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Adaptive Strategies in Urban Elevation Change for Flood Risk Management: The Case of Mamminasata Metropolitan Regions, Indonesia

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Abstract: This research aims to analyze elevation change as an adaptation strategy for flooding, identify the dynamics and patterns of adaptation and collaboration between actors, and evaluate the impact of elevation change on the urban environment of Mamminasata, Indonesia. This research uses qualitative methods with interpretative phenomenological analysis (IPA). Data collection involved observations, in-depth interviews, and documentation. The results show that elevation changes in buildings, land, and road infrastructure trigger an increase in elevation adaptation strategies by actors while expanding the flood-affected areas as a consequence of such measures. The nature of actors' strategies varies; communities tend to be spontaneous, independent, and informal, while developers and the government employ business strategies and policy support tactics. Consequently, these strategies are fragmented among actors because of the lack of uniformity in elevation regulations. This reflects a pattern of long-term urban adaptation, even in the absence of formal coordination or regulation. Elevation changes negatively impact ecosystems, land stability, and social and physical connectivity. This study recommends the application of elevation changes in planning regulations for zoning and land-use management, as well as collaborative governance, to support adaptation strategies of actors and promote sustainable urban resilience.

Keywords: adaptation strategies, elevation changes, flooding, phenomenological interpretation, metropolitan regions

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1. Introduction

By 2050, more than 70% of the world's population is expected to live in cities, accelerating the development of global cities characterized by population growth driven by urbanization and its impact on suburbs. This trend will drive the growth of suburbs and their transformation, highlighting the distinctiveness of suburban change [1, 2]. Urbanization and urban transformation drive the conversion of water catchment areas and agricultural land into housing and settlements. In 2006, land conversion in Makassar City primarily involved an increase in residential and housing areas, which grew by 13.92% from 7,849 to 10,294 ha by 2016, alongside a decrease in water catchment and agricultural land. By 2031, the built-up area is projected to reach 80.37% of the total city area [3]. Land use conversion in the Bumi Tamalanrea Permai settlement area has increased built-up land, which was previously a water catchment area and rice fields, from 57.36 ha, or 21.65%, in 1999 to 114.49 ha, or 43.20%, in 2018, with a further increase to 171.85 ha, or 64.85% [4].

Increasing urbanization, population concentration, urban densification, and climate change pressures are the main factors increasing the vulnerability of urban communities, ultimately leading to increased flood risk [5, 6]. There are constraints on implementing sustainable urban development, with limited integration of adaptation and mitigation strategies in climate action plans and broader climate-change frameworks [7, 8].

There are also differences in the design and integration of mitigation and adaptation methods [9]. Other perspectives often focus more on mitigation due to the influence of international networks and more immediate local benefits than on adaptation. Both approaches can complement each other and provide benefits in specific contexts [10].

The modification of urban space has become an important issue and practice for the general public and developers in dealing with flooding risks. The massive process of spatial and physical transformation of housing in water catchment areas encourages people to change the elevation of buildings to mitigate the risk of flooding. This elevation change phenomenon also occurs in new housing development practices through landfilling and elevating land surfaces (landraising) to avoid flooding, resulting in non-uniformity in spatial elevation [5]. Mitigation and adaptation approaches can complement each other in complex urban contexts, with mitigation focusing primarily on technical interventions to reduce hazards, and adaptation providing space for the response of urban actors such as communities, developers, and governments. This issue emphasizes the importance of a more thorough understanding of elevation-based adaptation strategies in this region. Therefore, the objectives of this study are to examine elevation change as a flood adaptation strategy, analyze the dynamics and adaptation patterns of the actors, and evaluate its impact on the urban environment.

2. Literature Review

One form of structural adaptation developed in flood-prone areas is elevation-based adaptation to reduce vulnerability to flooding [5]. Increased urban activities, particularly modifications to land-elevation-based spatial use, can contribute to environmental degradation, alter activity patterns, and increase flood risk in new urban areas [11]. The practice of building modification has been widely used in disaster mitigation, for example by raising house floors [12]. Adaptation is the proactive change of a person's structure and function that enables adjustment to environmental changes [13]. In development, the community gains knowledge in building urban resilience [14], and invests in improving physical and environmental conditions to mitigate flood risks, which contributes to increased resilience [15]. Important strategies used include raising walls and stairs to prevent floodwater entry [16]. The community has its own views and assumes responsibility for adapting to flood risks, though formal legal policies do not always align with these perceptions [17].

The dynamics and patterns of adaptation strategies among actors, and the functioning of collaboration between these actors have not received much systematic study. While elevation changes implemented by communities, developers, and governments can significantly contribute to urban resilience, they also have the potential to create inequality and spatial fragmentation. Therefore, this research aims to fill this gap by analyzing elevation-based adaptation strategies implemented by actors, examining how these strategies foster collaboration, and evaluating their impacts in the context of urban flood-risk environmental management practices.

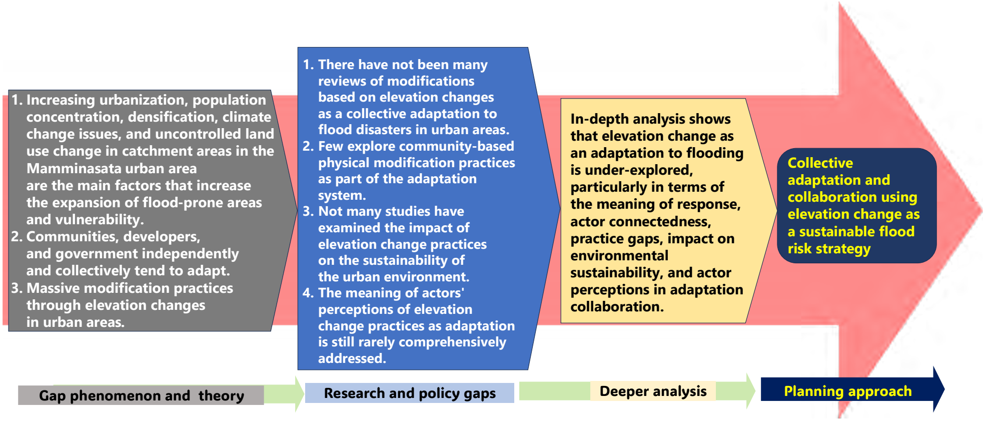

Fig. 1. Conceptual framework

The approach can make an essential contribution to developing a theory of adaptation that not only addresses technical interventions but also emphasizes the non-structural roles and interactions of actors in creating collaboration and sustainable urban resilience (Fig. 1).

Current studies tend to focus on technical and structural interventions for flood mitigation. There is still a lack of research focusing on the perceptions and meanings of the experiences of residents, developers, and government in responding to flood adaptation practices in informally growing urban areas, whether independently by residents, through collective efforts to modify their living environment, through developers engaging in landfilling practices, or through government in the policy-making process that shapes and responds to these elevation-change practices. This gap highlights the need for qualitative research using the IPA method to interpret the experiences of actors in technical and socio-spatial practices in urban settlements prone to flooding.

In this study, elevation changes refer to changes in physical form as an adaptation strategy for urban flood risks. This practice includes renovation actions, road quality improvement, landfilling, embankment construction, and the elevation of buildings, land, and road bodies carried out by individual or community actors, developers, and government, with the primary objective of flood resilience. Collective practice refers to adaptation through elevation change that does not involve formal rules. Various studies have not explored in depth the response of actors (communities, developers, and government) in terms of processes, adaptation strategies through elevation changes, and the meaning of emerging collective practices. This research integrates a phenomenological interpretation into the analysis to understand the actors' experiences. The research questions were as follows:

1. How did elevation change become a flood adaptation strategy and evolve as a collective practice?
2. What are the dynamics and patterns of actors' adaptation to flood risk?
3. What are the levels of connectedness, gaps in elevation-change practices, and collaboration challenges among urban actors?
4. What are the spatial benefits and impacts of elevation change in urban areas?

3. Materials and Methods

3.1. Study Area

The research location is a settlement area in the Mamminasata Metropolitan Area in Indonesia (Fig. 2), which includes:

– Bumi Tamalanrea Permai (BTP) settlement area, administratively located in Tamalanrea and Biringkanaya Districts (suburbs of Makassar City);
– Pesona Pelangi Cluster Housing and Royal Central Land Housing, administratively located in Moncongloe District, Maros Regency (peri-urban Mamminasata Metropolitan Area).

This housing and settlement area constitutes a flood zone and experiences flooding almost every year, causing damage to property and loss of life [18–20].

The Mamminasata Metropolitan settlement area was selected for the following reasons:

- it is a water catchment area, and former rice fields have been converted into residential areas;
- it is a flood-prone area;
- the community has taken the initiative to physically modify buildings and roads by elevating them, and developers have elevated residential land to overcome flooding;
- the spatial elevation efforts by communities, developers, and the government for flood mitigation remain underexplored.

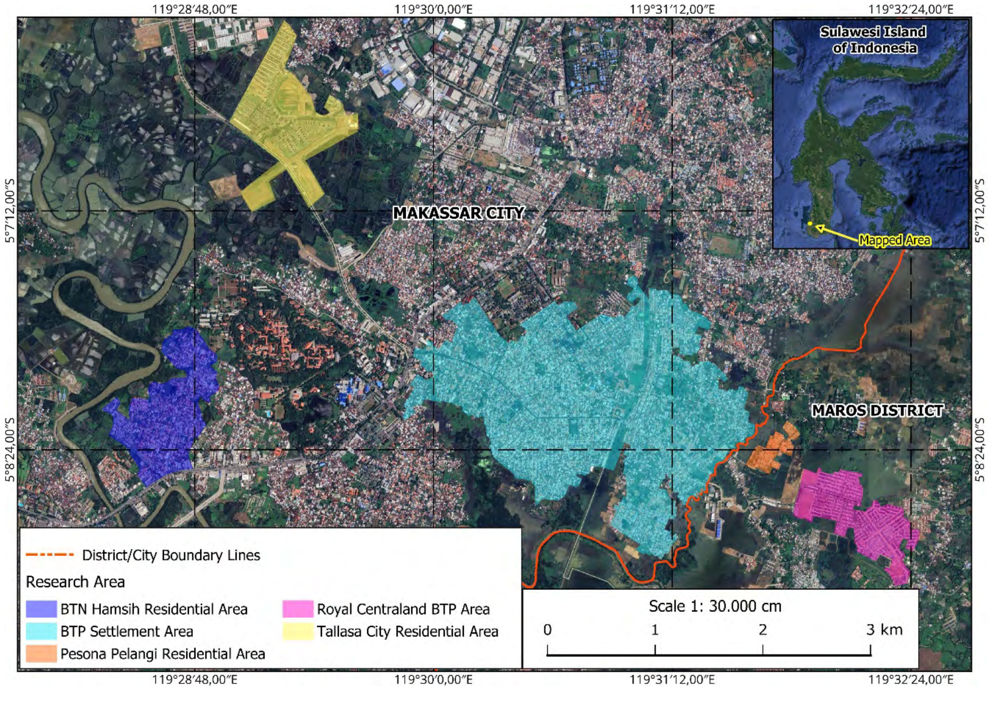

Fig. 2. Map of the research location, suburbs of Makassar city, and Maros Regency within the Mamminasata Metropolitan Area, Indonesia

Source: author's elaboration based on © 2024 Google

3.2. Method of Data Collection

The data collection process for this research included field and indirect observations, documentation, and in-depth interviews. The collection of visual-spatial research data, documentation, and in-depth interviews was carried out through the following stages. First, the researchers used the Google Earth Pro application based on Street View to observe changes in building elevation and road infrastructure from 2015, 2019, and 2024. Observations using Google Earth Pro or Google Maps provide Street View-based visuals and photos that allow users to examine past conditions [21]. This Street View method identifies spatial potential, especially building differentiation, landscape, and activities captured in photos [4]. Google Street View is regarded as a tool that goes beyond the digital as it is capable of evoking an emotional and historical sense of place [22].

In this study, field observations and interviews did not cover all residential areas. Instead, observations focused on residential areas, with segments of roads and buildings selected based on the number of buildings and roads with elevation changes, as well as flood-prone areas. This approach enabled observations that informed the selection of informants for in-depth interviews with actors involved in flood adaptation practices, ensuring that the research flow remained consistent with the qualitative and interpretive research design.

Second, field documentation was conducted directly using a smartphone camera to record direct evidence of physical changes to buildings and roads at the research site. The combination of these two methods allowed for spatial and on-site verification of changes and strengthened the validity of field-observation data (Fig. 3). Third, the researchers conducted in-depth interviews with communities, developers, and government officials.

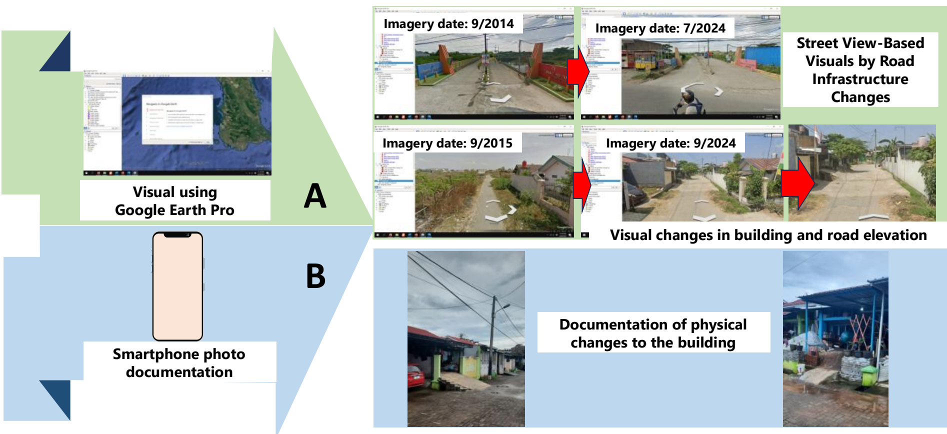

Fig. 3. Data collection process through Street View using the Google Earth Pro application and field documentation with a smartphone camera

Source: authors' elaboration based on folder © 2024 Google Earth Pro

3.3. Data Collection Instruments

The study was carried out between June and September 2024 in settlement areas within the Mamminasata Metropolitan Area, which show spatial elevation changes. In-depth face-to-face interviews were conducted using interview instruments. Each interview lasted approximately 45–60 min and was conducted directly by the researcher to ensure data consistency and accuracy.

Informants were selected using purposive sampling, deliberately identifying individuals who could provide valuable information on the elevation-change process. The informants included three groups: residents who had lived in the area for at least five years and held ownership status, housing developers, and government officials. These informants were selected because of their involvement in the process of changing the elevation of buildings, land, and neighborhood road infrastructure, including residents who had undertaken physical adaptations to their houses by raising neighborhood roads, housing developers involved in landfilling and road elevation, and government officials related to licensing, road infrastructure improvement at the lowest administrative level, including the village office and the spatial planning office as the licensor.

Interviews were conducted on a fully confidential and open basis using semi-structured interview instruments covering adaptation practices, flood experiences, elevation changes, and the roles of residents, developers, and government agencies (Table 1).

Table 1. Interview guidelines

Characteristics of Informants	Questions
Part A: Informant profile characteristics	Gender, age, educational background, income, number of family members, house and land ownership status, land condition before construction, length of time living in the building, and purchase mechanism (cash/credit)
Part B: Elevation changes of buildings, land and road infrastructure	Building characteristics, flooding experiences and motivations, elevation conditions, physical adaptations, government and developer roles, and impacts

Source: in-depth interview results

Although some locations were represented solely by one or two informants, the trend in elevation change practices showed the same pattern in terms of altering the elevation of buildings, land, and road infrastructure. Participants were selected based on their strategic information to ensure the relevance of their in-depth experiences regarding the phenomenon under study.

The research sample size was nine participants, corresponding to the average sample size in phenomenological studies that typically reach data saturation [23]. To meet the minimum standards for reaching saturation, as outlined in [24], a small sample was also used in accordance with IPA principles [25]. This study specifically focused on analyzing the elevation changes in depth. The number of participants was sufficient to provide comprehensive information, with no new themes emerging.

The distribution and characteristics of the samples were as follows (Table 2):
- in Bumi Tamalanrea Permai selection of three informants: two residents who made changes to building-floor elevation by raising floor levels, one government developer from the South Sulawesi BTP Project who was involved in landfilling;
- residents in Tallasa City housing who were also involved in landfilling and raising housing land;
- one resident in Bank Tabungan Negara Hamsih housing who raised the floor of his building;
- three informants in Pesona Pelangi housing: two resident who comprehensively modified the building by raising the land parcel and the road in front of the house, and one developer who had raised the housing access road;
- one private developer in Royal Centraland BTP housing, who also conducted landfilling.

Table 2. Characteristics of informants

Informant Code	Gender	Age	Location
R/S.B.	male	65	Pesona Pelangi Housing Cluster, Block A20
R/I.M.	male	62	Bumi Tamalanrea Permai Settlement, Block AC, No. 492
R/S.D.	male	60	Bumi Tamalanrea Permai Settlement, Block AD, No. 1
G/A.A.Z.	male	45	Official at the Buntusu Village Head Office.
D/R.M.	male	32	Staff at the Perumnas Office/BTP Project in South Sulawesi
D/A.R.	male	60	Staff at the Royal Centraland BTP Project Office
R/W.S.	male	58	BTN Hamsih/Antara Residential Area, Blok M1/17
D/A.C.	male	45	Marketing staff at the Pesona Pelangi Housing Cluster, Maros Regency
R/A.J.	male	38	Pesona Pelangi Housing, Block A19
R/A.F.	male	40	Tallasa City Housing

Key: R – resident, D – developer, G – government official.

3.4. Data Analysis Method

The analytical method used in this research is interpretive phenomenological analysis (IPA) (Fig. 4). The IPA method remains relatively underutilized in urban planning research; however, several studies have demonstrated its relevance in understanding life experiences and the formation of meaning in urban environments. IPA has been used to explore residents' emotional connections to urban spaces [26]. It can also be used to interpret perceptions of self-built dwellings in communal space practices [27] and user experiences in urban service design [28]. These studies support the use of IPA for understanding actors' perceptions of residential space and the urban environment, as changes in spatial elevation are not only considered technical interventions but also socially constructed spatial practices based on the actors' experiences.

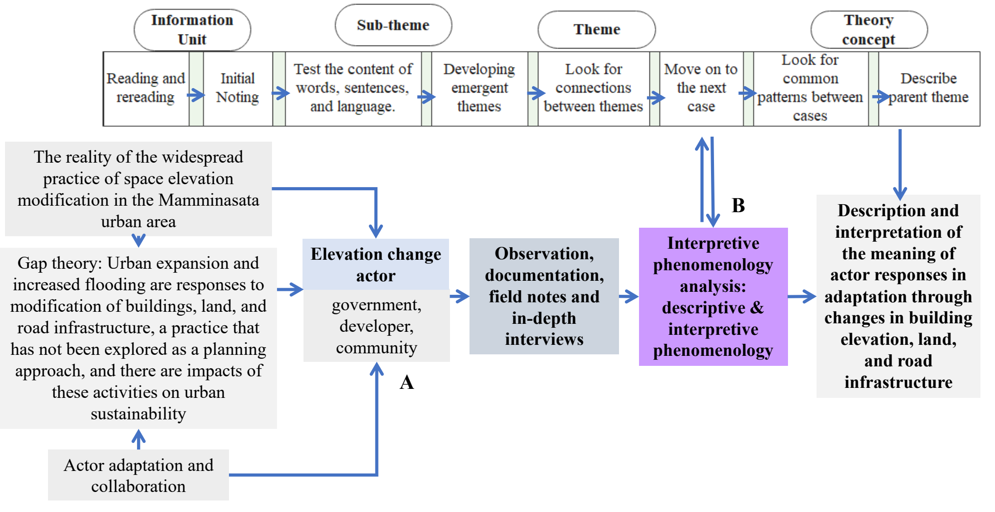

Fig. 4. Phenomenological interpretation process flow analysis:
A – the process of analyzing the construction of meaning and reality of changes in building elevations and residential land in flood disaster adaptation plans;
B – the phenomenological interpretation method of analysis

Source: own elaboration based on [25] and [31] (part B)

IPA seeks to reveal, understand, and explain the essence of lived experience in depth in relation to the dynamics of social issues [29]. A combination of purposive sampling and phenomenological analysis has been developed in social and psychosocial research [30]. In urban planning research, IPA remains rarely used for exploring the experiences of actors in spatial change, especially elevation changes, and it allows researchers to freely select participants capable of providing rich and detailed explanations of their experiences related to urban-environmental problems. IPA has two main components, involving specific and detailed descriptions and interpretations at each stage before moving on to broader claims [31]. Descriptive phenomenology focuses on describing lived experiences as they are, with no attempt to give them additional meaning. In contrast, interpretive phenomenology aims to uncover and interpret the deep meaning inherent in lived experience [25].

As shown in Figure 4, with point A the practice of elevation change in response to flood risk has not yet been formally integrated into urban planning. Therefore, a collaborative approach among urban actors is needed to support sustainable urban development in the Mamminasata Region, with point B data interpreted using conventional coding techniques, in which interview narratives are analyzed manually.

The stages of the IPA process are as follows:

1. Reading and re-reading. The process of reading the results of in-depth interviews involves immersing the researcher in the phenomenon through direct notes or through audio recording and documentation. The process of re-reading is essential for allowing key details to emerge.
2. Initial noting stage. This stage examines the content of words, sentences, and language (information) from the participants at the exploratory level. It enables the identification of information units in the participants' accounts.
3. Developing emergent themes. This stage arises from the fusion of stages 1. and 2. and emerges from the themes of reality, from the process of mapping interconnections, relationships, and patterns between exploratory notes in the second stage. The process of identifying emergent themes includes the possibility of the researcher reworking the narrative flow of the interview when uncomfortable with the initial narrative [25].
4. Searching for connections across emergent themes. At this stage, relationships among themes are mapped and sorted chronologically. The interpretation of the transformation process produces an information structure and theoretical development sourced from important information units identified in participants' accounts.
5. Moving on to the next cases. This stage of analysis is conducted on each case or participant. The development of the previous themes – the themes already developed – not only stands on the completed case but also becomes a source of concepts. Findings and concepts are written down and the analysis moves to the next case or participant until all realities are covered and theoretical concepts are produced. This step is carried out on all participants' transcripts by repeating the same process.
6. Looking for patterns across cases. The final stage involves identifying patterns that emerge across cases or participants [25].

4. Result

This approach involves deriving results from direct observations and in-depth interviews, with information abstracted into units through a systematic grouping process. These units are then categorized into sub-themes and themes, further refined and abstracted into concepts and theories, ensuring clarity in interpretation while accounting for potential variations. This process interprets the reality of community efforts to adapt to flood conditions through changes in land and building elevations. The results of direct observation in the field illustrate that individual communities, developers, and sub-district government officials attempt to carry out forms of adaptation planning for their environment. Furthermore, the results of in-depth interviews with communities, developers, and sub-district government officials indicate that they implement staged physical adaptation measures involving changes in building utilities and land as part of efforts to address flooding in urban settlements through land- and building-elevation adjustments.

4.1. Elevation Changes as a Flood Adaptation Strategy and Practice

Communities adapt to flood risks by modifying spaces based on elevation changes. One of the main strategies is to raise the floor of the house and the front yard in response to floods. First, residents raised the floor in the back and front areas of the house by up to 50 cm to prevent water from entering (Fig. 5a). Second, the front yard was raised by 50 cm as an additional protection measure, aligned with the height of the surrounding roads (Fig. 5b). Third, the kitchen floor in the back area was raised by 50 cm to maintain optimal space functionality, even in a flood-prone area (Fig. 5c).

a) b) c)

Fig. 5. Elevation changes in the form of individual adaptation through buildings: Pesona Pelangi Housing (a, b) and Bumi Tamalanrea Permai Settlement (c)

This finding highlights the physical adaptation processes undertaken by residents and developers and confirms the crucial role of information in adaptive decision-making. Furthermore, two broad concepts emerge: (1) forms of perception-based autonomous adaptation and mitigation strategies, which have become an actual practice in building the resilience of the area; and (2) the expansion of elevation-change strategies in flood-prone areas, which shows that such changes are not only individual but also developed into collective strategies. The two concepts outlined above underscore the need for regulations and implementation of adaptation through elevation changes (Fig. 6).

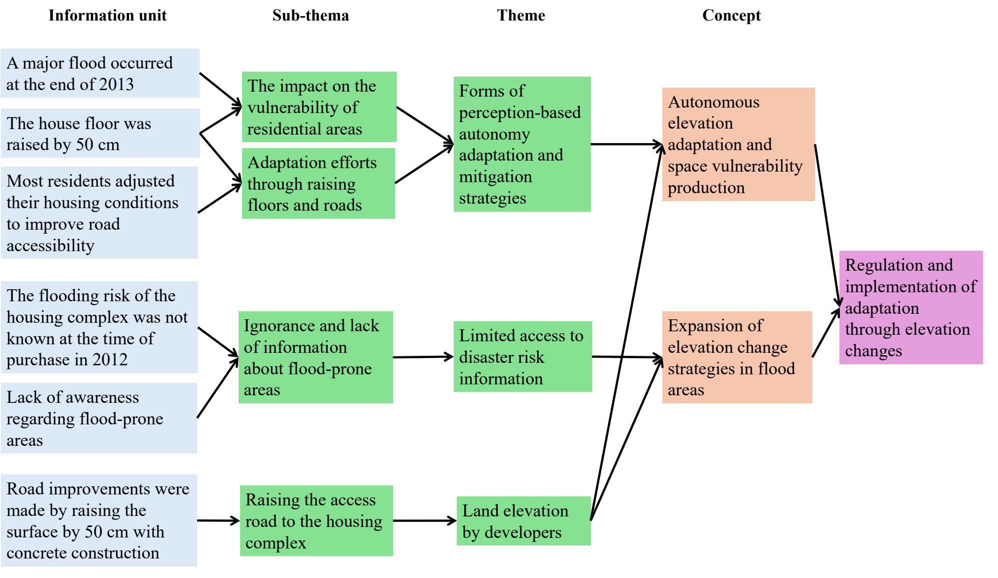

Fig. 6. Scheme for the formation of regulation and implementation of adaptation in elevation changes

Table 3. List of informants and summary of in-depth interviews findings on building elevation changes

Informant	Interview Information
Informant S.B. (65), Pesona Pelangi Housing Cluster, Block A20	We were unaware that this housing estate was prone to flooding when we purchased our home in 2012 and moved in early 2013. However, at the end of that year, we experienced a major flood, the worst we had ever had, with water inside the house reaching the knees of adults. In response, I renovated our home, raising the floor by 50 cm. Many of our neighbors took similar measures to adapt to the recurring floods (interview dated August 8, 2024)
Informant I.M. (62), Bumi Tamalanrea Permai Settlement, Block AC, No. 492	I own two houses in Block H and Block J, each modified to mitigate flooding. Initially, we raised the foundation by 50 cm to match the road level. Rather than a complete renovation at first, we raised the floor during the initial period of occupancy to about 30 cm above the previous (unraised) road level. Eventually, we rebuilt the structures entirely (interview dated August 10, 2024)
Informant S.D (60), Bumi Tamalanrea Permai Settlement, Block AD, No. 1	The government raised the road height by 50 cm, upgrading it from block paving to asphalt and concrete. Most residents have since adjusted their homes to accommodate the new road elevation (interview dated August 10, 2024)

Source: in-depth interview results

Overall, the informants stated that the community independently raises building elevations and neighborhood road elevations, while developers raise residential land with government permission. There are also cases where developers change the elevation of residential access roads in flood-prone areas. This practice encourages actors to implement long-term strategies. This form of elevation adaptation strategy has value as a collaborative planning approach between the community and developers in constructing neighborhood roads. This strategy requires the support of formal policy efforts to regulate and control strategies and practices related to elevation changes as part of an actor-based adaptation system that supports urban sustainability. The development of this theoretical concept deepens the experiences reported by informants S.B., I.M., and S.D. (see Table 3) based on the results of the in-depth interviews.

Communities, developers, and governments respond to flood risk by modifying spaces based on elevation-related measures. First, developers of new housing commonly fill paddy fields, thereby adjusting the elevation of the surrounding area. Developers also intervene in flooded housing areas by raising the road surface by 1–2 m (Fig. 7g). Second, individual residents (Fig. 7a) adapt by raising house foundations and courtyards by up to 1 m to match the elevated road levels. Third, government interventions focus on infrastructure improvements (Fig. 7e), through the elevation and paving of neighborhood roads to improve drainage and accessibility in flood-prone areas. These three efforts illustrate an integrated approach to urban flood-risk management.

Fig. 7. Adaptation efforts through elevation changes.
The community raises the foundation, floors, and elevates the road: Pesona Pelangi Housing, developers raised the residential entrance road by 1–2 m (a–e); government upgrades the concrete road in Bumi Tamalanrea Permai Settlement (f, g)

Source: survey results, Google Street View and team documentation

Developers explicitly described landfilling as a planned spatial intervention to secure housing investment by filling land to 1.5–4 m, as reported by developer informants (A.R., R.M., and A.C.; Table 4). This practice of changing land elevation is implemented prior to construction and also extends to road infrastructure, indicating that developers play a decisive role in shaping flood adaptation strategies through residential land elevation.

Table 4. List of informants and summary of in-depth interviews indicating changes in land elevation and road infrastructure

Informant	Interview Information
Informant A.A.Z. (45), official at the Buntusu Administrative Office	Most new housing developments use landfilling as a method to prevent flooding in the constructed areas. This technique involves raising the ground level significantly. For example, in the BTP housing area, which was originally rice fields and swamps, the land was elevated by up to 3 m (interview dated August 20, 2024)
Informant R.M. (32), official at the South Sulawesi BTP Project Office	Since 1989, the initial development of BTP involved filling swamp areas over 1 m deep. Over the years, the built-up areas have increasingly experienced flooding. In some new development blocks, the filling depth has increased to 2 in deeper swamp areas. For building units, foundations are elevated by 25–45 cm (interview dated August 23, 2024)
Informant A.R. (60), official at the Royal Centraland BTP Project Office	Royal Centraland Housing was built in 2018, starting with the landfilling process, and in 2019, construction of residential units began and continues to this day. The initial condition of this land was rice fields, and we filled it up to 4 m (interview dated August 23, 2024)
Informant W.S. (58), BTN Hamsih/Antara Residential Area, Block M1/17	Our neighborhood is prone to flooding; to adapt, we raised the floor by 50 cm (interview dated August 27, 2024)
Informant A.J. (38), Pesona Pelangi Housing, Block A19	Every year in the rainy season we experience stress, just as four hours of heavy rainwater rises in front of the road. For days at a time, this complex becomes like a swimming pool, we had to undertake a total change to a house with two floors and raise it by 1 m, and I also raised the road in front of my house by 50 cm (interview dated August 26, 2024)
Informant A.C. (45), marketing staff at Pesona Pelangi Housing Cluster, Maros Regency	When we built the cluster housing, it was landfilled and raised 1.5 m above the initial condition of the local road connecting Makassar. This local road has since been raised and concreted by an additional 40 cm. Although the housing was initially raised, it still cannot avoid flooding because it is near the river. The condition of the local road, combined with the large housing developments around our area that have raised their land to 4 m, has exacerbated flooding in this housing complex (interview dated August 26, 2024)

Source: in-depth interview results

The strategy of land and building elevation changes (which functions as a response to the physical geographical conditions of swamps and paddy fields and to the effects of urbanization, such as reduced catchment areas and increased flood frequency) synthesizes three main sub-themes, namely: (1) land elevation strategy through filling and elevation; (2) elevation change and flood area expansion, showing that land elevation can expand the flood-affected area; and (3) physical adaptation of buildings to flood risk.

These three sub-themes develop into two main themes, (a) flood area expansion as a consequence of micro-elevation changes, and (b) elevation-based strategic and practical changes to spaces and buildings. The first theme highlights the extent of elevation adaptation strategy practices, both by developers and communities, while the second theme emphasizes the environmental, ecological, social, physical, and spatial impacts of these practices – the expansion of flooding areas and the expansion of activities to involving elevation change strategies as an adaptation strategy to environmental conditions.

Finally, both concepts converge on one key notion: urban expansion accompanied by enhanced adaptation practices through spatial elevation changes is the main driver of collaborative adaptation strategy efforts in promoting urban resilience. The development of this theoretical concept reflects and deepens the empirical insights provided by informants A.A.Z., R.M., A.R., W.S., A.J., and A.C., whose in-depth interview results are presented in Figure 8.

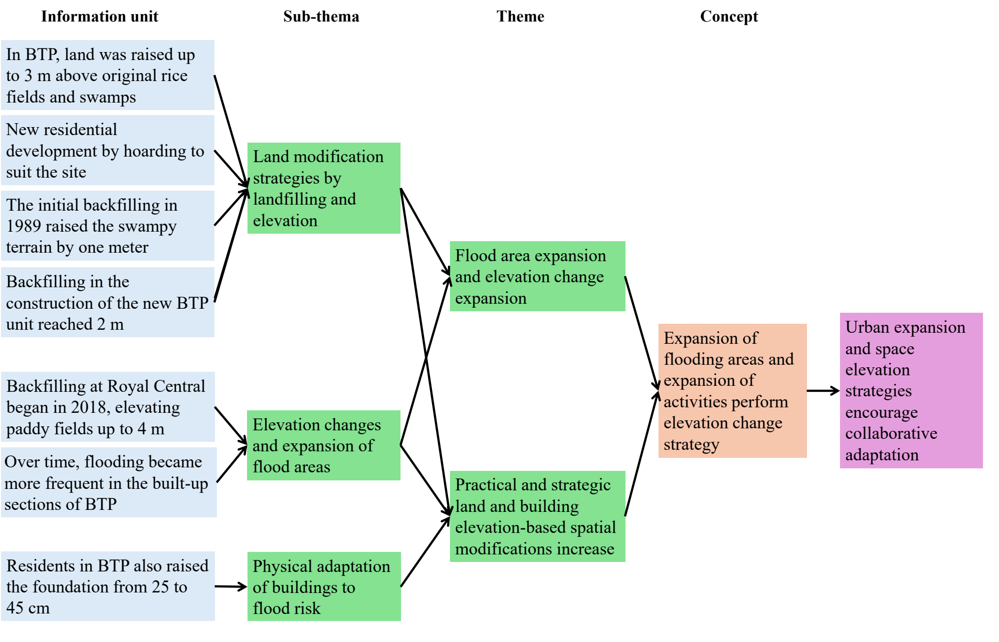

Fig. 8. Scheme for the formation of city expansion accompanied by the broadening of adaptation strategies based on elevation changes

4.2. Word Cloud Visualization and Category Distribution

Visual analyses of frequently occurring keywords in Figures 6 and 8 explain the frequency distribution of keyword occurrences in the interpretative scheme. Figure 9 shows a visualization in the form of a word cloud, emphasizing the frequency of keywords based on word size. The larger the font size, the more frequently the word appears in the analyzed data, namely "adaptation" and "elevation," each with 12 appearances, and "change/changes," "flood/flooding," and "road" with 9 appearances. Other keywords include "housing," "infrastructure," and "raising/raised" each appearing nine times.

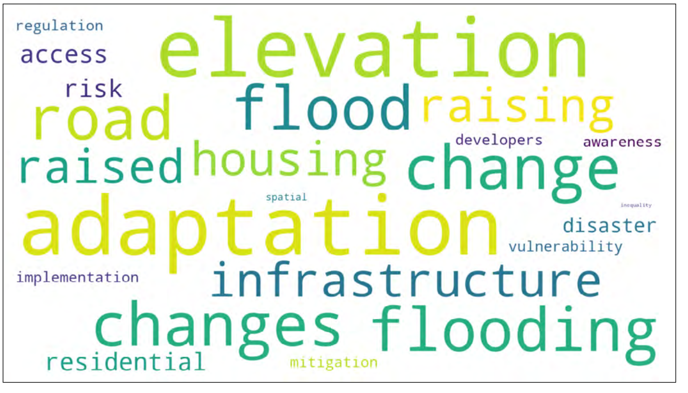

Fig. 9. Word cloud showing keyword occurrence frequency
Source: authors' elaboration, generated using ChatGPT (OpenAI)

The word cloud results illustrate that elevation modification practices function as a flood adaptation strategy in urban areas across buildings, land, and road infrastructure, and have become widespread activities in socio-spatial terms. However, these efforts are informal strategies that lack regulatory support, meaning that most adaptations are individual, practical, and contextually local in the Mamminasata urban settlement area. This word cloud visually emphasizes the research focus on elevation practices as an adaptive response and their impact on urban spaces.

5. Discussion

This chapter examines adaptive strategies in elevation change: levels of connectedness, challenges, and collaborative pathways to urban resilience.

5.1. Dynamics and Patterns of Actor Adaptation to Flood Risk

Adaptation strategies often focus on reactive and short-term responses, without careful long-term planning. The obstacle is the community's low adaptive capacity, which means many adaptation actions tend to be selfish and individualistic. In rural communities today, behavioral patterns of idealism and materialism have shifted, giving way to an individualistic culture [32]. Similar patterns occur in urban communities, where individualistic behavior is growing due to the influence of modern lifestyles [33]. Local value innovation is needed by adapting old values to the current context [32]. Community-based adaptation initiatives [14] coexist with individualistic adaptation initiatives, which – as shown in this research – also demonstrate resilience but with limitations. Although this response tends to be individualistic, community values and social networks shape the role of neighbors and community leaders, who can influence the adaptation process, especially in integrating the need for environmental security and safety. These social interaction values can support limited forms of collaboration that contribute to synergies in residential environmental planning, even though they have not yet been formally institutionalized.

Furthermore, the adaptation responses of developers and the government are not comprehensive enough to overcome the impact of residential development in flood-prone areas, as they are marked by static and partial policies and programs that are ad hoc and limited to structural handling of road improvements and the issuance of policies permitting landfilling for housing in existing settlement conditions. In the absence of land-elevation regulation, these practices affect the topographic pattern of urban land. Individual and community adaptation to flood risk in the Mamminasata urban environment reflects a response to dynamic and technically evolving environmental changes. Social communities explore changes in their surroundings through adaptation education [34]. The social community not only engages in adaptation education; they also exert social pressure on the government and surrounding communities. This social value colors the meaning of cooperative changes – a significant process within these communities that directly triggers independent and collaborative adaptation.

Firstly, changes in the height of buildings and infrastructure, such as raising the floors of houses and roads in residential areas, constitute the main informal strategies for flood risk mitigation. Secondly, although this collaborative approach incorporates elements of social pressure and interaction between individuals, communities, and the government in infrastructure development, such as road improvements, interactions between these actors do not always result in effective synergy. Instead, such interactions constitute a form of collective response that unfolds unevenly and simultaneously produces both benefits and adverse effects, including the transfer of flood risk to adjacent areas. In the context of elevation change, strategies are understood not as formal plans but as varying patterns of adaptation that emerge in response to flood pressure conditions. The strategies implemented by stakeholders vary; communities tend to be spontaneous, independent, and informal, while developers and governments implement non-spontaneous business strategies and policy support tactics for development. Consequently, these strategies are fragmented among stakeholders. However, this adaptation reflects a long-term strategic pattern in urban resilience, even in the absence of formal coordination and regulation. These strategies guide actors' responses to the pressures of spatial change caused by flooding.

Adaptation shows that these actions are a form of response to environmental pressures that affect development patterns, whereas urban resilience demonstrates how these efforts enhance communities' capacity to withstand flood risk. Moreover, the dynamics of human-environment interactions demonstrate a reciprocal relationship between humans and the built environment. Humans adapt by modifying building structures and the surrounding environment as a form of mitigation, while flood-affected conditions prompt a quick response from adaptive individuals. According to Hu et al. [35] environmental interactions, risk communication, and socioeconomic factors shape variations in adaptive behavior across different communities. However, in terms of elevation changes, the behavior of actors varies; yet, the adaptive behavior of the community in physical treatment shows a similar pattern in adjusting the elevation of their buildings. Regarding road elevation, the community tends to prioritize building changes for flood adaptation, while also considering raising the elevation of roads important for avoiding flooding. These elevation-change activities indicate that synergy has not yet been realized at the physical action level but is still limited to a shared perception of flood risk among actors, meaning that these adaptive actions are only partially effective and have the potential to cause negative impacts. Effective risk communication is required to achieve collective adaptive resilience.

According to Surya [11], the results of this study illustrate the non-structural approach in addressing floods, which continues to be hampered by the lack of effective collaboration between community actors, developers, and the government in efforts to achieve adaptive resilience to flooding. There are constraints within local authorities who are less skilled in integrating actor elements in addressing urban flooding. The research findings also reveal that community actors and developers demonstrate good adaptive resilience compared to the government, even though they operate informally. Thisfinding challenges Willett's [36] argument that local governments provide the primary framework for effective adaptation.

Elevation changes provide evidence that planning, implementation, and regulation do not align but instead operate independently. The absence of regulations related to changes in building elevations, land, and local road infrastructure contributes to the irregular development of urban spaces.

5.2. Levels of Adaptation Based on Actor Responses, Connectedness, Collaboration Gaps and Challenges

Adaptation level by actor

The actors' adaptive steps by means of elevation changes are categorized as described below.

First, residents are actors who quickly respond to the risk of flooding directly with pragmatic actions such as modifying buildings by raising the floor of the house (raising the foundation), raising the foundation for buildings that are completely changed, and making embankments by raising the front or terrace of the house. Further measures include adjusting the height of the building by raising and filling the road in front of the dwelling (see Figure 2, i.a.) The impact of this practice has significantly generated spillover effects on neighbors and the surrounding community, who then undertake elevation changes to adapt to surrounding conditions. The main impetus comes from direct flood experience that triggers quick responses and forms a collective memory of flooding and functional needs, such as mobility, safety activities, and daily comfort.

Second, developers are actors who can change the urban landscape and expand the practice of modifying spatial elevation through backfilling, elevating residential land, constructing drainage, and raising residential access roads to avoid flooding. The impact of this practice significantly produces spillover effects on a widespread scale, including elevation changes undertaken by surrounding communities to adapt to new conditions. This spillover effect creates new or worsening flood pockets in settlements. The main impetus comes from marketing strategies and economic interests, not the long-term sustainability of urban ecosystems.

Third, the government (city and regency) acts as a passive actor with limited power and initiative in regulating and controlling land and building elevation. It also behaves reactively by providing a sense of legality without establishing clear official rules in local spatial planning regulations or other technical guidelines to support such actions. The main impetus is its supporting role, which has not been effectively exercised or fully developed in providing policy direction and strategies for regulating and controlling the spatial and physical transformation of buildings and dwellings, especially changes in land elevation, buildings, and road infrastructure, resulting in the long-term unsustainability of the city. One of the main challenges for government performance in effective urban policies is its capacity for standardization in sustainability-related work practices [37], policies and regulations [38], and the lack of political support [39].

Connectedness and collaboration challenges in elevation-based adaptation strategies

The connection between the three levels of adaptation is still limited to the value of an actor's adaptation. There is some collaborative value in changing the elevation of road infrastructure, whether the community, government, or developers undertake repairs, backfilling, and elevating road infrastructure in residential neighborhoods that are at risk of flooding, although the efforts remain temporary. This relationship forms the foundation for adaptation-collaboration integration in urban sustainability governance. This means that limited collaboration relationships can be a starting point for integrated collaboration; therefore, this strategy may encourage better collaborations. This research is reinforced by Söpper [40], who clarifies that limited collaborative relationships are not only caused by the fragmented formal governance structure but also by differences in values, motivations, and cultural backgrounds among actors. Governance must be able to analyze how adaptation structures emerge, while culture helps understand why adaptation is partial, individual, and not integrated. Therefore, building integrated adaptation collaboration requires more than simply improving regulatory structures; it also requires efforts to understand and synergize adaptation values among communities, developers, and the government.

Schoon and Cox [41] emphasize the importance of cross-border collaboration to unify interests and overcome barriers created by governance fragmentation. Culture-based and cross-border collaboration is crucial for building and bridging adaptive approaches and collaborative planning. However, the widespread practice of elevation changes highlights a future gap in informal decision-making by actors in urban spaces, which may lead to uncontrolled and sporadic growth in the future.

The following challenges are related to the three levels of actors:

1) Developer practices. Developers lack agreed elevation standards, tend to transfer risks to neighboring areas that do not change elevation, and often elevate beyond areas that have previously been raised.
2) Community and government challenges. Communities have low technical capacity and limited information on long-term risks. Governments face policy and institutional fragmentation, lacking a system that integrates the three actors into a flood-responsive, elevation-based spatial planning scheme, combined with very weak coordination and a lack of pre- and post-development control.
3) Differences in objectives. Residents want to be safe and comfortable; developers focus on efficiency and profit; the government is in the middle, constrained by a limited budget and insufficient monitoring tools.

5.3. Benefits and Impact of Elevation Change

Some additional benefits arising from the actions of the three actors in changing the elevation of buildings, land, and road infrastructure are as follows:

First, these actions are beneficial to individuals. Such adaptation approaches provide greater environmental security and protection, especially against flood risks, and improve social welfare in the long term. Changes in road infrastructure can increase property values in the area and benefit property owners.

Second, these actions are beneficial to property developers and investors. They derive significant benefits from collaborative adaptation. Properties that become more resilient to disasters increase their investment value and are therefore more attractive in the market. The long-term sustainability of investments is also assured as adaptive infrastructure helps reduce the risk of disaster losses. In addition, their involvement in adaptation projects enhances their positive reputation and corporate social responsibility, which can strengthen their position in the community and market.

Third, these actions are beneficial to the government and infrastructure developers. For governments and infrastructure developers, collaborative adaptation generates benefits, such as increased community satisfaction. This is achieved because successful adaptation programs strengthen the relationship between the government and the community. In addition, reduced flood management costs are another positive impact, as infrastructure designed for disaster mitigation can reduce the need for expensive emergency responses. Better infrastructure resilience also ensures that disaster-management programs are more effective and sustainable.

Significant elevation changes affect the physical aspects of the environment, including water flow and drainage, soil stability, ecosystems, and community accessibility, which can result in social conflict. Elevation changes can affect the risk of inundation or flooding due to disrupted water flow and can also cause increased erosion that threatens soil stability. In addition, these changes can disrupt natural ecosystems, such as water catchment areas, which play an important role in maintaining ecological balance. Another impact is the disruption of social and physical connectivity, especially regarding community access to infrastructure.

6. Conclusion

Rapid urban development has increased flood risk, shaped actors' adaptation, and produced multidimensional impacts on urban systems. One such strategy is to change the elevation changes in buildings, land, and road infrastructure trigger an increase in elevation-based adaptation strategies by actors and expand the flood-affected areas as a consequence of these practices. Community adaptation strategies in response to flooding involve efforts to defend homes by spontaneously raising floors and foundations. When houses are flooded individually and independently, communities also collectively raise roads. These spontaneous practices do not apply to developers because they are closely related to housing development licensing policies, which constitute a long-term strategy for dealing with flooding in urban areas. This practice reflects individual efforts and has shaped an adaptation system based on local perceptions and experiences that contribute to the resilience of urban areas. This strategy also generates informal activities, but the main challenge is the differing goals of the actors. The community wants to feel safe, developers remain more focused on economic profit, the government has budget constraints, and coordination is still weak.

Elevation changes have implications for building utilities and physical changes to road infrastructure, including disruption of water flow and drainage, soil stability, disturbances to land ecosystems, and reduction of green open spaces. From a social aspect, this can trigger social conflicts due to the non-uniform nature of elevation changes in road infrastructure. From the urban sustainability perspective, this may lead to irregular development of housing and residential areas. Elevation changes can increase the risk of inundation or flooding due to disruption of water flow and create erosion risk that threatens soil stability. In addition, these changes can disrupt natural ecosystems, such as water catchment areas, which play an essential role in maintaining ecological balance. Another impact is the disruption of social and physical connectivity, especially regarding community accessibility to infrastructure.

The following is a set of recommendations for the government as a key actor in urban sustainability:

1) There is a need to establish an elevation-based collaborative framework: a spatial digital platform that integrates topographic information, building elevations, drainage, road infrastructure, flood patterns, and affected areas. There is a need to integrate data and planning regulations in zoning and land-use management for building elevation changes, land elevation, and road infrastructure permits in urban and regional spatial planning for urban adaptation. The government should strengthen permit supervision, involve citizens in spatial design, and develop specific regulations for areas with significant elevation changes.
2) Incentive-adaptation schemes: provide incentives by waiving building approval rules for well-off residents in low-lying and flood-prone zones, offering subsidies for the underprivileged, as well as tax reductions, technical and material assistance for developers and residents who build with adaptive and sustainable principles.
3) Future research needs to consider the dynamics of the evolving elevation change strategy expansion, as this encourages the formation of informal spaces and unstructured decision-making in the context of urban sustainability. Therefore, elevation mapping-based spatial research needs to be conducted to identify, analyze, predict, and model elevation-based spatial change in urban areas. A Digital Elevation Model (DEM) represents surface elevation as a Triangulated Irregular Network (TIN), enabling analysis and elevation prediction using data from imagery, land use, and hydrology [42]. Elevation can be modeled in 3D-GIS to simultaneously evaluate building height, roof structure, and topography [43]. GIS integrates field data with simulation models to predict floods based on elevation changes [44, 45]. Google Street View can be used for on-ground visual spatial analysis, while elevation profiles in Google Earth assess terrain elevation, and 3D-GIS DEM created with tools such as LiDAR [46], Sentinel, or UAV photogrammetry evaluate the impact of elevation changes on buildings, land, and roads based on variables such as topography, ground and building elevations, and land cover. Utilizing these visual-spatial analyses, adaptive requirements for changes in the elevation of building foundations, roads, and land, as well as changes in the risk of urban flooding, can be identified and further analyzed in future studies.

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E. A.: conceptualization, methodology, software, validation, formal analysis, resources, writing — original draft preparation, writing — review and editing, visualization, project administration, funding acquisition.

I.: conceptualization, software, investigation, resources, visualization, project administration, funding acquisition.

Declaration of Competing Interests

The authors declare that they have no conflicts of interest that could influence the work or research reported in this article.

Use of Generative AI and AI-Assisted Technologies

The word cloud (Fig. 9) was generated using ChatGPT (OpenAI) based on keywords provided by the authors.

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