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Sustainable Urban Planning: Policy Approaches to Disaster Risk Reduction and Environmental Impact Mitigation in Makassar City

A.M. Azhar Aljuirda[1], Anirwan[2]
[1]Universitas Indonesia Timur, Rappocini St. No 171-173 Makassar
[2]Universitas Pancasakti Makassar, Andi Mangerangi St. No. 73 Makassar
Corresponding Author: azharaljurida51@gmail.com

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Abstract: The urgency of this research stems from the escalating risks of flooding and air pollution in Makassar City, driven by rapid urbanisation and the uncontrolled proliferation of motorised vehicles. The study aims to examine the potential of urban planning and sustainable mobility policies in mitigating disaster risks and environmental impacts, as well as to formulate more adaptive policy strategies. A qualitative research design was employed, with data collected through in-depth interviews, document analysis, observation, and focus group discussions (FGDs). Data analysis was conducted using NVivo 12 Plus. The findings confirm that Makassar City faces severe ecological vulnerability as a result of the interplay between rapid urbanisation, land-use conversion, inadequate drainage infrastructure, and the extraordinarily high growth rate of motorised vehicles. These factors collectively contribute to annual flooding, air pollution, and the urban heat island effect. The situation reveals significant weaknesses in spatial planning and transportation policies, which remain predominantly oriented toward economic growth and have yet to be fully integrated with climate change adaptation principles. Furthermore, these policies are characterised by insufficient inter-agency coordination and limited community participation. Accordingly, policy strategies that prioritise green infrastructure development, drainage system revitalisation, environmentally sustainable public transportation, and climate-adaptive urban planning are identified as urgent imperatives for the resilience and long-term sustainability of Makassar City. In conclusion, climate-adaptive and sustainable urban planning constitutes a critical precondition for reducing disaster risk and preserving environmental quality in Makassar City.

INTRODUCTION

The background of this research is grounded in the recognition that Makassar City constitutes a region considerably vulnerable to recurring disasters (Aljuridaa & Anirwan, 2025). In February 2025, the city experienced severe flooding that inundated five sub-districts and displaced thousands of residents (Helmi, 2025). In addition, the number of registered motorised vehicles in Makassar reached 2.06 million units as of October 2024 (Fadhlurrahman, 2024). This rapid growth in vehicle numbers has contributed to increased greenhouse gas emissions and air pollution (Doan et al., 2025), which in turn exacerbates climate change (Han et al., 2023). These conditions underscore the urgency of investigating policy approaches to urban planning and sustainable mobility as mechanisms for reducing disaster risk and environmental degradation in Makassar. Consequently, holistic urban planning policies are required to foster more resilient urban environments (Yu et al., 2021). With an appropriate policy framework, Makassar City has the potential to develop a sustainable mobility system that not only mitigates environmental impacts (Masse et al., 2024) but also enhances resilience to future disasters.

Flood disasters and vehicle-related pollution in urban areas have emerged as a global issue affecting the quality of life of urban populations and the integrity of environmental systems (Iskandar et al., 2024). Studies indicate that rapid urbanisation in the absence of sound spatial planning significantly heightens flood risk through the reduction of permeable surfaces and the expansion of impervious cover (Peiris, 2024). Motorised vehicles have similarly been identified as a principal source of greenhouse gas emissions and air pollution, contributing to global

warming and the increased incidence of respiratory diseases in urban areas (Lestaluhu et al., 2023). In major cities, the proliferation of motorised vehicles has also been associated with the urban heat island effect, which intensifies climate change impacts and accelerates environmental degradation (Luth et al., 2023). These effects are particularly acute in cities with inadequate drainage systems and environmentally unsustainable transportation infrastructure (Varra et al., 2024). Accordingly, urban planning that is integrated with sustainable mobility policies represents a critical strategy for reducing flood disaster risk (Wang et al., 2024) and curbing vehicular emissions in urban areas (Saharan et al., 2024).

Several countries have implemented urban planning and sustainable mobility policies to address disaster risk and environmental degradation. Germany, for instance, has adopted the concept of the "Stadt der kurzen Wege" (city of short distances), which encourages the use of environmentally friendly transportation and reduces dependence on private vehicles (Holz-Rau & Sicks, 2013). China has implemented Transit-Oriented Development (TOD) policies that integrate public transportation with spatial planning to create more sustainable urban environments (He et al., 2025). Other countries have pursued Smart City Policies to leverage intelligent technologies in addressing potential disasters such as flooding (Gopinath et al., 2025). Moreover, effective urban planning must be supported by urban drainage management policies (Ahmad et al., 2025), the protection of water catchment areas (Yang & Lee, 2021), and the regulation of land-use conversion to mitigate flood risk (Jia & Zhang, 2024). The deployment of early warning systems (Villani et al., 2019), the expansion of green infrastructure capacity, and the optimisation of stormwater management are also identified as essential strategies in urban flood mitigation (P et al., 2024).

The state of the art in this field of inquiry demonstrates that research on urban planning policies, disaster risk, and environmental impacts is extensive, with a bibliometric analysis identifying 100 documents in the Scopus database as of March 2025.

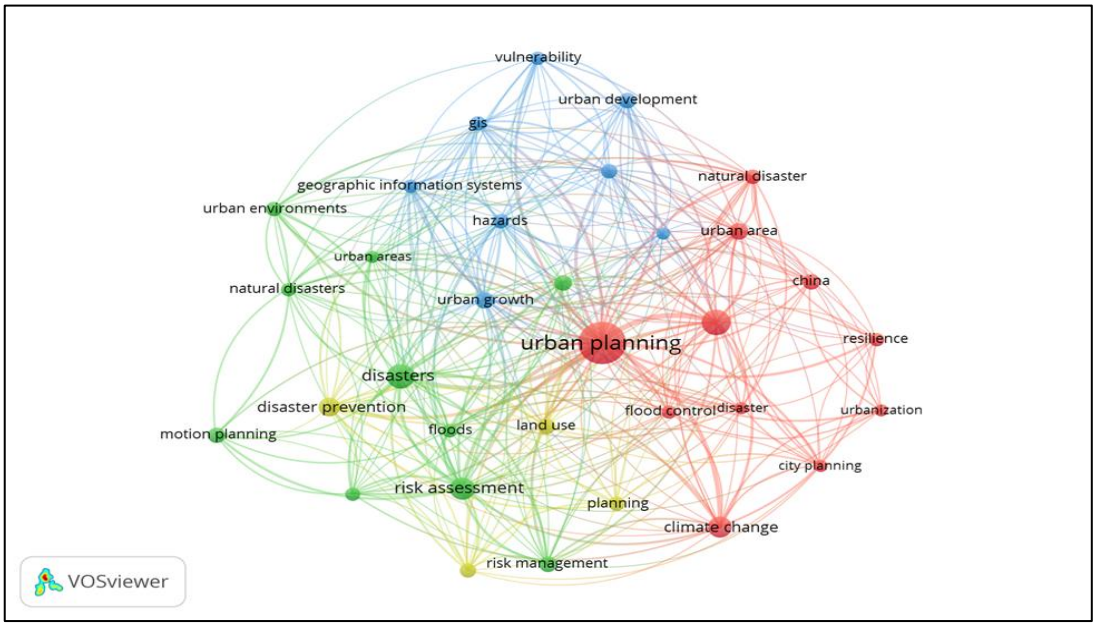

Figure 1. State of the art research

However, research that specifically integrates urban planning policy with sustainable mobility frameworks in the context of disaster risk mitigation and environmental impact reduction remains limited. The novelty of this study lies in its integrative approach, which embeds sustainable mobility strategies within a disaster-resilient urban planning policy framework. With a focus on Makassar City, this research offers both academic and applied policy contributions toward constructing a resilient and environmentally responsive urban environment amid the dual challenges of climate change and rapid urbanisation.

The central research problem concerns how urban planning and sustainable mobility policies can reduce flood disaster risk and environmental degradation in Makassar City. The research questions are as follows: (a) What are the primary factors driving the escalation of flood risk and air pollution in Makassar City? (b) How effective are current urban planning policies in reducing disaster risk and environmental impacts in Makassar City? (c) What policy strategies can be implemented to enhance Makassar City's resilience to disasters and mitigate environmental degradation, particularly vehicle-generated pollution?

This research is aligned with the eighth point of the Prabowo-Gibran Asta Cita agenda, specifically regarding the promotion of harmonious coexistence with the natural environment and cultural heritage, given that urban planning and sustainable mobility are oriented toward reducing disaster risk and environmental impacts in pursuit of a more resilient and sustainable city. The study is also directly relevant to Sustainable Development Goal (SDG) 11: "Sustainable Cities and Communities," as it focuses on sustainable urban planning and mobility as mechanisms for reducing disaster risk and environmental degradation, thereby contributing to the development of more inclusive, safe, resilient, and sustainable urban environments.

The problem-solving approach adopted in this study involves data-driven policy analysis to identify the principal factors underlying flood risk and air pollution in Makassar City. The study evaluates the effectiveness of existing urban planning policies through policy analysis methods and comparative case studies of cities that have successfully implemented sustainable mobility frameworks. Building on this analysis, the research formulates policy strategies grounded in sustainable development principles, including the enhancement of green infrastructure, the strengthening of environmentally sustainable public transportation, and the regulation of motorised vehicles to reduce emissions and improve urban disaster resilience. The resulting policy recommendations aim to provide comprehensive and practically applicable solutions for building a more resilient and sustainable Makassar City.

RESEARCH METHODS

This study employs a descriptive qualitative methodology with a policy study approach to analyse urban planning and sustainable mobility in the context of disaster risk reduction and environmental impact mitigation in Makassar City. Data were collected through in-depth interviews, document analysis, observation, and focus group discussions (FGDs) to ensure the comprehensiveness of the dataset. Interviews were conducted with key stakeholders, including the Makassar Environmental Agency (Dinas Lingkungan Hidup Makassar), the Makassar City Spatial Planning Agency (Dinas Penataan Ruang Pemerintah Kota Makassar), and the Regional Disaster Management Agency (Badan Penanggulangan Bencana Daerah/BPBD), in order to examine existing policies and challenges in their implementation. Documentary data encompassed secondary sources, including official government reports, academic studies, and relevant regulations pertaining to urban planning and sustainable transportation. Field observations were conducted at flood-prone zones and areas with elevated air pollution levels to assess prevailing conditions on the ground. Focus group discussions involved academics, environmental activists, and community representatives to elicit multi-stakeholder perspectives on policy planning.

Key informants were selected based on their relevance and roles in the formulation and implementation of policies related to urban planning and sustainable mobility in Makassar City. The Makassar Environmental Agency was selected due to its responsibility for managing air quality and mitigating environmental impacts from urban transportation. The Makassar City Spatial Planning Agency holds a strategic role in sustainable urban planning and the regulation of land-use conversion that may influence flood risk. The BPBD of Makassar City was included on account of its historical disaster data, mitigation policies, and coordination role in flood management. These three agencies collectively occupy a central position in shaping effective policies to strengthen Makassar City's resilience to disasters and reduce environmental impacts arising from urbanisation and transportation.

The collected data were transcribed and analysed using NVivo 12 Plus qualitative analysis software. Following data entry into the software, data validation was performed to assess the

authenticity and reliability of the information. This process involved several steps, including data triangulation cross-referencing findings from multiple data sources to confirm their accuracy and consistency as well as member-checking with informants and original sources to ensure interpretive accuracy. In addition, appropriate coding and categorisation techniques within NVivo were applied to ensure accurate representation of findings in the analysis. Data validation constitutes a critical step in guaranteeing the reliability and validity of research findings, thereby enhancing the credibility of the conclusions drawn.

RESULTS AND DISCUSSION

Makassar City confronts serious challenges arising from escalating flood disaster risk and air pollution, compounded by rapid urbanisation, land-use conversion, and uncontrolled growth in motorised vehicles. These conditions have significant implications for the quality of life of urban residents, environmental health, and the long-term sustainability of urban development.

Figure 2. Flooding in Makassar City, 2025

Recurrent annual flooding indicates systemic weaknesses in the drainage infrastructure and diminishing water catchment capacity, while the high volume of motorised vehicles contributes substantially to greenhouse gas emissions and air pollution, which in turn fuel climate change and respiratory disease (Abbas et al., 2023; Ismayanti & Aljurida, 2023; Rizal et al., 2025; Yahya et al., 2025). In this context, this study emphasises the critical importance of urban planning policies that are integrated with sustainable mobility strategies. Such an approach is regarded as capable of reducing disaster risk, mitigating environmental impacts, and enhancing the long-term resilience of Makassar City.

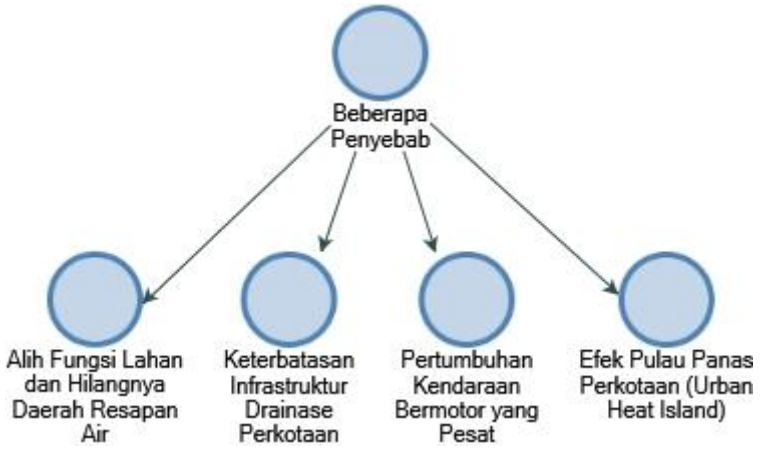

Figure 3. Causal Factors of Flood Risk and Air Pollution in Makassar City

Land-use conversion in Makassar City has intensified in tandem with rapid urbanisation, with productive agricultural land and green open spaces increasingly transformed into residential zones, commercial centres, and urban infrastructure (Arman et al., 2024). This process has resulted in the reduction of water catchment areas, such that rainfall that would otherwise be absorbed into the soil is instead discharged as surface runoff. This condition is further exacerbated by the dominance of impervious surfaces—such as asphalt and concrete—which significantly limits the soil's absorptive capacity. Consequently, the volume of water entering drainage channels increases sharply, often exceeding their retention capacity, which precipitates waterlogging and flooding. The loss of catchment areas also reduces groundwater reserves, with long-term implications for the stability of the urban ecosystem.

The inadequacy of drainage infrastructure in Makassar City constitutes one of the primary causes of waterlogging and flooding during the rainy season. Many drainage channels are sub-optimally connected, undersized, or heavily sedimented, resulting in drainage capacities well below actual requirements. The expansion of new residential areas without commensurate investment in drainage networks has further deteriorated conditions, particularly in densely populated districts. Additionally, the practice of disposing of solid waste into drainage channels obstructs water flow, causing rainfall to overflow into roads and residential areas. This situation illustrates the incapacity of existing drainage systems to keep pace with the rate of urbanisation, thereby escalating flood risk in Makassar.

The growth of motorised vehicles in Makassar City represents a principal contributor to urban air pollution.

Table 1. Number of Motorised Vehicles by Regency/City and Vehicle Type in South Sulawesi Province, 2023

Regency/City	Passenger Car	Bus	Truck	Motorcycle	Total
Kepulauan Selayar	1,300	74	505	23,031	24,910
Bulukumba	11,171	348	7,409	124,449	143,377
Bantaeng	2,981	103	2,297	37,531	42,912
Jeneponto	5,590	211	4,112	59,172	69,085
Takalar	6,497	73	3,803	106,220	116,593
Gowa	27,240	218	13,127	297,498	338,083
Sinjai	2,803	141	1,846	58,006	62,796
Maros	9,991	53	4,447	88,379	102,870
Pangkajene dan Kepulauan	10,457	79	5,720	107,150	123,406
Barru	4,986	10	2,533	56,725	64,254
Bone	14,082	3,699	10,227	219,253	247,261
Soppeng	6,433	1,301	5,496	77,996	91,226
Wajo	15,731	83	9,024	160,484	185,322
Sidenreng Rappang	15,267	171	8,003	125,732	149,173
Pinrang	15,103	45	8,278	208,347	231,773
Enrekang	3,244	50	3,159	55,937	62,390
Luwu	8,048	43	3,949	135,559	147,599
Tana Toraja	4,153	89	3,490	89,026	96,758
Luwu Utara	4,721	28	3,831	103,282	111,862
Luwu Timur	10,089	483	7,296	131,190	149,058
Toraja Utara	4,836	156	2,727	63,007	70,726
Makassar City	*275,344*	*17,796*	*92,323*	*1,470,840*	*1,856,303*
Kota Parepare	19,841	74	10,878	121,491	152,284
Kota Palopo	8,786	117	3,417	105,460	117,780
South Sulawesi	488,694	25,445	217,897	4,025,765	4,757,801

Source: BPS South Sulawesi, 2023

Data from the Central Statistics Agency (BPS) of South Sulawesi Province for 2023 indicate that Makassar City records the highest number of registered motorised vehicles among all regencies and cities in the province, totalling 1,856,303 units (BPS, 2023). Of this total, motorcycles account for the dominant share at 1,470,840 units, followed by passenger cars at 275,344 units, trucks at 92,323 units, and buses at 17,796 units. This figure far exceeds that of other regions, such as Gowa Regency, which ranks second with 338,083 units. These data reflect the high degree of dependence on private transportation—particularly motorcycles—among Makassar residents, which directly constitutes a primary source of urban air pollution through fossil fuel combustion. The surge in motorised vehicle numbers has also contributed to traffic congestion and a decline in environmental quality, necessitating serious attention within sustainable transportation policy.

The Urban Heat Island (UHI) effect in Makassar has become increasingly pronounced, driven by elevated vehicle emissions and the dominance of impervious surfaces resulting from land-use conversion (Asfan Mujahid et al., 2023). Concrete and asphalt surfaces absorb solar radiation during the day and release it at night, causing ambient temperatures in urban areas to remain consistently higher than in surrounding regions. This condition is compounded by emissions of carbon dioxide, nitrogen oxides, and particulate matter from more than 1.8 million motorised vehicles operating in Makassar, which not only diminish air quality but also accelerate heat accumulation. As a consequence, air pollution becomes more concentrated, public health grows increasingly susceptible to respiratory ailments, and local climate change risks—including the intensification of extreme rainfall and heatwaves—become progressively difficult to manage.

The risks of flooding and air pollution in Makassar City are the result of a complex interplay among rapid urbanisation, inadequate drainage infrastructure, and the exponential growth of motorised vehicles. Land-use conversion has eliminated water catchment areas and amplified surface runoff, while the deficiencies of the drainage system have rendered it incapable of accommodating rainfall volumes, making flooding an annual threat. Meanwhile, the dominance of motorcycles and private vehicles—surpassing 1.8 million units—has made fossil fuel emissions the primary driver of urban air pollution and the urban heat island effect. This situation underscores the imperative for more sustainable land-use policies, strengthened urban infrastructure, and environmentally responsible transportation strategies to reduce Makassar's vulnerability to ecological disasters and the deterioration of residents' quality of life.

Urban planning policies in many regions, including Makassar City, are frequently assessed as insufficiently effective in reducing disaster risk and environmental impacts, owing to their continued dominance by short-term approaches and economic growth orientation. Land-use conversion for residential, commercial, and infrastructure development purposes has routinely overlooked the importance of green open spaces and water catchment areas. This approach has paradoxically heightened vulnerability to flooding, air pollution, and the degradation of the urban ecosystem, indicating that environmental considerations remain subordinated to the imperatives of urban expansion.

Furthermore, inter-agency coordination in the implementation of urban planning policies remains weak, generating policy fragmentation. For instance, road infrastructure development that expands transportation access has not been accompanied by policies to regulate the number of motorised vehicles or to improve public transportation systems. This has resulted in the continued deterioration of traffic congestion and air quality. The disconnect between stated urban planning objectives and actual implementation reflects an emphasis on physical outputs over environmental quality and public welfare.

More broadly, urban planning policies have made limited progress in integrating climate change adaptation and disaster risk mitigation principles into development strategies. Yet phenomena such as flooding, the urban heat island effect, and air quality degradation demand adaptive approaches grounded in data, technology, and community participation. Without robust integration of environmental, social, and spatial dimensions, urban planning policies risk becoming merely normative documents incapable of addressing real-world challenges. A transformation of urban planning toward a more responsive, collaborative, and long-term sustainability-oriented adaptive governance model is therefore urgently required.

To realise a resilient and sustainable Makassar City, policy strategies capable of addressing the interrelated challenges of flooding, air pollution, and climate change are essential. These strategies must be oriented toward the reinforcement of infrastructure, the transformation of the transportation sector, and the development of adaptive and inclusive urban planning frameworks.

Figure 4. Policy Strategies Toward a Resilient and Sustainable Makassar City

Efforts to establish Makassar City as a resilient and sustainable urban centre must be grounded in the strengthening of green infrastructure and open spaces. Green open spaces serve not merely an aesthetic function but play a vital role in maintaining urban ecosystem equilibrium. Urban parks, multifunctional open spaces, and water catchment zones are capable of absorbing rainfall runoff, reducing flood risk, and improving air quality simultaneously. Green infrastructure elements such as bioswales and infiltration gardens offer natural, sustainable alternatives that are preferable to exclusive reliance on grey infrastructure. By expanding green spaces, Makassar can also mitigate the urban heat island effect, which has long been a contributing factor to elevated ambient temperatures.

In addition, the revitalisation of the urban drainage system represents a strategic imperative that must be urgently addressed. Numerous areas of Makassar continue to suffer from recurrent flooding due to limited drainage capacity and insufficient maintenance. The modernisation of drainage systems through technology adoption, the construction of large-capacity channels, and the integration of ecosystem-based solutions would substantially contribute to reducing waterlogging risk. However, technical interventions alone are insufficient. Robust regulation and enforcement of community behaviour are equally required, particularly regarding the widespread practice of disposing solid waste into drainage channels, which consistently exacerbates flooding. Accordingly, drainage revitalisation must be conceptualised as a combination of technological intervention, firm regulatory frameworks, and behavioural change at the community level.

In the transportation domain, the development of environmentally sustainable public transportation is essential for reducing air pollution and carbon emissions. Given that Makassar City registers more than 1.8 million motorised vehicles, the city faces a formidable challenge in terms of air quality. Expanding public transportation networks powered by clean energy—such as electric buses or Bus Rapid Transit/Mass Rapid Transit systems—must therefore be accorded priority status. Policy measures including the restriction of fossil fuel-powered vehicles, emission regulatory standards, and progressive parking tariffs can reduce community dependence on private vehicles. Concurrently, the provision of incentives for owners of low-emission and environmentally friendly vehicles will accelerate the transition toward a sustainable mobility system.

Furthermore, the integration of urban planning with climate change adaptation must serve as the foundational basis of all development policies. Rapid urbanisation and global climate change introduce risks including extreme rainfall, elevated temperatures, and sea-level rise. Without adaptive approaches, cities will become increasingly vulnerable to both flooding and

heatwaves. Consequently, spatial planning must be designed to account for long-term climate projections. The construction of disaster-resilient infrastructure, the development of technology-based early warning systems, and the implementation of adaptive urban design are integral components of this strategy.

All of the strategies outlined above will only be fully effective if they are accompanied by the active participation of communities throughout the planning and implementation processes. Urban resilience is determined not only by government policy but also by the collective awareness and agency of citizens. Communities must be engaged in the stewardship of green open spaces, the adoption of public transportation, and active involvement in disaster mitigation and adaptation programmes. Through the synergy of government policy, technological support, and active community engagement, Makassar City can realise its vision as a resilient, sustainable, and environmentally responsible urban centre in the face of the dual pressures of climate change and rapid urbanisation.

CONCLUSSION

The findings of this study confirm that Makassar City faces serious ecological vulnerability arising from the combined effects of rapid urbanisation, land-use conversion, inadequate drainage infrastructure, and the extraordinarily high rate of motorised vehicle growth. The loss of green open spaces and water catchment areas has intensified annual flood risk, while the limited capacity of existing drainage systems has rendered them incapable of accommodating surface runoff. Meanwhile, a vehicle fleet exceeding 1.8 million units has made air pollution and the urban heat island effect tangible threats to public health and environmental quality. These conditions indicate that spatial planning and transportation policies in Makassar remain predominantly oriented toward economic growth rather than disaster risk mitigation and environmental sustainability.

Moreover, the study demonstrates that the effectiveness of urban planning policies remains limited due to their insufficient integration with climate change adaptation and disaster risk mitigation principles. Weaknesses in inter-agency coordination, inadequate environmental regulation, and the marginalisation of community participation have collectively exacerbated the conditions of flooding, air pollution, and urban ecosystem degradation. Policy strategies that prioritise green infrastructure development, drainage system revitalisation, environmentally sustainable public transportation, and the integration of urban planning with climate change projections are therefore identified as pressing necessities. For future research, it is recommended that attention be directed toward analysing the effectiveness of adaptive policy implementation grounded in spatial data analytics and technology-based approaches in reducing urban ecological risks.

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