies have shown that urbanization increases flood intensity and raises surface runoff peaks. For instance, Arnold et al. showed that water runoff doubled with only a 10–20% growth in waterproof covers [258]. White and Greer indicated that increasing urbanization from 9% to 37% between 1973 and 2000 in Peñasquitos Creek, California, amplified runoff by 200% [259]. Likewise, approximately 250% higher runoff was observed in Texas and New York urban areas than in greenery areas [133,260,261]. Brody et al. noticed that expanding impervious land cover across 81 coastal regions in Texas and Florida was associated with a considerable increase in flood flow [133,262]. From 1997 to 2001, flooding affected the built environment in over thirty-seven counties; every square meter of extra impervious cover annually adds around USD 3600 of property damage [96]. Bae and Chang investigated how land cover change and socioeconomic variables have influenced flood damage in the Seoul metropolitan region of South Korea over the past 30 years. They found that high flood damage is spatially clustered on the outskirts, where rapid urbanization occurred, and the proportion of farmland and urban area demonstrated positive and negative correlations with flood damage [20].

Development type has been discussed as one of the most significant factors in shaping disaster-resilient cities [35,263]. Some scholars believe that the compact type is a slogan for sustainability [103,264]. However, inadequately managed compact urban forms can engender adverse consequences, such as traffic congestion, air pollution, heightened health hazards, diminished recreational spaces, escalated land values, and housing costs, disproportionately affecting lower-income households and renters [51,139,265]. Compactness facilitates efficient resource allocation and infrastructure development to enhance FR [10,114]. Compactness may reduce damage because it is less likely to include hazardous areas such as floodplains [51]; however, the concentration of population and infrastructure in specific areas can also exacerbate flooding impacts and pose challenges in coordinating evacuation efforts and providing aid during and after floods [70,133]. Monocentric cities with a single dominant center may face heightened flood risks due to concentrated exposure [50,103,266]. In contrast, polycentric cities, with multiple activity centers, offer redundancy in critical infrastructure and provide alternative hubs for shelter and emergency operations, bolstering flood resilience through decentralized strategies. However, clustering can also foster resilience through social cohesion and shared resources, where close-knit communities often exhibit higher levels of collective action and mutual support, affecting disaster response and recovery [65,128,129]. Lastly, landscape and FR are rooted in the understanding that natural features and ecological systems play a critical role in mitigating flooding [65,138,267]. Landscapes incorporating elements such as wetlands, forests, and green spaces are natural buffers against floodwaters by absorbing, slowing, and redirecting their flow [7]. These features help reduce flooding intensity, decrease erosion, and enhance water absorption into the soil, minimizing infrastructure damage. Furthermore, landscapes support biodiversity, which enhances sustainable development and safeguards against climate-posed escalating risks [30,268,269].

4.4. Effectiveness of UFIs on FR at Mesoscale

The mesoscale encompasses a range of elements: polyvalency, land use patterns, building densities, modularity, green spaces, transportation networks, and infrastructure systems within a defined area of a city. These features significantly influence the local hydrological cycle, stormwater management, and flood response. For example, polyvalency, or the multifunctionality of spaces within urban areas, is closely tied to FR as it enables diverse and adaptable land uses that can respond effectively to inundation events [139]. Open spaces serve multiple purposes, such as recreational areas, temporary flood storage during heavy rainfall, and flexible buffers against flooding [129,131,153]. Street network connectivity is critical to FR because it influences evacuation routes, emergency response times, and access to essential services during flood events [97,120,235,270,271]. Well-connected street networks with multiple routes and alternative paths can facilitate the movement of people and resources, reducing the risk of isolation or trapped populations during flood events. Additionally, interconnected streets provide opportunities for effective stormwater management through decentralized drainage systems and green infrastructure [167,242,272].

Population density has significant implications for FR, as it affects evacuation procedures, emergency response capabilities, and the overall vulnerability of urban areas to inundation [131,173,273]. High population densities in flood-prone zones increase the number of people at risk and the potential for widespread impacts on public health, safety, and infrastructure. However, dense urban areas also offer opportunities for efficient land use, infrastructure sharing, and collective responses to flooding. Modularity in resilient systems refers to the design principle that allows structurally or functionally distinct parts of a system to retain autonomy during periods of stress. This approach facilitates easier recovery from loss, making the system more resilient [274,275]. In FR, modularity can be applied to infrastructure, urban planning, and environmental management to ensure that even if one part of the system is affected by a flood, other parts can continue functioning, reducing the event's overall impact. For example, in urban planning, modularity can be applied by designing buildings and infrastructure in a way that allows for the isolation of flood-affected areas without disrupting urban functionality [39,88,139,202]. Harmony with nature is essential for fostering FR by integrating natural features and ecological processes into urban landscapes [7,139]. Nature-based solutions, such as blue–green infrastructure, mitigate flooding by absorbing excess water, reducing runoff, and enhancing soil permeability. Additionally, natural habitats provide essential ecosystem services, such as water filtration, carbon sequestration, and habitat for biodiversity, contributing to overall urban resilience.

Mixed-land use is a crucial principle in FR planning, as it promotes the integration of diverse activities and functions within urban areas, creating vibrant and resilient communities less susceptible to flood impacts [51,268,276]. Mixed-use development impacts FR in many ways. Firstly, mixed-use projects enable the integration of diverse amenities and services, enhancing the ability to adapt to challenging circumstances swiftly. Secondly, combining different land uses fosters stronger social connections, bolstering the capacity to absorb and recover from adverse events. Flood risk is distributed across multiple areas by spreading out different land uses. This means that even if one location is severely affected by flooding, others may remain unaffected or may be less impacted [277,278]. Hence, mixed land-use strategies facilitate shorter mobility distances and increase local self-sufficiency [67,192,279].

Flood evacuation route accessibility is critical for safety during flood events [235,280]. Cities need well-defined evacuation routes for effortless mobility, particularly in flood-prone areas. Clear signage, designated evacuation centers, and efficient transportation systems are essential to an effective evacuation plan. In the article "Enhancing Pedestrian Evacuation Routes During Flood Events", Musolino, Ahmadian, and Xia present a novel approach to increasing resilience by retrofitting existing infrastructure to enhance evacuation and access routes, thereby reducing the flood hazard rate based on flood and pedestrian characteristics. The research also emphasizes that the shortest path is not always the safest when designing an evacuation plan. It suggests that all possible evacuation routes should be considered to determine the safest path to an assembly point [281].

Additionally, cities can leverage technology, such as real-time monitoring and communication systems, to provide timely warnings and updates to residents about evacuation routes and flood risks [152,282,283]. Proximity to water bodies significantly impacts FR, as areas near rivers, lakes, or coastlines are more susceptible to inundation and flood risks [268,284–286]. While proximity to water bodies may offer recreational and economic opportunities, it also increases the vulnerability of communities to flooding events. Improving green infrastructure and restoring natural buffers along water bodies can mitigate flood impacts and enhance urban waterfront resilience. The open space index (OSR), or green space ratio, measures the amount of open and green space within urban areas relative to the total land area. Sharifi et al. defined it as "any unroofed ground space in the city (either natural or human-made), excluding various types of right-of-way, which can be publicly or privately owned" [10]. High OSR values indicate more abundance of parks, recreational areas, and natural landscapes. Green spaces absorb excess water, reduce runoff, and mitigate flood risks by providing natural drainage systems and flood storage areas. Additionally, green spaces contribute to the overall well-being and quality of life of urban residents, providing opportunities for recreation, relaxation, and social interaction. Floor area ratio (FAR) is a critical urban design parameter that influences FR by regulating the intensity of development and the density of built-up areas within a given space. The FAR represents a building's total floor area divided by the size of the lot it occupies [287]. In flood-prone areas, high FAR can exacerbate flood risks by increasing impervious surfaces; conversely, low FAR may allow for porous surfaces, facilitating water absorption and reducing flood vulnerability. Edge density refers to the amount of perimeter or edge relative to the area of a landscape patch or urban district, and it plays a significant role in FR by influencing water flow patterns and connectivity. Higher edge densities in urban areas result from irregularly shaped patches, intricate street networks, or fragmented land use patterns [103,104,288]. Excessive edge density can lead to localized flooding without proper stormwater management infrastructure.

4.5. Effectiveness of UFIs on FR at the Microscale

The microscale includes localized elements such as block design and surface permeability. For example, building setbacks, which are the distances between a building and its property lines, allow stormwater to collect and infiltrate into the ground temporarily [42,230,289]. More setbacks can provide more space for green infrastructure features like rain gardens and swales, attenuating and managing stormwater runoff [48,253,290,291]. Moreover, setbacks provide emergency access for responders during flood events, enabling efficient rescue operations and evacuation procedures. During the tsunami inundation, Tomiczek et al. investigated the effect of building setbacks on hydrodynamic loads and discovered that the spaces between buildings reduce water depth and vulnerability [71,292]. The concept of "patches" refers to the fragmentation of urban areas into smaller, more manageable units [293]. This fragmentation can take various forms, including dividing a city into smaller districts, creating green corridors, or implementing buffer zones between land uses [205]. Higher numbers of patches indicate greater landscape diversity and connectivity, which can enhance flood resilience by providing multiple pathways for water flow [133,139,261]. However, excessive patchiness indicates land use fragmentation and sprawl, which can compromise flood resilience by reducing contiguous green spaces and impeding effective stormwater management [112,208]. More patches can lead to a more fragmented urban landscape, slowing floodwater spread and reducing flooding risk in adjacent areas. It implies that smaller, more manageable units can be more easily managed and adapted to changing conditions, including climate change and increased flood risk [36,140,205]. However, the effectiveness of patches in enhancing FR depends on several factors, including the size and distribution of the patches, the types of land uses within each patch, and the presence of buffer zones or green corridors that can absorb and store floodwater [187,288,294]. For example, tiny or poorly connected patches may not effectively reduce flood risk. Similarly, patches that do not include buffer zones or green corridors may not provide sufficient space for floodwater to be absorbed and stored.

The shape of the patches influences FR by impacting water flow and distribution during inundation events. Irregularly shaped patches, characterized by jagged edges or intricate boundaries, create more diverse flow paths for floodwater than uniformly shaped patches [5]. This diversity can improve FR by dispersing water force and reducing concentrated flow or infrastructure damage. Irregular patch shapes can provide natural flood storage areas or retention zones, allowing water to be temporarily held and gradually released, thus mitigating peak flows downstream [21,22]. Lots size significantly impacts FR, as fine-grained lots manage flood risks better than larger ones. Fine-grained lots allow for greater land use diversity and more efficient land management practices. With smaller lots, green infrastructure is typically more accessible.

Additionally, smaller lots enable more flexibility in urban design, creating interconnected open spaces and waterways that can serve as natural drainage channels during heavy rainfall [17]. Worn-out urban texture, which includes aging infrastructure, deteriorating buildings, and neglected public spaces, can pose challenges to FR [69]. In such areas, inadequate maintenance and outdated infrastructure impede drainage systems, exacerbating flood risks during extreme weather events. Building conditions, including structural integrity and maintenance, directly impact FR [295]. Well-maintained buildings with robust foundations, watertight envelopes, and flood-resistant materials are better equipped to withstand inundation and minimize flood damage [66,296,297]. Conversely, deteriorating or poorly maintained buildings are more susceptible to flood damage, compromising occupant safety and resilience. The sky view factor (SVF), the ratio of the visible sky to the total field of view at a given point in the urban environment, influences FR. High SVF areas with abundant open space and vegetation tend to experience lower temperatures, reduced heat stress, improved ventilation, and decreased flood vulnerability due to more permeable surfaces [10,128].

Building height influences adaptability, pedestrian safety, and overall resilience to flooding [10]. Low-rise buildings with elevated ground floors or flood-resistant foundations are less vulnerable to inundation and can remain functional during floods with minimal damage. In contrast, high-rise buildings with ground-level entrances may face higher flood risks and require additional protection measures to safeguard occupants and assets. Beijing Normal University, Beijing Hydrological Center, and the China Institute of Water Resources and Hydropower Research highlight the importance of urban planning in mitigating flooding risks [298,299]. The study found that urban buildings' arrangement and heights significantly impact pedestrian safety during floods. Li et al. explored how different urban configurations affect flooding severity, finding that the arrangement of buildings and conveyance porosity in the primary flow direction has a notably positive impact on flood reduction [143]. Additionally, higher building coverage ratios result in more impervious surfaces and less open space for stormwater infiltration and storage, leading to increased runoff volumes and faster flood peaks during rainfall events [22,37,268,300]. Impervious surface ratio, the proportion of non-absorbent surfaces such as pavement and rooftops to the total land area, directly impacts FR. High impervious surface ratios in urban areas increase surface runoff during rainfall, overwhelming drainage systems and exacerbating flooding [22,133,137]. A study in Nanjing City, China, examined the influence of the built environment on FR, revealing the high effects of the impervious surface ratio on FR [76]. Mustafa et al. demonstrated a procedure for automatically designing flood-sensitive urban layouts based on porosity-based hydraulic computations of inundation flow for a set of 2000 building layouts [37]. Their findings indicated that conveyance porosity and increasing building setbacks decreased upstream water depth and severity.

Block size impacts FR by influencing permeability, connectivity, and land use patterns within urban areas [114,230]. Smaller block sizes, interconnected streets, and pedestrian-friendly design promote efficient stormwater management, reduce flood risks, and enhance mobility during flood events. Additionally, smaller blocks encourage mixed land uses, diverse building typologies, and compact development patterns, fostering resilience and vibrancy in urban neighborhoods. Building configuration, furniture, and facade design influence FR by affecting building functionality, durability, and adaptability [10,139,230]. Well-designed furniture and facade elements, such as elevated entrances, flood barriers, green facades, and waterproof materials, can minimize flood damage, ensure occupant safety, and facilitate recovery efforts [301]. FR is impacted by street elements such as aspect ratio, front setback and usage, and emergency route design [133,230]. Streets with appropriate setbacks from buildings allow effective stormwater management and create space for green infrastructure or flood barriers. Moreover, designing streets with clear emergency routes, minimizing obstructions, and incorporating features like raised medians or traffic islands for temporary flood storage can enhance evacuation and emergency response capabilities during flooding events [10,42,131,154,230,256]. Curved streets can alter flow paths and velocities, potentially affecting flood propagation within a block. Sharp bends or curves may cause flow constrictions or eddies. Longer streets provide more pathways for stormwater to flow, potentially increasing the volume and velocity of runoff within a block, particularly in areas with inadequate drainage infrastructure. Street orientation can influence exposure to sunlight and wind, affecting evapotranspiration rates [42,289,302]. Additionally, street orientation may impact the distribution of impervious surfaces and vegetation within a block, influencing runoff patterns and flood dynamics. Mohammed conducted a computational analysis study in Ethiopia and discovered that street network layouts that follow stormwater flow direction significantly impact runoff volume [302].

5. Discussions and Conclusions

This study fills the existing literature gap by examining potential connections between UFIs at three scales and FR. By examining the collective body of literature reviewed, the discussion delves into the strengths, limitations, and implications of existing studies in this domain, offering insights into current knowledge and avenues for future research. We will briefly discuss the key aspects of each element.

5.1. Concise Discussion

Understanding the interplay between UFIs and FR has several benefits for urban resilience. Studies have diverse perspectives on urban form's influence on FR results because they use different indices at different levels and focus on a specific city, limiting their generalizability. Urban areas vary widely in their susceptibility to flooding, depending on topography, soil type, climate, historical development patterns, economic forces, and cultural preferences. Finally, studies and approaches from multiple disciplinary backgrounds have different theoretical frameworks, research methods, and priorities. Studying macroscale urban form elements such as city size and density, degree of distribution and clustering, urban growth rate, and landscape elements provides valuable insights into understanding FR. City size and density influence the extent of impervious surfaces and natural systems' capacity to absorb rainfall, affecting surface runoff and flood risk. Moreover, distribution and clustering impact FR by altering the effectiveness of water flow paths and drainage systems. Urban growth and rapid urbanization can outpace infrastructure development, increasing flood vulnerability. Landscape elements affect water absorption, runoff, and floodplain dynamics. Studying the mesoscale encompasses an array of factors crucial for FR. Polyvalency fosters adaptability and resourcefulness in crises, aiding flood management strategies. Street network connectivity ensures efficient evacuation routes and emergency responses. Flexibility allows adaptive measures to be implemented swiftly, accommodating changing flood dynamics. Population density influences evacuation processes, emergency service accessibility, and community resilience capacities. Modularity promotes resilience by reconfiguring spaces and infrastructure to effectively respond to flooding events.

Harmonizing with nature promotes ecosystem services that aid flood mitigation, such as wetlands or green infrastructure providing natural flood protection. Mixed-land use diversifies urban functions, reducing vulnerability by dispersing critical assets and services. Proximity to water bodies necessitates careful planning to mitigate flood risks, incorporating buffer zones and floodplain management strategies. The number and shape of patches, building setbacks, and urban texture all impact FR at the microscale. A higher number of patches, especially when interconnected by green spaces or porous surfaces, can enhance infiltration and reduce surface runoff, mitigating flood risk. Similarly, the shape of patches plays a crucial role, with irregular shapes promoting better FR by creating natural flow paths and increasing surface area for absorption. Building setbacks impact FR by influencing flood extent and potential damage. Parks, green belts, and recreational areas also provide recreational amenities and natural buffers against flooding. FR is influenced by the condition of buildings, street depth, sky view factor, building height, and the ratio of impervious surfaces. According to the revised literature review, Table 5 presents how each element influences FR by dividing it into three dimensions: Negative influence refers to aspects or factors that cause a decrease in FR; positive influence relates to aspects that enhance FR; dual influence refers to aspects or characteristics that can positively and negatively affect FR, depending on context, implementation, or interaction with other elements. In Figure 6, we relate each urban form to resilience characteristics, drawing on previous studies and expert opinions. The correlation ratio ranges from 0 to 100%, where 0 indicates no association between the variables. In comparison, 100% indicates an ideal association, meaning that the categorical variable can explain all continuous variable variability. Our findings reveal that many elements are closely linked to crucial resilience attributes such as collaboration, resourcefulness, connectivity, redundancy, complexity, modularity, flexibility, diversity, multifunctionality, robustness, and adaptability.

Table 5. The linkages between UFIs and FR at multiple scales.

Scale	Morphological Indicator	Definitions	Influence
Macroscale urban form	City size and density [124,303]	The size of a city is a quantitative indicator that distinguishes whether it is large or small based on the linear relationship between population and area.	Negative
	Degree of distribution [62]	The degree of clustering can be used to measure urban form (compactness, polycentricity, or concentricity) through the global Moran's I coefficient [304,305].	Dual
	Degree of clustering [62]	The degree of distribution is used as an index indicating that the population or urban area is unevenly distributed. Local Moran's I is a familiar LISA (Local Indicators of Spatial Association) statistic that identifies locations with significant clustering or spatial outliers [304,305].	Positive
	Urban growth rate [306]	The urban growth rate refers to the rate at which the population of urban areas increases relative to the total population.	Negative
	Landscape elements	Landscape refers to the visible features of an area of land, including its physical elements such as terrain, vegetation, water bodies, and human-made structures.	Positive
Mesoscale urban form	Polyvalency [22,152]	It refers to a space's ability to be open to multiple interpretations and appropriated ways. It is a form of flexibility that extends beyond physical reconfigurability via moving walls or panels.	Positive
	Street network connectivity [22,152]	It refers to the design and layout of streets within a city or urban area, aiming to ensure that all parts of the city are accessible and well-connected.	Positive
	Flexibility [80,307]	The ability of urban spaces and structures to adapt to changing needs, conditions, and future scenarios. It involves aligning placeness factors with perceived urban design qualities (PUDQs) to enhance adaptive attributes.	Positive
	Building heights [230,308]	Building heights are critical to urban planning and design, influencing cities' physical and social characteristics. They are closely related to the economic context, physical systems, transportation, environmental effects, and culture.	Dual
	Population density [105,309]	Population density is a measure that quantifies the number of people living in a specific area, typically expressed as the number of people per unit area.	Negative

Table 5. *Cont.*

Scale	Morphological Indicator	Definitions	Influence
Mesoscale urban form	Modularity [310,311]	Modularity refers to the design principle of breaking down a system or product into smaller, independent modules or components.	Positive
	Harmony with nature [22,139,312]	Harmony enhances incorporating natural ecosystems into urban forms to absorb and reduce flood risk and surface imperviousness, such as blue-green infrastructure (GBI).	Positive
	Mixed-land use [124,284,313]	Mixed-land use refers to integrating various land uses within a single area, such as residential, commercial, retail, and recreational spaces.	Positive
	Flood evacuation routes [22,314]	Evaluate the availability and accessibility of flood evacuation routes to ensure safe and efficient evacuation. Dijkstra's algorithm, which finds the shortest path between two nodes in a weighted graph, can be used to calculate the optimal evacuation routes.	Positive
	Proximity to water bodies [260,284]	Identifying urban areas within flood-prone zones, such as floodplains or coastal areas, is a fundamental indicator of flood vulnerability.	Negative
	Landscape percentage [20,288]	A compensation metric that measures the percentage of landscape belonging to urban areas	Positive
	Open space index [10]	Open space index describes the relationship between unbuilt space and the total built surface.	Positive
	Floor area ratio (FAR) [141,287]	The FAR is a zoning regulation that limits the amount of floor area on a specific piece of land. It calculates the ratio of a building's total floor area to its total land area.	Negative
	Edge density [187]	An aggregate metric that measures urban landscape fragmentation	Negative
	Fractal dimension (FD) [266,294]	FD refers to applying fractal geometry to urban morphology's complex, scale-free patterns. This approach helps understand urban growth and development's non-linear, self-similar structures. FD can be defined using generalized entropy and correlation functions, providing a mathematical framework for analyzing urban form diversity and complexity.	Dual
Microscale urban form	Number of patches [101,288]	The number of urban patches in a city or urban area is a critical metric in urban morphology, reflecting the complexity and diversity of urban landscapes.	Negative
	Shape of the patch [261,294]	It typically refers to a specific area's geometric configuration or form within an urban environment.	Dual
	Building setbacks [42]	Building setback distance is calculated as the total property width (or depth) minus the allowable building footprint.	Positive
	Worn-out urban texture [22]	Worn-out urban texture refers to the physical and visual characteristics of urban environments that have been altered or degraded over time due to various factors such as urban development, environmental changes, and human activities.	Negative

Table 5. *Cont.*

Scale	Morphological Indicator	Definitions	Influence
Microscale urban form	Access to open space [288,315]	It refers to the availability and ease of access to public outdoor areas frequently used for recreational or environmental purposes. These areas include parks, playgrounds, trails, nature reserves, beaches, and other green spaces.	Positive
	Buildings' condition [316]	Poor building conditions increase buildings' vulnerability to flooding.	Negative
	Street depth (SP) [17]	It refers to the distance between the front property lines of buildings on opposite sides of a street.	Positive
	Sky view factor (SVF) [10,128]	SVF provides valuable insights into building spatial arrangements and the openness of urban spaces. It can be calculated using ENVI-MET [317]	Positive
	Building height and mass [314,318]	Building height and massing describe the physical characteristics of buildings. Massing refers to the arrangement and distribution of volume within a building or a group of buildings. Building height refers to the vertical distance from the ground to a building's highest point, including any architectural features such as spires, antennas, or other protrusions.	Dual
	Impervious surface ratio (ISR) [120,319]	ISR is a measure used to quantify the amount of impervious surfaces in a given area. It is calculated by dividing the total area of all impervious surfaces by the total area of the site.	Positive

Note: Influence classification according to the revised literature review, specialized experts, and the authors.

Urban form strategies and FR lead to dual-aspect influences. For instance, while high-density areas can yield numerous socioeconomic and environmental benefits, they may also become prime targets for terrorist attacks. Compact urban forms promote efficient land use by reducing sprawl and long-distance commuting, conserving natural habitats and agricultural land, and promoting sustainable development. Compact urban forms with tall buildings and limited vegetation can exacerbate the urban heat island effect, leading to higher temperatures and decreased thermal comfort, which can negatively impact public health, particularly during heat waves, and increase energy consumption for cooling. Enhancing land use diversity may affect housing affordability and prioritization, and excessive compactness harms well-being and livability while posing challenges to renewable energy adoption. These trade-offs highlight the complexity of urban planning, where balancing multiple objectives is essential for sustainable development. Similarly, connectivity, often hailed as a desirable urban form measure, can prove detrimental in the context of resilience to health epidemics, as heightened connectivity can facilitate disease spread. Other urban form elements, such as 'city size' and 'degree of clustering', may have varying implications across different phases. Hence, the trade-offs inherent in pursuing each of these characteristics must be carefully examined. Urban planners must consider potential trade-offs with other hazard mitigation strategies while implementing FR measures to ensure comprehensive and balanced resilience. A holistic approach is essential when applying this conceptual framework to assess urban form resilience, necessitating a thorough understanding of its components' interrelationships.

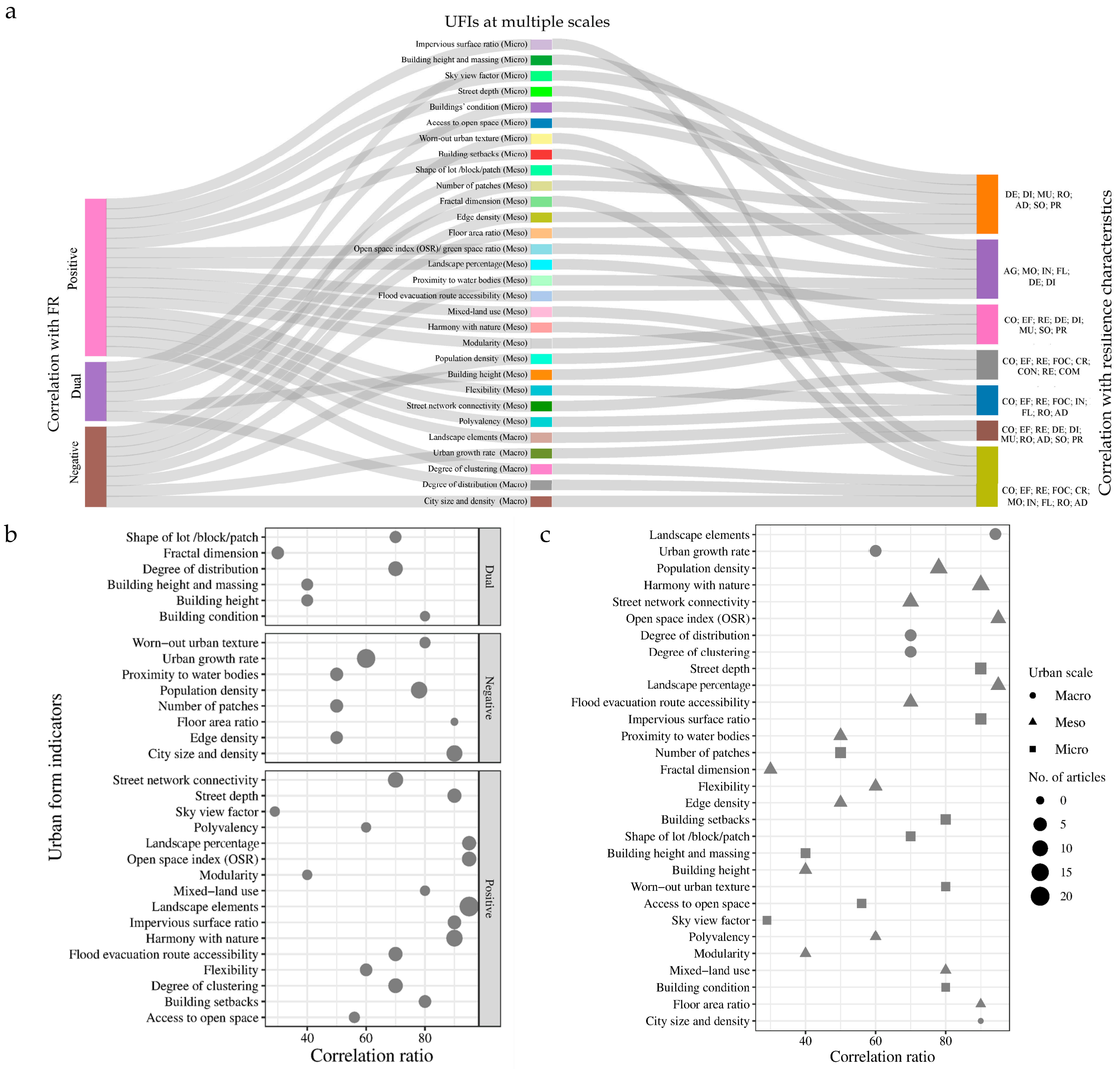


Figure 6. Multi-scale urban form elements relevant to FR, based on the evidence discussed in Sections 4 and 5. (**a**), a Sankey plot shows the relationship between FR, urban form elements, and urban resilience characteristics. The following are abbreviations for urban resilience characteristics: foresight capacity (FOC); creativity (CR); connectivity (CON); redundancy (RE); complexity (COM); agility (AG); modularity (MO); independence (IN); flexibility (FL); deformability (DE); diversity (DI); multifunctionality (MU); robustness (RO); adaptability (AD); self-organization (SO); and productivity (PR). (**b**), the number of articles that discuss urban form and FR, and (**c**), the correlation between scales of urban form and FR articles.

5.2. Literature Review Gaps and Prospective Research

Our research offers valuable perspectives on the correlation between UFIs and FR. Nevertheless, significant aspects that warrant further investigation in subsequent studies remain: While UFIs play a role in FR, some have garnered more attention than others, leaving certain elements relatively underexplored. Moreover, there is a notable gap in evidence regarding how specific UFIs empirically relate to FR and overall urban form resilience, as shown in Table 6. Previous studies on FR assessment focused on individual components of urban form, such as land use patterns, building design, or infrastructure systems. However, a more holistic and integrated approach is required to consider the complex interplay between various urban form indicators in multi-scalar analysis. Achieving complete FR is likely unattainable due to conflicts and trade-offs arising from different priorities and stressors (such as natural disasters, socioeconomic challenges, and environmental concerns). For example, a strategy to enhance FR might conflict with efforts to preserve biodiversity or maintain affordable housing, illustrating that addressing one aspect of resilience may inadvertently compromise another.

Table 6. Articles addressing UFIs at various scales and FR. In addition, the papers address possible conflicts resulting from actions intended to enhance FR and overall urban resilience.

Scale	Morphological Indicators	No. of Articles	No. of Articles Discussing Conflict	%
Macroscale urban form	City size and density	13	7	6.9%
	Degree of distribution	9	5	5.0%
	Degree of clustering	9	5	5.0%
	Urban growth rate	18	12	11.9%
	Landscape elements	20	6	5.9%
Mesoscale urban form	Polyvalency	2	0	0.0%
	Street network connectivity	11	4	4.0%
	Flexibility	5	3	3.0%
	Building heights	4	3	3.0%
	Population density	14	8	7.9%
	Modularity	2	1	1.0%
	Harmony with nature	14	8	7.9%
	Mixed-land use	9	6	5.9%
	Flood evacuation route	8	3	3.0%
	Proximity to water bodies	6	1	1.0%
	Landscape percentage	8	3	3.0%
	Open space index (OSR)	9	3	3.0%
	Floor area ratio (FAR)	1	1	1.0%
	Edge density	5	3	3.0%
	Fractal dimension (FD)	5	0	0.0%
Microscale urban form	Number of patches	6	2	2.0%
	Shape of the patch	4	2	2.0%
	Building setbacks	5	3	3.0%
	Worn-out urban texture	3	1	1.0%
	Access to open space	3	1	1.0%
	Buildings' condition	2	0	0.0%
	Street depth (SP)	8	5	5.0%
	Sky view factor (SVF)	3	2	2.0%
	Building height and massing	4	3	3.0%
	Impervious surface ratio (ISR)	7	0	0.0%

As a result, researchers and policymakers must carefully navigate these trade-offs and develop nuanced approaches that balance competing priorities to enhance FR and overall urban resilience effectively. Most discussion and conflict in urban form revolves around density; however, the study acknowledges that other UFIs might also lead to contradiction, albeit to a lesser extent, implying that additional conflicts may emerge as research in the field progresses. Therefore, more in-depth studies are needed to examine the possible trade-offs between different urban form elements and develop ways to help decision-makers minimize these trade-offs. In addition, prospective research could include longitudinal studies that track the evolution of urban form and FR outcomes after various interventions, providing valuable insights for future policymaking. Analyzing UFIs and FR is concentrated in developed countries; more research is needed in developing countries with socioeconomic vulnerabilities and inadequate infrastructure and resources. Nature-based solutions, low-impact development (LID), green infrastructure (GI) tools, and other non-structural interventions should be evaluated in various urban forms.

In addition to physical factors, non-physical factors such as administrative, social, and economic factors also play a crucial role in determining FR. As global urbanization continues, providing planners and decision-makers with insights into resilient urban forms can help prevent cities from becoming trapped in undesirable trajectories and avert potential disasters. Given the variability of optimal form parameters across contexts, more context-specific studies are needed to give planners and policymakers tailored guidelines for enhancing urban resilience. More research can develop and apply weighting schemes that prioritize these UFIs based on their relative importance and contribution to the FR. For example, machine learning algorithms are crucial in assessment instead of relying consistently on multi-criteria decision-making (MCDM) (AHP, fuzzy AHP, VIKOR, etc.), which depends on subjectivity. Furthermore, assessing the efficacy of UFIs in pre- and post-flood mitigation scenarios and projecting potential susceptibility scenarios is essential to gaining practical insights to develop flood mitigation strategies. Thus, we recommend studying different forms under the same conditions and at various scales in the same region.

5.3. Conclusions

Our systematic review highlights the multifaceted relationship between UFIs and FR. By meticulously examining existing literature, we have identified key insights and trends contributing to a deeper understanding of how urban form influences FR across various spatial scales. Our findings highlight the importance of considering diverse urban form factors, ranging from microscale land use patterns to macroscale city morphology. By synthesizing the knowledge gleaned from this review, we aim to inform urban planners, policymakers, and researchers about the critical role of urban form in reinforcing FR. Nevertheless, significant aspects warrant further investigation in subsequent studies, so our study presents literature review gaps and several opportunities for prospective research.

Further empirical evidence is required on the trade-offs between the efficacy of UFIs, FR, and overall urban resilience through interdisciplinary collaborations. Despite our extensive study, we relied only on English articles from nine search engines. One recommendation for improvement is diversifying the sources, languages, and methodologies used for gathering information. In addition, it could involve exploring alternative search engines or databases that provide a more comprehensive understanding of the topic. For example, researchers could consider utilizing specialized search engines tailored to their field of study or accessing repositories of other literature, such as conference proceedings or technical reports. These repositories may contain valuable insights not captured by traditional academic databases. Additionally, complementary research methods, such as qualitative interviews, surveys, or case studies, can offer alternative perspectives and enrich the findings.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16125076/s1, Table S1. PRISMA 2020 checklist.

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